UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MICRON TECHNOLOGY, INC.,
Petitioner

v.

YANGTZE MEMORY TECHNOLOGIES COMPANY, LTD.,
Patent Owner

Case No.: IPR2025-00117
U.S. Patent No. 10,672,711

DECLARATION OF SYLVIA D. HALL-ELLIS, Ph.D.

Micron Ex. 1093, p. 1
Micron v. YMTC
IPR2025-00228

I, Sylvia D. Hall-Ellis, Ph.D., declare as follows:

INTRODUCTION

1. My name is Sylvia D. Hall-Ellis. I have been retained as an expert by Micron Technology, Inc., ("Micron") who I am informed is the petitioner in this action.

2. I have written this declaration at the request of Micron to provide my expert opinion regarding the public availability and authenticity of the publication by Shailesh Dhungana, Bradley J. Nordell, Anthony N. Caruso; Michelle M. Paquette, William A. Lanford, Kris Scharfenberger, Danya Jacob, and Sean W. King titled "Combinatorial Survey of Fluorinated Plasma Etching in the Silicon-Oxygen-Carbon-Nitrogen-Hydrogen System" published in the *Journal of Vacuum Science & Technology A*, Volume 34, Issue 6, November 2016, 061302-1–18. My Declaration sets forth my opinions in detail and provides the basis for my opinions regarding the authenticity and public availability of this publication. If called to testify in the above-captioned matter, I will testify with regard to the opinions and bases set forth below.

3. I reserve the right to supplement or amend my opinions, and bases for them, in response to any additional evidence, testimony, discovery, argument, and/or other additional information that may be provided to me after the date of this Declaration.

4. I am being compensated for my time spent working on this matter at my normal consulting rate, plus reimbursement for any additional reasonable expenses. My compensation is not in any way tied to the content of this report, the substance of my opinions, or the outcome of this proceeding. I have no other interests in this proceeding or with any of the parties.

5. All of the materials that I considered and relied upon are discussed in this declaration.

QUALIFICATIONS

6. I am currently an Adjunct Professor in the School of Information at San José State University in San José, California. I obtained a Masters of Library Science from the University of North Texas in 1972 and a Ph.D. in Library and Information Science from the University of Pittsburgh in 1985. Over the last fifty years, I have held various positions in the field of library and information resources. I was first employed as a librarian in 1966 and have been involved in the field of library sciences since, holding numerous positions.

7. I am a member of the American Library Association (ALA) and its Association for Library Collections & Technical Services (ALCTS) Division, and I served on the Committee on Cataloging: Resource and Description (which wrote the new cataloging rules) and as the chair of the Committee for Education and Training of Catalogers and the Competencies and Education for a Career in

Cataloging Interest Group. I also served as the Chair of the ALCTS Division's Task Force on Competencies and Education for a Career in Cataloging. Additionally, I have served as the Chair for the ALA Office of Diversity's Committee on Diversity, as a member of the REFORMA National Board of Directors, and as a member of the Editorial Board for the ALCTS premier cataloging journal, *Library Resources and Technical Services*, as a Co-Chair of the Membership Committee for the Library Research Round Table (LRRT) of the American Library Association, and as a member of the LRRT Nominating Committee. Currently I serve as a Member of the CORE Margaret Mann Citation Committee and as a Member of the Member of the CORE Awards & Scholarship Coordination Committee.

8. I have also given over one hundred presentations in the field, including several on library cataloging systems and Machine-Readable Cataloging ("MARC") standards. My current research interests include library cataloging systems, metadata, and organization of electronic resources.

9. My full curriculum vitae is attached as Exhibit A.

I. PRELIMINARIES

A. Scope of Declaration and Legal Standards

10. I am not an attorney and will not offer opinions on the law. I am, however, rendering my expert opinion on the authenticity of the document

referenced herein and on when and how this document was disseminated or otherwise made publicly available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising reasonable diligence, could have located the document before the date discussed below.

11. I am informed by counsel that a printed publication qualifies as publicly accessible as of the date it was disseminated or otherwise made available such that a person interested in and ordinarily skilled in the relevant subject matter could locate it through the exercise of ordinary diligence.

12. While I understand that the determination of public accessibility under the foregoing standard rests on a case-by-case analysis of the facts particular to an individual publication, I also understand that a printed publication is rendered "publicly accessible" if it is cataloged and indexed by a library such that a person interested in the relevant subject matter could locate it (*i.e.*, I understand that cataloging and indexing by a library is sufficient, though there are other ways that a printed publication may qualify as publicly accessible). One manner of sufficient indexing is indexing according to subject matter category. I understand that the cataloging and indexing by a single library of a single instance of a particular printed publication is sufficient, even if the single library is in a foreign country. I understand that, even if access to a library is restricted, a printed publication that has been cataloged and indexed therein is publicly accessible so long as a

presumption is raised that the portion of the public concerned with the relevant subject matter would know of the printed publication. I also understand that the cataloging and indexing of information that would guide a person interested in the relevant subject matter to the printed publication, such as the cataloging and indexing of an abstract for the printed publication, is sufficient to render the printed publication publicly accessible.

13. I understand that routine business practices, such as general library cataloging and indexing practices, can be used to establish an approximate date on which a printed publication became publicly accessible.

B. Persons of Ordinary Skill in the Art

14. I am told by counsel that the subject matter of this proceeding generally relates to the field of semiconductor technology, and more specifically, to a method for forming a three-dimensional (3D) memory device.

15. I have been informed by counsel that a "person of ordinary skill in the art at the time of the inventions" is a hypothetical person who is presumed to be familiar with the relevant field and its literature at the time of the inventions. This hypothetical person is also a person of ordinary creativity, capable of understanding the scientific principles applicable to the pertinent field.

16. I am told by counsel that a person of ordinary skill in this subject matter or art would have been aware of and generally knowledgeable about 3D

NAND's structure, how it is manufactured, and its component parts. This person would typically be someone who would have had a bachelor of science degree in electrical engineering or a similar discipline, along with 2-3 years of professional experience working with (e.g., researching, designing, or teaching) monolithic 3D structures and NAND memory devices, or an equivalent level of skill, knowledge, and experience (e.g., an advanced degree may replace some of the professional experience). I have been further informed by counsel that a person of ordinary skill in the art would have been familiar with and able to understand the information known in the art relating to these fields, including the publication discussed in this declaration.

C. Indexing and Public Availability

17. In preparing this report, I used authoritative databases, such as the OCLC bibliographic database, the Library of Congress Online Catalog and the Institute of Electrical and Electronic Engineers' *IEEE Xplore* database, to confirm citation details of the publication discussed. It is my expert opinion that this standard protocol was followed for the publication discussed in Section III below.

18. Based on my experience working in research libraries, it is my opinion that members of the public would have been able to locate the material discussed herein on their own or with the assistance of a research librarian with relative ease using the tools and resources described herein.

19. A researcher may discover material relevant to his or her topic in a variety of ways. One common means of discovery is to search for relevant information in an index of periodical and other publications. Having found relevant material, the researcher will then normally obtain it online, look for it in libraries, or purchase it from the publisher, a bookstore, a document delivery service, or other provider. Sometimes, the date of a document's public accessibility will involve both indexing and library date information. However, date information for indexing entries is often unavailable. This is especially true for online indices.

20. Indexing services use a wide variety of controlled vocabularies to provide subject access and other means of discovering the content of documents. The formats in which these access terms are presented vary from service to service.

21. Before the widespread development of online databases to index articles in journals, magazines, conference papers, and technical declarations, libraries purchased printed volumes of indices. Graduate library school education mandated that students learn about the bibliographic control of disciplines, the prominent indexing volumes, and searching strategies required to use them effectively and efficiently. Half of the courses that I studied in library school were focused on the bibliography and resources in academic disciplines.

22. Librarians consulted with information seekers to verify citations, check availability in union catalogs, printed books catalogs, and the OCLC database, and make formal requests for materials, *e.g*., books, conference proceedings, journal articles. Requests were transmitted using Telex machines, rudimentary email systems, and the United States Postal Service. During my career, I have performed and supervised staff who handled these resource sharing tasks.

D. Summary of Opinions

23. I am informed by counsel that the alleged priority date for U.S. Patent No. 10,672,711 is August 31, 2017. As I will explain below, it is my opinion that the publication discussed in my Declaration was publicly accessible before the alleged August 31, 2017, priority date.

II. LIBRARY CATALOGING PRACTICES

A. MARC Records

24. I am fully familiar with the library cataloging standard known as the MARC standard, which is an industry-wide standard method of storing and organizing library catalog information. MARC was first developed in the 1960s by the Library of Congress. A MARC-compatible library is one that has a catalog consisting of individual MARC records for works made available at that library.

25. Since at least the early 1970s and continuing to the present day, MARC has been the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.[1] As explained by the Library of Congress:

> You could devise your own method of organizing the bibliographic information, but you would be isolating your library, limiting its options, and creating much more work for yourself. Using the MARC standard prevents duplication of work and allows libraries to better share bibliographic resources. Choosing to use MARC enables libraries to acquire cataloging data that is predictable and reliable. If a library were to develop a "home-grown" system that did not use MARC records, it would not be taking advantage of an industry-wide standard whose primary purpose is to foster communication of information.
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> Using the MARC standard also enables libraries to make use of commercially available library automation systems to manage library operations. Many systems are available for libraries of all sizes and are designed to work with the MARC format. Systems are maintained and

[1] A complete history of the development of MARC can be found in MARC: Its History and Implications by Henrietta D. Avram (Washington, DC: Library of Congress, 1975) and available online from the Hathi Trust (https://babel.hathitrust.org/cgi/pt?id=mdp.39015034388556;view=1up;seq=1; last visited December 7, 2025).

improved by the vendor so that libraries can benefit from the latest advances in computer technology. The MARC standard also allows libraries to replace one system with another with the assurance that their data will still be compatible.

Why Is a MARC Record Necessary?, LIBRARY OF CONGRESS, http://www.loc.gov/marc/umb/um01to06.html#part2 (last visited December 7, 2025).

26. Thus, almost every major library in the world is MARC-compatible. *See, e.g.*, *MARC Frequently Asked Questions (FAQ)*, LIBRARY OF CONGRESS, https://www.loc.gov/marc/faq.html (last visited December 7, 2025) ("MARC is the acronym for Machine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began nearly fifty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogs used today."). MARC is the ANSI/NISO Z39.2-1994 standard (reaffirmed in 2016) for Information Interchange Format. The full text of the standard is available from the Library of Congress at http://www.loc.gov/marc/bibliographic/ (last visited December 7, 2025).

27. A MARC record comprises several fields, each of which contains specific data about the work. Each field is identified by a standardized, unique,

three-digit code corresponding to the type of data that follow. *See, e.g.*, http://www.loc.gov/marc/umb/um07to10.html (last visited December 7, 2025); http://www.loc.gov/marc/bibliographic/ (last visited December 7, 2025). For example, a work's title is recorded in field 245, the primary author of the work is recorded in field 100, a work's International Standard Book Number ("ISBN") is recorded in field 020, a work's International Standard Serial Number ("ISSN") is recorded in field 022, and the publication date is recorded in field 260 under the subfield "c." *Id.*[2] If a work is a periodical, then its publication frequency is recorded in field 310, and the publication dates (*e.g.*, the first and last publication) are recorded in field 362, which is also referred to as the enumeration/chronology field. *See* http://www.loc.gov/marc/bibliographic/bd3xx.html (last visited December 7, 2025).[3]

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[2] In some MARC records, field 264 is used rather than field 260 to record publication information. *See* http://www.loc.gov/marc/bibliographic/bd264.html (last visited October 15, 2021) ("Information in field 264 is similar to information in field 260 (Publication, Distribution, etc. (Imprint)). Field 264 is useful for cases where the content standard or institutional policies make a distinction between functions").

[3] Upwards of two-thirds to three-quarters of book sales to libraries come from a jobber or wholesaler for online and print resources. These resellers make it their business to provide books to their customers as fast as possible, often providing turnaround times of only a single day after publication. Libraries purchase a significant portion of the balance of their books directly from publishers themselves, which provide delivery on a similarly expedited schedule. In general,

28. The library that initially created the MARC record is reflected in field 040 in subfield "a" with that library's unique library code. *See*, *e.g.*, http://www.loc.gov/marc/umb/um07to10.html (last visited December 7, 2025); http://www.loc.gov/marc/bibliographic/ (last visited December 7, 2025). Once a MARC record for a particular work is originally created by one library, other libraries can use that original MARC record to then create their own MARC records for their own copies of the same work. These other libraries may modify or add to the original MARC record as necessary to reflect data specific to their own copies of the work. However, the library that created the original MARC record would still be reflected in these modified MARC records (corresponding to other copies of the same work at other libraries) in field 040, subfield "a". The modifying library (or libraries) is reflected in field 040, subfield "d". *See* http://www.loc.gov/marc/bibliographic/bd040.html (last visited December 7, 2025).

29. I consulted the Directory of OCLC Libraries (http://www.oclc.org/contacts/libraries.en.html; last visited December 7, 2025) in order to identify the institution that created or modified the MARC record.

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libraries make these purchases throughout the year as the books are published and shelve the books as soon thereafter as possible in order to make the books available to their patrons. Thus, books are generally available at libraries across the country within just a few days of publication.

30. MARC records also include one or more fields that show information regarding subject matter classification. For example, 6XX fields are termed "Subject Access Fields." *See* http://www.loc.gov/marc/bibliographic/bd6xx.html (last visited December 7, 2025). Among these, for example, is the 650 field; this is the "Subject Added Entry – Topical Term" field. *See* http://www.loc.gov/marc/bibliographic/bd650.html (last visited December 7, 2025). The 650 field is a "[s]ubject added entry in which the entry element is a topical term." Id. These entries "are assigned to a bibliographic record to provide access according to generally accepted thesaurus-building rules (*e.g.*, Library of Congress Subject Headings (LCSH), Medical Subject Headings (MeSH))." *Id.*

31. Further, MARC records can include call numbers, which themselves contain a classification number. For example, a MARC record may identify a 050 field, which is the "Library of Congress Call Number." *See* http://www.loc.gov/marc/bibliographic/bd050.html (last visited December 7, 2025). A defined portion of the Library of Congress Call Number is the classification number, and "source of the classification number is Library of Congress Classification and the LC Classification-Additions and Changes." *Id.* Thus, the 050 field may be used to show information regarding subject matter classification. As another example, a MARC record may identify a 082 field, which is the "Dewey Decimal Classification Number." *See*

http://www.loc.gov/marc/bibliographic/bd082.html (last visited December 7, 2025). A defined portion of the Dewey Decimal Classification Number is the classification number, and "source of the classification number is the Dewey Decimal Classification and Relative Index," which is published online. *Id.* Thus, the 082 field may be used to show information regarding subject matter classification consistent with the Dewey Decimal Classification System.

32. Each item in a library has a single classification number. A library selects a classification scheme (*e.g.*, the Library of Congress Classification scheme just described or a similar scheme such as the Dewey Decimal Classification scheme) and uses it consistently. When the Library of Congress assigns the classification number, it appears as part of the 050 field, as discussed above. For MARC records created by libraries other than the Library of Congress (*e.g.*, a university library or a local public library), the classification number may appear in a 09X (*e.g.*, 090) field. *See* http://www.loc.gov/marc/bibliographic/bd09x.html (last visited December 7, 2025).

33. When a MARC-compatible library acquires a work, it creates a MARC record for its copy of the work in its computer catalog system in the ordinary course of its business. This MARC record (for the copy of a work available at the particular library) may be later accessed by researchers in a number of ways. For example, many libraries, including the Library of Congress, make

their MARC records available through their website. As an example, the MARC record for the copy of *The Unlikely Spy*, by Daniel Silva,[4] available at the Library of Congress can be viewed through the Library of Congress website, at https://catalog.loc.gov/vwebv/staffView?searchId=20265&recPointer=1&recCount=25&bibId=2579985 (last visited Dember 7, 2025). One could, of course, always physically visit the library at which the work is available, and request to see that library's MARC record for the work. Moreover, members of the Online Computer Library Center ("OCLC") can access the MARC records of other member institutions through OCLC's online bibliographic database, as I explain further below.

B. OCLC

34. The OCLC was created "to establish, maintain and operate a computerized library network and to promote the evolution of library use, of libraries themselves, and of librarianship, and to provide processes and products for the benefit of library users and libraries, including such objectives as increasing availability of library resources to individual library patrons and reducing the rate of rise of library per-unit costs, all for the fundamental public purpose of furthering ease of access to and use of the ever-expanding body of worldwide scientific,

[4] *The Unlikely Spy* is a 1996 novel written by Daniel Silva, who happens to be one of my favorite authors.

literary and educational knowledge and information."[5] Among other services, OCLC and its members are responsible for maintaining the WorldCat database (http://www.worldcat.org/; last visited December 7, 2025), used by independent and institutional libraries throughout the world. All libraries that are members of OCLC are MARC-compatible. *See, e.g.*, https://help.oclc.org/Metadata_Services (last visited December 7, 2025). These guidelines pertain to OCLC-MARC tagging (that is, content designation). Cataloging rules and manuals (such as AACR2 and RDA) govern the content of records.

35. When an OCLC member institution acquires a publication, like the other MARC-compatible libraries discussed above, it creates a MARC record for this publication in its computer catalog system in the ordinary course of its business. MARC records created at the Library of Congress are tape-loaded into the OCLC database through a subscription to MARC Distribution Services daily or weekly. Once the MARC record is created by a cataloger at an OCLC member library, the MARC record is then made available to any other OCLC members online and thereby made available to the public. The publication corresponding to the MARC record has been cataloged and indexed according to its subject matter

[5] Third Article, Amended Articles of Incorporation of OCLC Online Computer Library Center, Incorporated (available at https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf; last visited December 7, 2025).

such that a person interested in that subject matter could, with reasonable diligence, locate and access the publication through any library with access to the OCLC bibliographic database or through the Library of Congress.

36. When a MARC-compatible library creates an original MARC record for a work, the library records the date of creation of that MARC record in field 008, characters 00 through 05, in the ordinary course of its business. *See* http://www.loc.gov/marc/bibliographic/bd008a.html (last visited December 7, 2025). For OCLC member institutions that use OCLC software to create original MARC records, the date of creation in field 008 is automatically supplied by the OCLC software. The MARC record creation date in field 008 thus reflects the date on which, or shortly after which, a work was first acquired and cataloged by the library that created the original MARC record.

37. When other MARC-compatible libraries subsequently acquire their own copies of the same work, as mentioned, they create MARC records in their own computer catalog systems for their copies in the ordinary course of business[6] They may use a MARC record previously created for that work (by another MARC-compatible library) to create their own MARC records for their own copies

[6] Initial contributions to the bibliographic database for a work are called "master records."

of that same work.[7] The previously created MARC record used by subsequently-acquiring libraries to create MARC records for their own copies may be obtained through the OCLC bibliographic database, as described above. If, when creating a MARC record to represent its own copy of the work, the subsequently-acquiring library uses the master MARC record in its original form, the subsequently-acquiring library cannot reenter data into the 008 field; therefore, the date in the 008 field will continue to reflect the date the MARC record was initially created by the originating library. On the other hand, if the subsequently-acquiring library modifies the previously created MARC record when creating its own MARC record for its own copy of the work, the subsequently-acquiring library may enter into the 008 field of its own MARC record the date its own MARC record was created.[8] But the library that created the original MARC record used by the subsequently-acquiring library would still be reflected in the MARC record of the subsequently-acquiring library in field 040, subfield "a". Thus, the work identified

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[7] When a local library uses a master record in OCLC and produces (or downloads) it to the in-house system, the three-character symbol for the subsequent library is added to the holdings for the work.

[8] This practice is not required by, but is nevertheless consistent with, the MARC standard. Many MARC records exist today whose 008 fields indicate when the first original MARC record for a work was created, rather than when a derivative record was created based on the original MARC record by a subsequently-acquiring library for its own computer catalog system.

by any MARC record possessed by any MARC-compatible library would have been accessible to the public at least as of the date shown in the 008 field, or shortly thereafter, either from the library that possesses the MARC record itself, or from the originating library indicated in field 040, subfield "a". As discussed, a MARC-compatible library in the ordinary course of its business creates a MARC record in its own catalog system for a work when it acquires a copy of that work.

38. Moreover, when a MARC record is created by a library for its own copy of a work, field 005 is automatically populated with the date that MARC record was created in year, month, day format (YYYYMMDD). *See* http://www.loc.gov/marc/bibliographic/bd005.html (last visited December 7, 2025).[9] Thereafter, the library's computer system may automatically update the date in field 005 every time the library updates the MARC record (e.g., to reflect that an item has been moved to a different shelving location within the library). *Id.*[10] Thus, the work identified by any MARC record possessed by any MARC-compatible library would have been accessible to the public at least as of the date shown in the 005 field, or shortly thereafter, from the library that possesses the

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[9] Some of the newer library catalog systems also include hour, minute, second (HHMMSS).

[10] Field 005 is visible when viewing a MARC record via an appropriate computerized interface.

MARC record itself. As noted, because the 005 field may be updated each time the library updates its MARC record the work identified by the MARC record may, in fact, have been accessible to the public from that library much earlier than the date indicated in the 005 field.

39. Moreover, MARC records for copies of works available at the Library of Congress can have a 955 field. The 955 field in MARC records obtained from the Library of Congress provides Local Tracking Information, which is a record of internal steps in the cataloging process followed by the Library of Congress. *Id.* Entries in the 955 field for a particular work are generated by Library of Congress staff as the work progresses through the cataloging process. *Id.* One of the mandatory fields that library staff must enter for each step is the date (in the form of "yyyy-mm-dd" or "yy-mm-dd") the step was taken. *Id.* Thus, the work identified by a MARC record possessed by the Library of Congress would have been accessible to the public at least as of the earliest date shown in the 955 field, or shortly thereafter, from the Library of Congress.[11]

40. Based on my personal experience as a professional librarian using the MARC and OCLC resources, it has been my experience that both of these resources were continuously operational and available since at least 1992. Indeed,

[11] https://www.loc.gov/aba/publications/FreeDCM/DCM_2019-03.pdf (last visited December 7, 2025).

in the course of my work, I have regularly used both of these resources over the past 30+ years, and I have consistently found the information contained within these resources to be complete and reliable. I have never found the date of accessibility as indicated in fields 008, 005, or 955 to be incorrect. And in only a minute number of cases have I found any errors at all in these records – none of which affected my ability to render an accurate opinion as to accessibility, indexing, or subject headings.

C. Journals and Monographic Serials

41. Catalogers can create MARC records for all types of print, online, and digital resources. For example, MARC records cover serial publications, including both serially-published monographs and journals. OCLC hosts MARC records for more than 320 million serial publications. Serial publications are those publications that have the same collective title but are intended to be continued indefinitely with enumeration such as a volume or issue number (*e.g.*, magazines, journals, etc.). In the OCLC bibliographic database, the first issue of the serial publication is typically cataloged (*i.e.*, a corresponding MARC record is created), but the date is left open-ended with the use of a punctuation mark such as a dash. OCLC serial publication MARC records represent the entire run of the serial title. With knowledge of the first issue published, future issues can be predicted based on the information provided in the MARC record, for example in field 362. In my

extensive professional experience, is it highly unusual for a library to stop collecting and shelving a serial publication prior to the end of its publication run. If a subscription to a serial publication ends its run or is cancelled before the end of its run, the library will denote that it has stopped receiving new volumes by filling in the end date in the MARC record.

42. The handling of printed journal subscriptions is shown on the cover or the first few pages of individual issues. As was the best practice among libraries, issues arrived at a central facility and were immediately received, verified as part of a subscription, checked in, and stamped or labeled with the institution's name and date. Determining that the issue was part of the library subscription ensured that the entire set of publications for the year had been received so that they could be professionally bound and retained. This process also verified that all of the published issues arrived so that the library staff did not have to request or claim an issue that did not arrive as expected. In large public libraries with branches and multi-campus libraries within academic institutions, the journals were sorted and delivered to the subscribing unit. The new issue was placed in the public area; the older issue was stored so that it remained available.

43. The foregoing process has been standard library practice longer than I have been working in the profession. I first learned the steps in the process in the late 1970s and later supervised it. Although the checking in process has become

automated and now links electronically to holdings records for the MARC record for each serial title, the manual placement of a stamp or label and placing the issue in a public area has not changed for 50 years. It is my expert opinion that this standard protocol was followed for the serial publication discussed below.

III. PUBLICATION IN THIS PROCEEDING

A. "Combinatorial Survey of Fluorinated Plasma Etching in the Silicon-Oxygen-Carbon-Nitrogen-Hydrogen System" by Shailesh Dhungana, Bradley J. Nordell, Anthony N. Caruso, Michelle M. Paquette, William A. Lanford, Kris Scharfenberger, Danya Jacob, and Sean W. King ("Dhungana") [Exhibit 1032]

44. Exhibit 1032 ("Dhungana") is a copy of the journal article titled "Combinatorial Survey of Fluorinated Plasma Etching in the Silicon-Oxygen-Carbon-Nitrogen-Hydrogen System" by Shailesh Dhungana, Bradley J. Nordell, Anthony N. Caruso, Michelle M. Paquette, William A. Lanford, Kris Scharfenberger, Danya Jacob, and Sean W. King (hereafter "Dhungaga").[12] The Dhungana article was published in the 2nd series, Volume 34, Number 6 of the *Journal of Vacuum Science and Technology A* and was downloaded from the publisher's website.[13] Exhibit 1032 bears endorsement identification "Micron v.

[12] https://ptacts.uspto.gov/ptacts/public-informations/petitions/1556876/download-documents?artifactId=5wEt73tPCxBWi260sIZ1t_JAS5Za3FUdIDhgWA7wSQ8QeskKKskcOr8

[13] https://pubs.aip.org/avs/jva/article-abstract/34/6/061302/245005/Combinatorial-survey-of-fluorinated-plasma-etching?redirectedFrom=PDF

YMTC, IPR 2025-00117, pages 1-19." The Dhungana article appears beginning on page 061302-1 of this issue dated November-December 2016. Exhibit 1032 is a true and correct copy of the Dhungana article (pages 061302-1 -- 061302-18) that I understand has been submitted as an exhibit in these proceedings. Specifically, the text of the article is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the document.

45. The Dhungana article was published in digital and print versions. [14] Exhibit 1032 is a copy of the digital version available from the publisher, AIP Publishing. The publisher indicated that the Dhungana article was received on July 11, 2016, accepted on September 28, 2016, and published on October 11, 2016 (Exhibit 1032, page 2). The publisher posted a copy of the Dhungana article abstract on its website.[15] Right clicking on the "CHORUS" link opens a copy of the article and the survey (62 pages). I obtained a copy of the print version of the Dhungana article (attached as Exhibit B) from the Linda Hall Library of Science, Engineering & Technology (Kansas City, Missouri). Based on finding a copy of

[14] The digital and the print versions of the Dhungana article contain identical content.

[15] https://pubs.aip.org/avs/jva/article-abstract/34/6/061302/245005/Combinatorial-survey-of-fluorinated-plasma-etching?redirectedFrom=fulltext

the Dhungana article in the Linda Hall Library of Science, Engineering & Technology, it is my opinion that the Dhungana article published in the *Journal of Vacuum Science and Technology A* was publicly available on December 14, 2016, as shown on the cover of Exhibit B. In common practice these stamps are applied at or around the time the issue is entered into the library's collection and the volume is made available to library patrons within a short time thereafter. Exhibit B was found within the custody of a library – a place where an authentic copy of this journal would likely be. Exhibit B is a true and correct copy in a condition that creates no suspicion about its authenticity.

46. Attached hereto as Attachment 1A is a true and correct copy of the MARC record for the *Journal of Vacuum Science and Technology A* from the Linda Hall Library of Science, Engineering & Technology online catalog. The library ownership is indicated by the presence of the library's code ("LHL") in field 049. The library continues to update and enhance this MARC record to meet current cataloging rules. The most recent enhancement to Attachment 1A occurred on September 6, 2023, as shown in field 005 ("20230906"). I personally identified and retrieved the MARC record that is Attachment 1A.

47. Based on finding a copy of the Dhungana article in the Linda Hall Library of Science, Engineering & Technology and MARC record in its online library catalog attached as Attachment 1A, it is my opinion that the Dhungana

article published in the *Journal of Vacuum Science and Technology A* was publicly available on December 14, 2016, as shown on the cover of Exhibit B. In common practice these stamps are applied at or around the time the issue is entered into the library's collection and the volume is made available to library patrons within a short time thereafter. Attachment 1A also shows that the Dhungana article was catalogued with a descriptor term reading "Vacuum technology $v Periodicals" (see Attachment 1B, Library of Congress subject heading sh85141743 and Attachment 1C, Library of Congress subject heading sh85099890) in the 650 field.

48. As noted in the holdings information (362 field), the Linda Hall Library of Science, Engineering & Technology has received the *Journal of Vacuum Science and Technology A* since January 1983 and continues to receive the publication. In view of the MARC record for Exhibit B, the Dhungana article was publicly on December 14, 2016, because the serial title had been received, cataloged, and indexed at the Linda Hall Library of Science, Engineering & Technology and made part of its online catalog database.

49. Attached hereto as Attachment 1D is a true and correct copy of the MARC record for the *Journal of Vacuum Science and Technology A* obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 1D, that library code is "NSD," which means that the MARC record for this serial was

cataloged as part of the National Serials Data Program at the Library of Congress. As can be seen in field 008 ("Date entered on file") in the MARC record for the Dhungana article, a cataloger at the Library of Congress created OCLC record number 8697396 on August 18, 1982 ("820818"). The library continues to update and enhance this MARC record to meet current cataloging rules. The most recent enhancement to Attachment 1D occurred on November 5, 2025, as shown in field 005 ("20251105"). I personally identified and retrieved the MARC record that is Attachment 1D. The "BLvl" entry in Attachment 1D is "s," which indicates that the *Journal of Vacuum Science and Technology A* is a serial publication. Field 310 of Attachment 1D reads "Bimonthly, $b Jan./Feb. 1985-." Accordingly, the MARC record for the Dhungana article corresponds to the *Journal of Vacuum Science and Technology A* from the time the serial title began publication and includes the date of the Dhungana article.

50. Attachment 1D includes an entry in field 050 ("TJ940 $b .J668")—as described above, a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system) and an entry in field 082 ("621.5/5/05"), a subject matter consistent with the Dewey Decimal classification system. Attachment 1D further includes four descriptor terms reading "Vacuum technology $v Periodicals" (see Attachment 1B, Library of Congress subject heading sh85141743 and Attachment 1C, Library of

Congress subject heading sh85099890), "Surface chemistry $v Periodicals" (see Attachment 1E, Library of Congress subject heading sh2010115113), "Thin films $v Periodicals" (see Attachment 1F, Library of Congress subject heading sh85134864 and Attachment 1C, Library of Congress subject heading sh85099890), and "Surfaces (Physics) $v Periodicals" (see Attachment 1G, Library of Congress subject heading sh2010114089) in the 650 fields. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 1D was indexed according to its subject matter by virtue of at least three independently sufficient classifications: the field 050 entry, the field 082 entry, and the field 650 entries. As of August 18, 1982, the MARC record attached hereto as Attachment 1D was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that subscribed to the serial, which means that the corresponding publication was publicly available on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

51. WorldCat indicates that the *Journal of Vacuum Science and Technology A* as cataloged at the Library of Congress is currently available from 587 libraries.[16] In view of the above, this issue of the *Journal of Vacuum Science and Technology A*

[16] https://search.worldcat.org/title/8697396

was publicly available in a digital version on October 11, 2016, and in print version on December 14, 2016, because by that date it had been cataloged and indexed at the Library of Congress, made part of the OCLC bibliographic database, and received at the Linda Hall Library of Science, Engineering & Technology. For these reasons, it is my opinion that the Dhungana article was published and accessible to the public on October 11, 2016, in a digital version, and on December 14, 2016, in a print version.

IV. SUMMARY OF OPINIONS

52. In view of the foregoing, it is my opinion that the publication described above were publicly available no later than the corresponding date listed in the table below:

Exhibit	Publication	Publicly Available
1032 & B	Dhungana, Shailesh, Bradley J. Nordell, Anthony N. Caruso, Michelle M. Paquette, William A. Lanford, Kris Scharfenberger, Danya Jacob, and Sean W. King. "Combinatorial Survey of Fluorinated Plasma Etching in the Silicon-Oxygen-Carbon-Nitrogen-Hydrogen System." *Journal of Vacuum Science and Technology A*, vol. 34, no. 6 (November-December 2016): 061302-1--061302-18.	October 11, 2016, digital version December 14, 2016, print version

53. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-

examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

54. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

DATED: December 15, 2025 By: Sylvia D. Hall-Ellis, Ph.D.

ATTACHMENT 1A

leader 03774cas a2200637 a 4500
001 992759783405961
005 20230906181228.0
008 820818c19839999nyubr1p 0 a0eng d
010 ##$a 83643441 //r963 $zsn 82003445
012 ##$a3 $b3 $i8403 $j2 $k1 $l1 $m1
022 0#$a0734-2101
030 ##$aJVTAD6
032 ##$a716990 $bUSPS
035 ##$a(OCoLC)8697396
035 ##$a(Horizon)382241
035 ##$a(MoKL)275978-lhalldb
035 ##$a(lhalldb)275978-lhalldb
037 ##$bAIP Subscription Fulfillment Division, 500 Sunnyside Blvd., Woodbury, NY 11797
040 ##$aNSD $cNSD $dHUL $dNST $dDLC $dNST $dSER $dNST $dDLC $dAIP $dNST $dAIP $dNSD $dNST $dNSD $dAIP $dDLC $dNST $dNSD $dDLC $dWAU $dLHL $beng
042 ##$ansdp $alc
049 ##$aLHLA
050 00$aTJ940 $b.J668
210 0#$aJ. vac. sci. technol., A, Vac. surf. films
222 #0$aJournal of vacuum science & technology. A. Vacuum, surfaces, and films
245 00$aJournal of vacuum science & technology. $nA, $pVacuum, surfaces, and films : $ban official journal of the American Vacuum Society.
246 10$aJournal of vacuum science and technology. $nA, $pVacuum, surfaces, and films
246 10$aVacuum, surfaces, and films
260 ##$aNew York : $bPublished for the Society by the American Institute of Physics, $c1983-
300 ##$av. : $bill. ; $c29 cm.
310 ##$aBimonthly $b<, Jan./Feb. 1985->
321 ##$aQuarterly, $bJan.-Mar. 1983-
362 0#$a2nd ser., v. 1, no. 1 (Jan.-Mar. 1983)-
500 ##$aTitle from cover.
510 1#$aComputer & control abstracts, $x0036-8113 $bJan.-Mar. 1983-
510 1#$aElectrical & electronics abstracts, $x0036-8105 $bJan.-Mar. 1983-
510 1#$aPhysics abstracts. Science abstracts. Series A, $x0036-8091 $bJan.-March 1983-
510 2#$aMetals abstracts, $x0026-0924
510 2#$aWorld aluminum abstracts, $x0002-6697
510 1#$aSPIN, $b1983-
510 2#$aChemical abstracts, $x0009-2258
510 2#$aCurrent physics index, $x0098-9819
510 2#$aCoal abstracts, $x0309-4979
525 ##$a2nd series, vol.21, no.5 includes a separate supplement titled: 50 Years of science, technology, and the AVS (1953-2003)
530 ##$aIssued also on microfilm.
580 ##$aEach year the Mar./Apr. issue is republished and issued separately in a special hardbound edition which contains the proceedings of the U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride (after 1988 the name of the conference varies).
650 #0$aVacuum technology $vPeriodicals.
710 2#$aAmerican Vacuum Society.

710 2#$aAmerican Institute of Physics.
780 01$tJournal of vacuum science and technology $x0022-5355 $w(OCoLC)1754855 $w(DLC) 68053979
787 1#$aU.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride. $tProceedings of the ... U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride $x1056-6546 $w(DLC) 91643096 $w(OCoLC)23753006
850 ##$aAAP $aArU $aAzU $aCLSU $aCSt $aCU $aCU-A $aCU-I $aCU-RivP $aCU-S $aCU-SB $aCaAEU $aCaNSHD $aCaOLU $aCaOOM $aCaOTCL $aCaOTU $aCaOWA $aCaOWtU $aCaSSU $aCoFS $aCoU $aCtU $aCtW $aCtY-KS $aDGW $aDLC $aDeU $aFU $aGAT $aICJ $aICU $aICarbS $aIEN $aINS $aIU $aIaAS $aInLP $aInU $aKMK $aKyLoU $aKyU $aLU $aMBU $aMCM $aMChB $aMH-GM $aMH-O $aMdU $aMiD $aMiDW $aMiEM $aMiU $aMnU $aMoKL $aMoSW $aMoU $aMsU $aMtBC $aNN $aNNC $aNNE $aNRU $aNSyU $aNcD $aNcRS $aNcU $aNcWsW $aNjP $aNjR $aNmU $aOCU $aOU $aOrCS $aOrU-S $aPBL $aPPT $aPPiC $aPPiU $aPSt $aPU $aTU $aTxArU $aTxCM $aTxDaM $aTxHR $aTxU $aUU $aViBlbV $aViU $aVtU $aWM $aWaU $aWvU $aWyU
890 ##$aJournal of vacuum science & technoglogy. A, Vacuum, surfaces, and films.
901 ##$cSer
936 ##$aJan./Feb. 1985
945 ##$bJournal of vacuum science & technology. A, Vacuum, surfaces, and films : an official journal of the American Vacuum Society.
948 ##$aLTI 04/26/2017

ATTACHMENT 1B

MARC record

LC control no.:	sh 85141743
LCCN Permalink:	https://lccn.loc.gov/sh85141743 (link opens in a new tab)
000	00587nz a2200217n 4500
001	sh 85141743
005	20250804133729.9
003	DLC
008	860211|| anannbabn |b ana
010	$a sh 85141743
035	$a (DLC)sh 85141743
035	$a (DLC)136879
040	$a DLC $c DLC
053 0	$a TJ940
150	$a Vacuum technology
450	$a Industrial vacuum
450	$a Vacuum $x Industrial applications
450	$a Vacuum in industry
550	$a Ultrahigh vacuum
550	$w g $a Vacuum
999 f f	$i ea5205c0-a818-4ab5-a7a8-b2d688e76aa5 $s f4ae72b1-75d9-4d77-98dc-f71478ffc3bd

ATTACHMENT 1C

MARC record

LC control no.:	sh 85099890
LCCN Permalink:	https://lccn.loc.gov/sh85099890 (link opens in a new tab)
000	01290cz a2200313n 4500
001	sh 85099890
005	20250804134933.4
003	DLC
008	040419 | anannbabn |b ana
010	$a sh 85099890
035	$a (DLC)sh 85099890
035	$a (DLC)6226910
035	$a (DLC)sp 85099890
035	$a (DLC)314952
040	$a DLC $c DLC $d DLC
053 0	$a AP $c General periodicals
053 0	$a PN4700 $b PN5650 $c History
150	$a Periodicals
360	$i subdivision $a Periodicals $i under specific subjects, e.g. $a Engineering--Periodicals; United States--History--Periodicals
450	$a Journals (Periodicals)
450	$a Magazines
550	$w g $a Library materials
550	$w g $a Mass media
550	$w g $a Serial publications
550	$a Newspapers
550	$a Press
670	$a UMI business vocab. $b (Journals)
680	$i Here are entered works on the periodicals of the world and, with appropriate subdivisions, works on special aspects or sections of periodicals. Works on periodicals in a specific language, or in a specific country or larger area, are entered under the adjectival form of the language or area, e.g. $a Arabic periodicals; Canadian periodicals.
999 f f	$i f3c2f118-a0af-4986-bcda-385995e5c57d $s 6e61730c-f0c8-4352-b06f-cb3fc2acd8a0

ATTACHMENT 1D

Bibliographic Record - OCLC Number: 8697396

LDR	Record Status	'c' - Corrected or revised
	Type of Record	'a' - Language material
	Bibliographic Level	's' - Serial
	Type of Control	' ' - No specified type of control
	Encoding Level	' ' - Full level
	Descriptive Cataloging Form	'a' - AACR2
001	8697396	
005	20251105200618.2	
008	Date Entered on File	'820818'
	Type of Date/Publication Status	'c' - Continuing resource currently published
	Date1/Beginning Date of Publication	'1983'
	Date2/Ending Date of Publication	'9999'
	Place of Publication, Production, or Execution Code	'nyu' - New York
	Frequency	'b' - Bimonthly
	Regularity	'r' - Regular
	Type of Continuing Resource	'p' - Periodical
	Form of Original Item	' ' - None of the following
	Form of Item	' ' - None of the following
	Nature of Entire Work	' ' - No specified nature of entire work
	Nature of Contents	' '
	Government Publication	' ' - Not a government publication
	Conference Publication	'0' - Not a conference publication
	Original Alphabet or Script of Title	'a' - Basic Roman
	Entry Convention	'0' - Successive entry
	Language Code	'eng' - English
	Modified Record	' ' - Record is not modified
	Cataloging Source Code	'c' - Cooperative cataloging program

010 83643441 **$z** sn 82003445 **$z** 2004204902

040 NSD **$b** eng **$c** NSD **$d** HUL **$d** NST **$d** DLC **$d** NST **$d** SER **$d** NST **$d** DLC **$d** AIP **$d** N ST **$d** AIP **$d** NSD **$d** NST **$d** NSD **$d** AIP **$d** DLC **$d** NST **$d** NSD **$d** DLC **$d** WAU **$d** C US **$d** MYG **$d** NSD **$d** MYG **$d** SYS **$d** WAU **$d** NLM **$d** OCLCQ **$d** MUQ **$d** WAU **$d** D LC **$d** NSD **$d** CUS **$d** CLU **$d** NLGGC **$d** IUL **$d** IEEEX **$d** OCLCQ **$d** DLC **$d** OCLCQ **$d** IUL **$d** OCLCF **$d** OCLCQ **$d** CLS **$d** OCLCA **$d** L2U **$d** OCLCO **$d** DLC **$d** PUL **$d** O CL **$d** OCLCL **$d** OCLCQ

012 3 **$b** 3 **$j** 4 **$k** 1 **$l** 1 **$m** 1

016 7 9890566 **$2** DNLM

016 7 SR0088359 **$2** DNLM

019 56061703 **$a** 255626104 **$a** 503286784 **$a** 960174412 **$a** 1011754372 **$a** 1016349646 **$a** 111495 7584

022 0 0734-2101 **$z** 1553-1813 **$2** 1

023 0 0734-2101 **$2** 1

030 JVTAD6

032 716990 **$b** USPS

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042 nsdp **$a** pcc
050 0 0 TJ940 **$b** .J668
082 0 4 621.5/5/05 **$2** 19
210 0 J. vac. sci. technol., A, Vac. surf. films
222 0 Journal of vacuum science & technology. A. Vacuum, surfaces, and films
245 0 0 Journal of vacuum science & technology. **$n** A, **$p** Vacuum, surfaces, and films : **$b** an official journ al of the American Vacuum Society.
246 1 **$i** Issues for <July/Aug. 2002>- also called: **$a** JVST A
246 3 Journal of vacuum science and technology. **$n** A, **$p** Vacuum, surfaces, and films
246 3 Vacuum, surfaces, and films
246 1 **$i** Vols. for 2003-<2009> have title: **$a** Journal of vacuum science & technology. **$n** A, **$p** An inter national journal devoted to vacuum, surfaces, and films
260 New York : **$b** Published for the Society by the American Institute of Physics, **$c** 1983-
300 volumes : **$b** illustrations ; **$c** 29 cm
310 Bimonthly, **$b** Jan./Feb. 1985-
321 Quarterly, **$b** Jan./Mar. 1983-Oct./Dec. 1984
336 text **$b** txt **$2** rdacontent
337 unmediated **$b** n **$2** rdamedia
338 volume **$b** nc **$2** rdacarrier
362 0 2nd ser., v. 1, no. 1 (Jan./Mar. 1983)-
500 Title from cover.
510 2 Chemical abstracts **$x** 0009-2258
525 Some issues accompanied by supplements.
530 Also issued on microfilm and CD-ROM.
580 Each year the Mar./Apr. issue is republished and issued separately in a special hardbound edition whic h contains the proceedings of the U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride (after 1988 the name of the conference varies).
588 Latest issue consulted: 2nd. ser. vol. 30, no. 1 (Jan./Feb. 2012) (surrogate).
650 0 Vacuum technology **$v** Periodicals.
650 0 Surface chemistry **$v** Periodicals.
650 0 Thin films **$v** Periodicals.
650 0 Surfaces (Physics) **$v** Periodicals.
650 6 Vide (Technologie) **$v** Périodiques.
650 6 Chimie des surfaces **$v** Périodiques.
650 6 Couches minces **$v** Périodiques.
650 6 Surfaces (Physique) **$v** Périodiques.
650 7 52.99 mechanical engineering: other. **$0** (NL-LeOCL)077604687 **$2** bcl
650 7 33.99 physics: other. **$0** (NL-LeOCL)077595807 **$2** bcl
650 7 Thin films. **$2** fast **$0** (OCoLC)fst01150018
650 7 Surfaces (Physics) **$2** fast **$0** (OCoLC)fst01139265
650 7 Surface chemistry. **$2** fast **$0** (OCoLC)fst01139210
650 7 Vacuum technology. **$2** fast **$0** (OCoLC)fst01163626
650 1 7 Vacuümtechniek. **$2** gtt
655 4 Computer network resources.
655 7 Periodicals. **$2** fast **$0** (OCoLC)fst01411641

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655 7 Periodicals. **$2** lcgft **$0** http://id.loc.gov/authorities/genreForms/gf2014026139 **$0** (uri) http://id.loc.gov/authorities/genreForms/gf2014026139

710 2 American Vacuum Society. **$1** https://id.oclc.org/worldcat/entity/E39QH7Jmr4Kc8DpR6Kcv7dXYJt

710 2 American Institute of Physics. **$1** https://id.oclc.org/worldcat/entity/E39QH7Jmt4Pmkvj8gdHvCc3FhR

776 0 8 **$i** Online version: **$t** Journal of vacuum science & technology. A, Vacuum, surfaces, and films (Online) **$x** 1520-8559 **$w** (DLC)sn 98004661 **$w** (OCoLC)37329463

780 0 1 **$t** Journal of vacuum science and technology **$x** 0022-5355 **$w** (DLC) 68053979 **$w** (OCoLC)1754855

787 1 U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride. **$t** Proceedings of the ... U.S. Workshop on the Physics and Chemistry of Mercury Cadmium Telluride **$x** 1056-6546 **$w** (DLC) 91643096 **$w** (OCoLC)23753006

787 0 8 **$i** CD-ROM: **$t** JVST. A & B **$x** 1071-8028 **$w** (DLC)sn 93004137 **$w** (OCoLC)28742810

850 AAP **$a** ArU **$a** AzU **$a** CLSU **$a** CSt **$a** CU **$a** CU-A **$a** CU-I **$a** CU-RivP **$a** CU-S **$a** CU-SB **$a** CaAEU **$a** CaNSHD **$a** CaOLU **$a** CaOOM **$a** CaOTCL **$a** CaOTU **$a** CaOWA **$a** CaOWtU **$a** CaSSU **$a** CoFS **$a** CoU **$a** CtU **$a** CtW **$a** CtY-KS **$a** DGW **$a** DLC **$a** DeU **$a** FU **$a** GAT **$a** ICJ **$a** ICU **$a** ICarbS **$a** IEN **$a** INS **$a** IU **$a** IaAS **$a** InLP **$a** InU **$a** KMK **$a** KyLoU **$a** KyU **$a** LU **$a** MBU **$a** MCM **$a** MChB **$a** MH-GM **$a** MH-O **$a** MdU **$a** MiD **$a** MiDW **$a** MiEM **$a** MiU **$a** MnU **$a** MoKL **$a** MoSW **$a** MoU **$a** MsU **$a** MtBC **$a** NN **$a** NNC **$a** NNE **$a** NRU **$a** NSyU **$a** NcD **$a** NcRS **$a** NcU **$a** NcWsW **$a** NjP **$a** NjR **$a** NmU **$a** OCU **$a** OU **$a** OrCS **$a** OrU-S **$a** PBL **$a** PPT **$a** PPiC **$a** PPiU **$a** PSt **$a** PU **$a** TU **$a** TxArU **$a** TxCM **$a** TxDaM **$a** TxHR **$a** TxU **$a** UU **$a** ViBlbV **$a** ViU **$a** VtU **$a** WM **$a** WaU **$a** WvU **$a** WyU

856 4 1 **$u** http://ojps.aip.org/journals/doc/JVTAD6-home/top.html

856 4 1 **$u** http://ojps.aip.org/jvsta/

856 4 1 **$u** http://ieeexplore.ieee.org/servlet/opac?punumber=4915548 **$z** Restricted to IEEE Xplore subscribers

891 2 0 **$9** 853 **$8** 1 **$a** v. **$b** no. **$u** 4 **$v** r **$i** (year) **$j** (month) **$w** q **$x** 01/03

891 4 0 **$9** 863 **$8** 1.1 **$a** 1-2 **$i** 1983-1984

891 2 0 **$9** 853 **$8** 2 **$a** v. **$b** no. **$u** 6 **$v** r **$i** (year) **$j** (month/month) **$w** b **$x** 01/02

891 4 1 **$9** 863 **$8** 2.1 **$a** 3 **$b** 1 **$i** 1985 **$j** 01/02

029 1 AU@ **$b** 000002514471

029 1 AU@ **$b** 000024060224

029 1 AU@ **$b** 000024722034

029 1 AU@ **$b** 000026092954

029 1 AU@ **$b** 000053477148

029 1 AU@ **$b** 000054273955

029 1 NLGGC **$b** 843389524

029 1 NLM **$b** 9890566

029 1 NZ1 **$b** 2694905

029 1 NZ1 **$b** 9735214

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IPR2025-00228

ATTACHMENT 1E

MARC record

LC control no.:	sh2010115113
LCCN Permalink:	https://lccn.loc.gov/sh2010115113 (link opens in a new tab)
000	00510nz a2200169n 4500
001	sh2010115113
005	20250804140438.4
003	DLC
008	100831|| anannbabn |n ana
010	$a sh2010115113
035	$a (DLC)481988
035	$a (DLC)sh2010115113
040	$a DLC $b eng $c DLC
150	$a Surface chemistry $v Periodicals
667	$a Record generated for validation purposes.
670	$a Work cat.: Surface science,
999 f f	$i 0e853e5f-25b9-4d0b-a9fd-dbd5c21c4906 $s 97b7b8e2-b30f-4da0-85c3-20e2f3c3f4c5

ATTACHMENT 1F

MARC record

LC control no.:	sh 85134864
LCCN Permalink:	https://lccn.loc.gov/sh85134864 (link opens in a new tab)
000	00699nz a2200253n 4500
001	sh 85134864
005	20250804133708.3
003	DLC
008	860211i| anannbabn |b ana
010	$a sh 85134864
035	$a (DLC)sh 85134864
035	$a (DLC)130224
040	$a DLC $c DLC $d DLC
053 0	$a QC176.82 $b QC176.9 $c Solid-state physics
053 0	$a TA418.9.T45 $c Materials
150	$a Thin films
450	$a Films, Thin
450	$a Solid film
550	$w g $a Solid state electronics
550	$w g $a Solids
550	$w g $a Surfaces (Technology)
550	$a Coatings
550	$a Thick films
999 f f	$i cfeb87dc-c84e-4f22-ad44-c8ff7d9e7614 $s 06454e1c-cbb0-4674-bfab-ed7ea4c51d54

ATTACHMENT 1G

MARC record

LC control no.:	sh2010114089
LCCN Permalink:	https://lccn.loc.gov/sh2010114089 (link opens in a new tab)
000	00518nz a2200169n 4500
001	sh2010114089
005	20250804140427.8
003	DLC
008	100817|| anannbabn |n ana
010	$a sh2010114089
035	$a (DLC)480439
035	$a (DLC)sh2010114089
040	$a DLC $b eng $c DLC
150	$a Surfaces (Physics) $v Periodicals
667	$a Record generated for validation purposes.
670	$a Work cat.: Applied physics, c1995-
999 f f	$i 90d0902a-11a0-4f65-8969-f01c287371a1 $s d527bdbd-f297-4b61-a887-b9018fb7348a

EXHIBIT A

CURRICULUM VITAE SYLVIA D. HALL-ELLIS

EDUCATION

Ph.D., University of Pittsburgh, Pittsburgh, Pennsylvania, 1985
M.P.S., University of Denver, Denver, Colorado, 2014
Post Graduate Studies, University of Texas – San Antonio, Texas, 1975-1976
M.L.S., University of North Texas, Denton, Texas, 1972
B.A., Rockford University, Rockford, Illinois, 1971

PROFESSIONAL EXPERIENCE

1981- **Consultant for higher education, non-profit organizations, and corporations.**

2002- **Adjunct Professor, School of Information, San José State University, San José, California.** Serve as part-time faculty member teaching graduate students in technical services (cataloging, bibliographic control, classification), "core courses," and special topics.

2014-2016 **Director, Grants and Resource Development, Colorado Community College System.** Provided leadership and vision to foster the continued growth of rigorous scholarship, innovative projects, and creative work for statewide system, 13 campuses, and 50 teaching sites serving 155,000 students. Responsible for leadership and ensured efficient functioning of contract and grants in compliance with state & federal requirements and successful implementation and management. Served as a subject matter expert and liaison for college Grant Directors for all issues relating to grants and subcontracts.

2010-2014 **Senior Grant Administrator, Morgridge College of Education, University of Denver (Colorado).** Provided leadership and vision to foster continued growth of rigorous scholarship, innovative research, and creative work in the Morgridge College of Education. Ensure that contract and grants processes function effectively and efficiently for 60 faculty and researchers with a focus on the successful progression and efficient management of grants totaling $13M. Worked effectively and collegially with Department Chairs and Program Coordinators on operational grant-related management activities and with a broad range of internal and external constituencies. Supported the dissemination and promotion of faculty research and scholarship to outside constituents at conferences and through publications. Assisted Principal Investigators and grant project teams by coaching, mentoring, and financial management.

2011-2013 **Interim Director & Assistant Dean, Westminster Law Library, Sturm College of Law, University of Denver.** Planned, organized, and directed all administrative activities for the library serving students, faculty, and alumni; oversaw the employment, retention, promotion, transfer and termination of library personnel; represented the library at professional conferences and public meetings; created and promoted a climate and culture of acceptance for new programs and services, a positive high-quality image of the law library, and that reflect the organization's values, encourage excellent performance, and reward high productivity and innovation; provided leadership and set strategic direction of the organization; ensured that the library provided excellent customer service through solution-oriented staff response to patron needs and by responsiveness and continuous improvement of the organization; promoted, developed, and maintained positive working relationships with colleagues and customers including key stakeholders and groups, higher education institutions, the legal community, other regional libraries and districts statewide, and national library organizations.

2007-2014 **Associate Professor, Library & Information Science, Morgridge College of Education, University of Denver (Colorado).** Served in leadership role and worked collaboratively in program, college, campus and community environments. Advised and supervised students, taught core and specialized courses at the graduate level in an integrative, student-centered learning environment. Served on LIS, College, and University committees, and maintained working relationships with colleagues in other academic units and information professionals in the Rocky Mountain region and beyond. Served on and chair doctoral student dissertation committees. Oversaw and facilitated the College and LIS graduate student association.

2002-2007 **Assistant Professor, Library & Information Science, College of Education, University of Denver (Colorado).** Served as tenure-track faculty member teaching graduate students in "core courses," resource description and access, service learning, and independent studies. Advised graduate students, participate on LIS and College committees, and serve on doctoral student dissertation committees. Oversaw and facilitated the LIS graduate student association and alumni association.

2000-2002 **Affiliate Faculty, Library & Information Science, College of Education, University of Denver (Colorado).** Served as part-time faculty member teaching graduate students in technical services (cataloging, bibliographic control, classification), "core courses," and special topics. Oversaw and facilitated the LIS graduate student association and alumni association.

2000-2001 **Special Assistant to the Secretary's Regional Representative, U.S. Department of Education, Region VIII, Denver, Colorado.** Served as the principal advisor and representative of the U. S. Secretary of Education's Regional Representative (SRR). Ensured the implementation of major goals of the SRR and the Secretary. Provided leadership on behalf of the SRR in contacts with high-level officials in Region VIII requiring sensitive policy interpretation in communication with senior Department officials to solve problems and resolve issues raised by State and local education officials. Served as the primary contact for School-to-Work/Career, Children's Health Insurance Program, and Safe and Drug-Free Schools. Delivered technical assistance to local education agencies and institutions of higher education in technology, professional development, and school construction.

1999-2000 **Catalog Librarian, Jefferson County Public Library, Lakewood, Colorado.** Performed original, copy cataloging and classification of library materials (English and Spanish) using standard library protocols; completed original descriptive cataloging and subject analysis; enhanced brief catalog and authority records in III.

1997-1999 **Development Officer, McREL International, Aurora, Colorado.** Served as senior member of corporate management team in strategic planning, development of proposals and contracts, implementation, and evaluation of new services, products, and programs for educational agencies. Provided creative leadership to corporate committees to solicit ideas, identify goals and objectives, plan, develop, present, and evaluate professional development opportunities.

1995-1997 **Education Specialist, Education Service Center, Region One, Edinburg, Texas.** Served as member of Administrative Cabinet team in strategic planning, development of proposals and contracts, implementation, and evaluation of telecommunications capabilities, services, products, and programs for 40 school districts serving 283,000 students in 7 counties. Provided creative leadership to regional and state committees to solicit ideas, identify strategic goals and objectives, plan, develop, present, and evaluate funding opportunities and professional development for 400 librarians.

1993-1996 **Assistant Professor of Library Science, Sam Houston State University, Huntsville, Texas.** Served a faculty member teaching 400 graduate students in technical services (cataloging, bibliographic control, classification), automation, and networking. Participated in distance education program and coordinated annual conference. Conducted university and Texas Library Association-funded field research focused on library collection development and academic achievement.

1992-1993 **Head Librarian, Rocky Mountain College of Art & Design, Denver, Colorado.** Responsible for the daily operation, selection and acquisition of materials, formulation of policies for library operations, media center, and photography/slides archives. Designed and implemented library automation and delivery of electronic resources to college community.

1981-1985 **Development Officer, PRLC, Inc., Pittsburgh, Pennsylvania.** Served as senior member of corporate management team in strategic planning, development of proposals and contracts, implementation, and evaluation of new services, products, and programs for 100 institutional member organizations. Coordinated the development of proposals and contracts totaling $4,000,000 annually. Provided creative leadership to corporate committees to solicit ideas, identify goals and objectives, plan, develop, present, and evaluate professional development opportunities.

1981 **Director of Library Development, Pennsylvania Department of Education, Harrisburg, Pennsylvania.** Responsible for statewide development, technical assistance, professional development, resource sharing, children's services, institutional library services, networking, and state aid program for all libraries throughout the Commonwealth. Functioned as liaison to Governor's Advisory Council, LSCA Advisory Council, District Administrators, private colleges, universities, consortia managers, and network directors. Supervised $14,000,000 formula-based state aid program and $3,000,000 grant awards to individual libraries, consortia, and networks.

1978-1981 **Assistant Director, Southern Tier Library System, Corning, New York.** Coordinated operation of system-wide programs (technical assistance, professional development, resource sharing, technical services, outreach) to 40 public libraries in 5 counties serving 500,000 residents. Solicited ideas, identified goals, sponsored, and evaluated professional development opportunities and technical assistance sessions.

1976-1978 **Division Librarian for Technical Services, Corpus Christi Public Libraries, Corpus Christi, Texas.** Provided leadership in acquisitions, cataloging, serials control, and processing for main library and 4 branches serving 250,000 residents. Participated as senior member of library management team. Compiled and prepared technical evaluations, reports, and statistical analyses of Division operations to measure the achievement and cost of annual goals, objectives, and staff performance.

1975-1976 **System Coordinator, San Antonio Major Resource Center, San Antonio, Texas.** Served as senior member of the management team for District X Office, charged to provide technical assistance, resource sharing, media services, and professional development to librarians and staff representing 30 public library jurisdictions in 21 counties serving 1,500,000 residents. Functioned as liaison to System Director, staff, and members of governing bodies with the System Board of Directors and the Texas State Library and Historical Commission. Prepared LSCA grant applications and monitored awards totaling $1,100,000 annually.

1973-1975 **Bilingual Branch Librarian, San Antonio Public Library, San Antonio, Texas.** Worked as librarian providing reference, information, and readers' advisory services in branch serving 50,000 Spanish-speaking residents in southwest San Antonio. Participated in collection development and resource acquisition activities, specializing in children's work, Spanish language resources, and multicultural studies.

1972-1973 **Librarian, Holding Institute, Laredo, Texas.** Worked as high school librarian serving 500 boarding students in Spanish-speaking environment of private school. Provided reference, research assistance, and library instruction to students and 35 faculty members.

1966-1971 **Rockford Public Library, Rockford, Illinois.** Worked in branches as part-time as a Library Assistant, Clerk, and Page in city library serving 150,000 residents.

PUBLICATIONS

Editor-reviewed Monographs (Completed and in Progress)

Hall-Ellis, Sylvia D., and Mary Bolin. *Contemporary Cataloging in an RDA Environment: A Handbook for Students and Practitioners.* Chicago, IL: American Library Association. Under contract & In development.

RDA Testing: Lessons Learned and Challenges Revealed. Sylvia D. Hall-Ellis and Robert O. Ellett, Jr., eds. Binghamton, N.Y.: Haworth, 2012. 128 p.

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Hall-Ellis, Sylvia D. "Prepared to Lead: Talent, Skills, and Competencies." In *Telling the Technical Services Story*. Chicago, IL: American Library Association, 2020. Program Presentation for Re-Accreditation by the American Library Association, School of Information, San Jose State University, 2022.

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Hall-Ellis, Sylvia D., ed. "Standard III: The Faculty." In the *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, Morgridge College of Education, 2010. 22 p.

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Hall-Ellis-Sylvia D. "Job Design for Cataloging and Metadata Librarians." Submitted to *Journal of Library Administration.* In progress.

Hall-Ellis, Sylvia D. "The Relationship of Situational Leadership and the Dreyfus Model of Skill Acquisition for Supervisors in Cataloging and Metadata Services." To be submitted to *Library Resources and Technical Services.* In progress.

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Faculty Voices: Testimonials from the Frontiers of a Development Education Redesign. Elaine DeLott Baker, Marilyn Smith, and Sylvia D. Hall-Ellis, eds. Denver, Colo.: Colorado Community College System, 2014.

Lewis, Melanie, Jamie M. Van Leeuwen, and Sylvia D. Hall-Ellis. *Project Homeless Connect 7 Event Evaluation.* Denver, Colo.: University of Colorado Denver, 2009.

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Bruntjen, Scott and Sylvia D. Hall. *Recommendations on the Development of System-Wide Efforts of the Northern Waters Library Service.* Ashland, Wisc.: Northern Waters Library Service and The Blue Bear Group, Inc., 1989.

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Other Publications

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* St. Paul, MN: St. Catherine University, 2017. 255 p.

Hall-Ellis, Sylvia D., and Robert O. Ellett, Jr., guest editors. *RDA Testing: Lessons Learned and Challenges Revealed: A Special Issue of Cataloging & Classification Quarterly* 49, no. 7-8 (November 2011).

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Fundamentals of Cataloging I: An Online ALCTS Course.* Chicago, Ill.: American Library Association, 2009.

Hall-Ellis, Sylvia D., Angela J. Kinney and Martha Ann Bace, editors. *Best Practices in Cataloging Education Identified at the 2007 ALCTS Pre-conference: A Special Issue of the Journal for Library and Information Science Education* 49, no. 2 (Spring 2008).

Hall-Ellis, Sylvia D. *Cataloging Education: A New Emphasis for the Library and Information Science Curriculum.* Presentation delivered to the ALCTS Pre-conference, 132nd Annual Conference, American Library Association, Washington, D.C., June 22, 2007. http://www.loc.gov/aba/professional/

Hall-Ellis, Sylvia D. "*Cataloger Competencies: Do the Employers Require What the Professors Teach?*" Presentation delivered to the ALCTS CCS Heads of Cataloging Discussion Group, 131st Annual Conference, American Library Association, New Orleans, Louisiana, June 26, 2006. http://dlist.sir.arizona.edu/

Hall-Ellis, Sylvia D., guest editor, with Deborah S. Grealy, Clara L. Sitter, and Tassos Petrou. *Library Students' Voices in Colorado: An Issue of Colorado Libraries* 31:1 (Spring 2005).

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, College of Education, 2003. 125 p. with CD-ROM.

Hall-Ellis, Sylvia D. and Deborah S. Grealy, guest editors. *Library Education in Colorado: An Issue of Colorado Libraries* 29, no. 2 (Summer 2003).

Hall-Ellis, Sylvia D., ed. *Library and Information Science Program Self-Study Document for Accreditation by the American Library Association.* Denver, Colo.: University of Denver, College of Education, 2003.

Hall-Ellis, Sylvia D. "Adaptive Furniture for the ADA-Qualified: An Investigative Study." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "Cataloging Electronic Serials: A Study in User Access and Article Delivery." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "E-books: Acquisition and Circulation Issues in Public Libraries." 2001. Unpublished manuscript.

Hall-Ellis, Sylvia D. "Authority Control and Its Importance in School Library Media Online Catalogs." 1999. Unpublished manuscript.

Hall, Sylvia D. "Cooperation Improving Service in San Antonio System." *Texas Libraries* XXXVII (Spring 1976): 27-29.

Hall, Sylvia D. "Summer is Sea Monstrously Fun!" *Texas Library Journal* L (December 1974): 224-226.

Hall, Sylvia D. "A Brief Annotated Bibliography of Non-book Materials on the Mexican American." *Texas Library Journal* XLVIII (October 1972): 213-232.

Book Reviews

ALA Book of Library Grant Money. Ann Kepler, ed. 8th ed. Chicago, IL: American Library Association, 2011. 978-0-8389-1058-0, $175.00 [*Colorado Libraries,* June 2012]

Developing a Compensation Plan for Your Library. Paula M. Singer and Laura L. Francisco, comps. 2nd ed. Chicago, IL: American Library Association, 2009. 978-0-8389-0985-0, $57.00 [*Colorado Libraries,* March 2012]

Frugal Librarian. Carol Smallwood, ed. Chicago, IL: American Library Association, 2011. 978-0-83891-075-7, $42.00 [*Colorado Libraries,* February 2012]

Dowlin, Ken. *Getting the Money: How to Succeed in Fundraising for Public and Nonprofit Libraries.* Westport, Conn.: Libraries Unlimited, 2008. 978-1-59158-597-X, $50.00 [*Colorado Libraries,* February 2009]

Lundahl, Mats. *Bebo de Cuba; Bebo Valdés y Su Mundo*, by Mats Lundahl. Traducción de Linda Oakeshott Dragó. Barcelona: RBA Libros, 2008. 978-849-86-7259-6, $33.99 [*Críticas*, November 2008]

Bonelli, Florencia. *Marlene*, by Florencia Bonelli. Buenos Aires: Aguilar, Altea, Taurus, Alfaguara, 2008. 978-987-04-0995-3, $24.95 [*Críticas*, October 2008]

Keret, Etgar. Traducción de Ana María Bejarano. *Pizzería Kamikaze y Otras Relatos.* México, D.F.: Editorial Sexto Piso, 2008. 968-5679-29-0, no price given [*Críticas*, September 2008]

Littauer, Marita, and Florence Littauer. *Enriquece tu Comunicación. Miami, Fla.: Editorial Unilit, 2008.* 978-0-7899-1521-4, $11.99 [*Críticas*, August 2008]

Martínez, Guillermo. *La Muerte Lenta de Luciana B.* New York: Rayo Planeta, 2008. 978-0-06-156551-9, $14.95 [*Críticas*, May 2008]

Matthews, Joseph R. *The Evaluation and Measurement of Library Services.* Westport, Conn.: Libraries Unlimited, 2007. 978-1-59158-532-9, $50.00 [*Colorado Libraries,* April 2008]

Gómez-Jurado, Juan. *A Masacre de Virginia Tech: Anatomía de una Mente Torturada.* Barcelona: Ediciones El Andén, 2007. 978-84-935789-4-7, €16.50 [*Críticas*, February, 2008]

Matthews, Joseph R. *Library Assessment in Higher Education.* Westport, Conn.: Libraries Unlimited, 2007. 978-1-59158-531-2, $45.00 [*Colorado Libraries,* February 2008]

Chacón, Inma. *La Princesa India: Cuando el Viento Azul.* México: Alfaguara, 2006. 970-770398-9, $19.95 [*Críticas*, June 2006]

Vargas Llosa, Mario. *Israel/Palestina: Paz o Guerra Santa.* fotogs. by Morgana Vargas Llosa. Spain/U.S.: Aguilar: Santillana, 2006. 84-03-09691-7, paper, $19.95 [*Críticas*, May 2006]

Findlay, Diane. *Digging into Dewey.* Fort Atkinson, Wisc.: Upstart Books, 2005. 978-1-932146-18-9, $16.95 [*Colorado Libraries,* May 2006]

Pequeñas Resistencias 4: Antología del Nuevo Cuento Norteamericano y Caribeño. Menéndez, Ronaldo, Ignacio Padilla & Enrique del Risco, eds. Madrid**:** Páginas de Espuma, 2005. 84-95642-59-X, paper, $36.95 [*Críticas*, April 2006]

Rueda, André. *Vengo a Salvar a España: Biografía de Un Franco Desconocido.* Madrid**:** Nowtilus (Investigación Abierta), 2005. photogs., bibliog. 84-9763-202-8, paper, $23.95 [*Críticas*, March 2006]

Becerra, Ángela. *El Penúltimo Sueño.* 1st ed. Barcelona: Planeta, 2005. 84-08-05795-2, $25.95. [*Críticas*, January 2006]

Aguilar Camín, Héctor. *La Conspiración de la Fortuna.* 1st ed. México: Planeta, 2005. 970-37-0368-2, $19.95 [*Críticas*, October 2005]

México en Sus Libros. Enrique Florescano with Pablo Mijangos, editors & compilers. 1st ed. México, D.F.: Taurus Aguilar, 2004. 968-19-0783-3, $16.95 [*Críticas*, September 2005]

Historia Económica de México. Coordinator, Enrique Semo. México: Universidad Nacional Autónoma de México, Editorial Oceano de México, 2004. 13 vols. 970-32-0805+3 (obra completa), $9.25 each [*Críticas*, August 2005]

Czarnowsky, Christyne A. and Michael H. Williams. *Managing Your Wired Workforce: A Practical Guide.* Denver, Colo.: Bradford Pub., 2003. 1-883726-79-4, $24.95 [*Colorado Libraries,* 2004]

Abraham Lincoln. Colección Grandes Biografías. Madrid: Edimat Libros, 2003. 84-8403-858-0, €4.95 [*Críticas*, 2004]

Alponte, Juan María. *Colón: el Hombre, el Navegante, la Leyenda.* México, D.F.: Aguilar, 2003. 968-19-1260-8, $16.95 [*Críticas*, 2004]

Olcese Salvatecci, Alfieri. *Cómo Estudiar con Èxito: Téchnicas yHhábitos Para Aprender Major.* México, D.F.: Alfaomega Grupo Editor, 2002. 970-15-0764-9 [*Críticas*, 2003]

Mujeres Como Islas: Antología de Narradoras Cubanas, Dominicanas, Puertoriqueñas. Edición: Olga Marta Pérez, Thelma Jiménez, Andrés Blanco D., eds. Santo Domingo, República Dominicana: Ediciones Ferilibro, 2002. 959-209-419-5 [*Críticas*, 2003]

Tibol, Raquel. *Los Murales de Diego Rivera: Universidad Autónoma Chapingo.* México, D.F.: Editorial RM, Universidad Autónoma Chapingo, 2002. 968-5208-08-5 [*Críticas*, 2003]

Lindsay-Poland, John. *Emperors in the Jungle: the Hidden History of the U.S. in Panama.* Durham, N.C.: Duke University Press, 2003. 0-8223-3098-9, $18.95 [*Críticas*, 2003]

Kaplan, Allison G. and Ann Marlowe Riedling. *Catalog It! A Guide to Cataloging School Library Materials.* Worthington, Ohio: Linworth Pub., 2002. 1-58683-014-7, $44.95 [*Colorado Libraries,* 2002]

Bardach, Ann Louise. *Cuba Confidential: Love and Vengeance in Miami and Havana.* New York: Random, 2002. 0-375-50489-3, $25.95 [*Library Journal*, 2002]

Swan, James. *Fundraising for Libraries: 25 Proven Ways to Get More Money for Your Library.* New York: Neal Schuman, 2002. 1-55570-433-6, $69.95 [*Colorado Libraries,* 2002]

Puíg de Lange, Victoria. *Sol Con Agua.* Nashville, Tenn.: Editorial Vistazo/Ediciones Reio Negro, 2002. 0-9724506-0-2, $17.75 [*Críticas*, 2002]

The Encyclopedia of Latin American Politics. Edited by Diana Kapiszewski; assistant editor, Alexander Kazan. Westport, Conn.: Oryx Press, 2002. 1-57356-306-4, $74.95 [*Library Journal*, 2002]

Vargas Lizano, Isabel. *Y Si Quieres Saber de Mi Pasado.* Con la colaboración de J.C. Vales. Madrid: Santillana Ediciones Generales, S.L., 2002. 84-03-09278-4, $18.95 [*Críticas*, 2002]

Ruy Sánchez, Alberto. *Los Jardines Secretos de Mogador: Voces de Tierra.* México, D.F.: Alfaguara, S.A., 2001. 968-19-0879-1, $16.95 [*Críticas*, 2002]

Chávez, Ricardo and Celso Santajuliana. *El Final de las Nubes.* Barcelona: RBA Libros, S.A., 2001. 84-7901-760-0, $11.95 [*Críticas*, 2002]

The Power of Language / El Poder de la Palabra: Selected Papers from the Second REFORMA National Conference. Edited by Lillian Castillo-Speed and the REFORMA National Conference Publications Committee. Englewood, Colo.: Libraries Unlimited, 2001. 1-563089459, $35.00 [*Colorado Libraries,* 2001]

Martínez, Rubén. *Crossing Over: A Mexican Family on the Migrant Trail.* Metropolitan: Holt, 2001. 0-8050-4908-8, $26.00 [*Library Journal*, 2001]

Guevara, Ernesto "Che." *The African Dream: the Diaries of the Revolutionary War in the Congo.* Translated from the Spanish by Patrick Camiller. With an introduction by Richard Gott and a foreword by Aleida Guevara March. New York: Grove Press, 2001. 0-8021-3834-9, $13.00 [*Library Journal*, 2001]

Cooper, Gail and Garry Cooper. *New Virtual Field Trips.* Englewood, Colo.: Libraries Unlimited, 2001. 1-56308-887-8, $27.50 [*Colorado Libraries,* 2001]

NATIONAL SERVICE & PROFESSIONAL AFFILIATIONS

American Library Association, Life Member
Association for Library Collections & Technical Services (now CORE)
Cataloging, Classification, and Metadata Section
Awards & Scholarships Coordination Committee, 2025-
Margaret Mann Citation Committee, 2023-
ALCTS Editorial Board, Member, 2015-2019
Committee on Cataloging: Description and Access, Member, 2008-2012
Test Site for RDA, Manager, 2009-2011
Nominating Committee, Member, 2007-2008
Committee for Education and Training of Catalogers, Chair, 2006-2007, Member, 2003-2007
Competencies & Education for a Career in Cataloging Interest Group, Chair, 2010-2012; Member, 2010-
President's Program Committee, 2015-2016
Education Committee, Member, 2005-2007
Task Force on Competencies and Education for a Career in Cataloging, Chair, 2007-2009
2007 Annual Meeting Pre-conference, "What They Don't Teach in Library School: Competencies, Education and Employer Expectations for a Career in Cataloging," Steering Committee Chair
Fundraising Committee, Member, 2004-2006
Office of Diversity
Committee on Diversity, Chair, 2010-2011
Diversity Research Advisory Committee, Member, 2009-2010
Spectrum Scholar Mentor, 2009
Diversity Grants Review Committee, Member, 2007, 2010, 2012
Office of Statistics and Research
Research and Statistics Committee, Member, 2005-2007; Intern, 2003-2005
Library Research Round Table
Nominating Committee, 2022-2023
Membership Committee, 2019-2021
Board of Directors, Member At-Large, 2009-2012
Office of Accreditation
Accreditation Panel Member (training completed 2004)
Accreditation Review Panel Member (training completed 2004)

REFORMA, Life Member
National Board of Directors, 2005-2013
National Fundraising Chair, 2005-2013
National Recruiting and Mentoring Committee, 2008-2010
Colorado Chapter, Secretary, 2004-2005
Colorado Chapter Liaison to National Board of Directors, 2004-2013

American Association of Law Libraries (AALL), Life Member Online Audiovisual Catalogers Association (OLAC) Colorado Association of Law Librarians (CoALL)

American Association of University Women Association for Library and Information Science Education (ALISE)
University of Denver ALISE Representative, 2003-2008; 2010-2011
Membership Advisory Committee, 2007-2010
Technical Services Education Special Interest Group, 2003-
Garfield Doctoral Dissertation Award Reviewer, 2012
Garfield Doctoral Dissertation Scholarship Reviewer, 2014

American Association of University Professors (AAUP), 2006-
American Grant Writers Association, 2014- Grant Professionals Institute, 2016- National Grants Management Association, 2014-
Grant Reviewer (National and Regional Team Leader), U.S. Department of Education, 1998- Grant Reviewer, Broadband Technologies Opportunity Program, U.S. Department of Commerce, 2009
Grant Reviewer, Institute of Museum and Library Services, 1998-2000
Grant Reviewer, Colorado Department of Education, 2014-
Grant Reviewer, Colorado State Library, 1998-
Grant Reviewer, American Association of Community Colleges *Working Connections* program, 1999
Peer Reviewer, *Journal for Library and Information Science Education,* 2005-
Peer Reviewer, *Journal of Library Metadata,* 2009
Peer Reviewer, *International Journal of Library and Information Science,* 2011
Regular Columnist, *The Bottom Line*, 2013-2016
Book Reviewer, *Library Journal*, 2001
Book Reviewer, *Críticas*, 2002-2009
Book Reviewer, *Colorado Libraries,* 2000-2012

REGIONAL SERVICE & PROFESSIONAL AFFILIATIONS

Mountain Plains Library Association
Professional Development Grants Committee, Member, 2005-2006
Professional Development Policy and Guidelines Sub-committee Chair, 2006

Colorado Association of Libraries
"Student Voices" Column Editor, *Colorado Libraries,* 2005-2006
Conference Planning Committee, Member, 2002
Technical Services and Automation Division, Chair, 2002-2003; Member, 2000-
Academic Libraries Division, Peer Review Conference Papers Committee, Member, 2007-2009
Education Committee, Member, 1988-1993
Diverse Populations Committee, Member, 2009-2013

SERVICE TO THE UNIVERSITY OF DENVER
Center for Teaching and Learning Faculty Advisory Board, 2007-2008; 2010-2012
Center for Community Engagement and Service Learning Advisory Board, 2007-2012
Faculty Senate
Executive Committee, 2008-2013
Nominations, Rules & Credentials Committee, Chair, 2008-2013; Member 2007-2013
Appointment, Promotion, and Tenure Revision Committee, 2010-2012
Grievance Policy Committee Member, 2007-2010
Law Library Director Search Committee Chair, 2012-2013
PROF Grant Review, College Representative to the University Review Team, 2006, 2008
Project Homeless Connect Evaluations, Principal Investigator, 2006-2009
University Technology Council, 2007-2009
University of Denver Hyde Interviews for Incoming Freshmen, 2003-2012

SERVICE TO THE MORGRIDGE COLLEGE OF EDUCATION
Appointment, Tenure & Review Committee
Member, voting, 2003-2005; 2007- 2009
Chair, Clinical Faculty Promotion & Tenure Policy Subcommittee, 2008-2009
Member, Community Engagement Subcommittee, 2007-2009
Member, Tenure Review Panel, 2003
Advancement and Alumni Relations Committee, Chair, 2003-2007; Member, 2002-2007

College Building Committee Member, 2004-2010
College of Education Student Association, Faculty Advisor, 2004-2007; 2009-2010
Faculty Senator, 2007-2013
Research and Scholarship Committee, Chair, 2008-2009; Member, 2002-2003, 2008-2009
Research and Grant Mentoring Committee, Chair, 2009-2010
Research Task Force Member, 2010-2012
Search Committee Member, Assistant Professor for Curriculum & Instruction, 2010-2011
Workload Task Force Member, 2010-2011

SERVICE TO THE LIBRARY & INFORMATION SCIENCE PROGRAM

Library and Information Science Student and Alumni Association, Faculty Advisor, 2002-2008
ALA Student Chapter, Faculty Advisor, 2005-2008
Beta Phi Mu Phi Chapter, Faculty Advisor, 2004-2014
Steering Committee Member, Accreditation by the American Library Association, 2001-2004
Search Committee Member, Associate Professor for LIS, 2006
Search Committee Chair, Assistant Professors for LIS, 2003, 2005, 2006, 2007
Search Committee Ex-Officio Member, Director for LIS, 2004

SERVICE TO SAM HOUSTON STATE UNIVERSITY

Rio Roundup: South Texas Literature Conference, Conference Coordinator, 1993
External Relations, Fund Raising, Grants Committee, Chair, 1993-1995
Advisory Council Committee, Chair, 1993-1995
Students, Admissions, and Advisement Committee, Chair, 1994
Institutional Effectiveness Committee, Member, 1993-1995

SERVICE TO THE COLLEGE OF EDUCATION AND APPLIED SCIENCE

Faculty Affairs Committee, Member, 1993-1995
Curriculum Committee, Member, 1993-1995
Continuing Education Committee, Member, 1993-1995

SERVICE TO THE COMMUNITY

French Teacher & Student Exchange with Laon, France, Monarch High School, Boulder Valley School District (Boulder, Colorado), 2017-
Denver/Boulder Games 2022, Board of Directors, Secretary-Treasurer, 2015-2018
United Way Campaign Committee, College of Education, 2006
Arapahoe County, Election Judge for the County Clerk and Recorder, 2000-2005
Arthritis Foundation, Rocky Mountain Chapter, Certified Educator & Trainer, 1999-2008
Bonfils Blood Center, Silver Level Donor, 2000-2016
Denver Museum of Natural History, Docent, 1992
Tech Prep of the Lower Rio Grande Valley, Inc. (Harlingen, Texas) Board of Directors, 1995-1997
Executive Committee, 1996-1997; Chair, Development Committee, 1995-1997; Chair, Fiscal Agency Committee, 1995-1996; Chair, Colleges and Universities Committee, 1996-1997
Gilpin County (Colorado) Public Library Board of Trustees, 1986-1989; Vice President, 1987-1989
City of Central (Colorado) Economic Development Committee, 1987-1989
Columbine Family Health Centers, Inc. (Nederland and Black Hawk, Colorado) Board of Directors, 1988-1989

CERTIFICATION

Permanent Public Librarian Certificate - Pennsylvania, New York, Texas
Westlaw Expert Witness, 2008-
Certified Grant Writer®, 2016-

AWARDS AND HONORS

Advanced Practitioner for Service Learning and Community Engagement, University of Denver, 2011
Platinum Star Alumnae, College of Information, Library Science & Technologies, University of North Texas, 2009
Commendation for Integration of Technologies in Teaching & Learning Environment, University of Denver, 2006
Outstanding Adjunct Faculty Member Award, College of Education, University of Denver, 2002
Beta Phi Mu, Pi, University of Pittsburgh, 1985
Alpha Lambda Sigma, University of North Texas, 1972
Albert Nelson Marquis Lifetime Achievement Award, Who's Who in America
Who's Who in American Women
Who's Who of Women Executives
Dictionary of International Biography
Who's Who in the East
Who's Who in the South and Southwest
Who's Who in the World
Who's Who of Online Professionals
Who's Who in Library and Information Science
2,000 Notable Women
Who's Who of Emerging Leaders
Who's Who in Professional and Executive Women
Who's Who in American Education
International Who's Who of Professional and Business Women
International Leaders in Achievement
International Educator of the Year
Who's Who in Finance and Industry
Who's Who in Finance and Business

Invited International and National Conference Presentations

Hall-Ellis, Sylvia D. *Presentation of the Robert O. Ellett Endowed Scholarship.* Presentation delivered to the School of Information at San Jose State University Alumni & Student Program, American Library Annal Conference, San Diego, Calif., June 29, 2024.

Driscoll, Margaret, Christy Confetti Higgins, Scott Brown, and Sylvia D. Hall-Ellis. *A View from Within: Open House Tour of Three Canvas Core Courses*. Presentation to be delivered at the School of Information, San José State University Professional Development Seminar, San José, California, October 17, 2019.

Hall-Ellis, Sylvia D. *Invest in Me -- I'm Your Future: Succession Planning for Libraries.* Keynote presentation delivered at the ALCTS President's Symposium, Boston, Mass., January 8, 2016.

Seidel, Kent E. and Sylvia D. Hall-Ellis. *Making Grants Work for You: Strategies for Doctoral Students and Early Career Scholars.* Presentation delivered at the University Council for Educational Administration, Early Career Scholars Session, Indianapolis, Ind., November 9, 2013.

Hall-Ellis, Sylvia D. *So You Want to be a Manager; Leadership Skills and Competencies for Technical Services Managers and Administrators.* Presentation delivered at the 138th Annual Conference, American Library Association, Chicago, Ill., June 29, 2013.

Seidel, Kent E., Karen S. Riley, Lyndsay Agans, Susan Korach, and Sylvia D. Hall-Ellis. *Making Grants Work for You (Instead of Just Working for Grants).* A panel discussion delivered at the University Council for Educational Administration, Early Career Scholars Session, Denver, Colo., November 17, 2012.

Hall-Ellis, Sylvia D. *After the Great TS Reorganization: The Westminster Law Library.* Presentation delivered at the 137th Annual Conference, American Library Association, Anaheim, Calif., June 23, 2012.

Hall-Ellis, Sylvia D. *Conversations with Catalogers in the 21st Century.* A panel discussion sponsored by the ALCTS Competencies for a Career in Cataloging Interest Group, delivered at the 137th Annual Conference, American Library Association, Anaheim, Calif., June 22, 2012.

Hall-Ellis, Sylvia D., moderator. *Mid-Career Leaders Program.* A panel discussion sponsored by the ALA Committee on Diversity delivered at the 136th Annual Conference, American Library Association, New Orleans, La., June 26, 2011.

Hall-Ellis, Sylvia D., moderator. *Diversity Town Hall.* A community conversation sponsored by the ALA Committee on Diversity delivered at the 136th Annual Conference, American Library Association, New Orleans, La., June 24, 2011.

LaBarre, Kathryn, Sylvia D. Hall-Ellis, Karen Anderson, Rick Hasenyager, Christopher Cronin, and Penny Baker. *Briefings from RDA Test Participants.* A panel discussion delivered at the Midwinter Conference, American Library Association, San Diego, Calif., January 7, 2011.

Miksa, Shawne, Marjorie Bloss, and Sylvia D. Hall-Ellis. *Educating the Next Generation of Catalogers: Teaching RDA.* A panel discussion delivered at the 97th Annual Conference, Association for Library and Information Science Education, San Diego, Calif., January 7, 2011.

Hall-Ellis, Sylvia D., Robert Maxwell, John Hostage, and George Prager. *RDA Panel: What Cataloging Managers Need to Know.* Presentation delivered at the 103rd Annual Conference, American Association of Law Librarians, Denver, Colo., July 12, 2010.

Hall-Ellis, Sylvia D. and Stacey L. Bowers. *Catalogers in the RDA Environment: Skill Sets, Expectations and Challenges.* Presentation delivered at the 103rd Annual Conference, American Association of Law Librarians, Denver, Colo., July 11, 2010.

Hall-Ellis, Sylvia D. *Comfortable in Your Cataloging and Metadata Specialist Skin? Or, So You Want to Hire a Cataloger.* Presentation delivered to the ALCTS Research Group at the 134th Annual Conference, American Library Association, Chicago, Ill., July 11, 2009.

Perez, Megan, Sylvia D. Hall-Ellis, and Denise Anthony. *From Novice to Expert: Collaboration for Succession Planning.* A "hot topic" presentation delivered at the 14th ACRL Conference, Seattle, Wash., March 13, 2009.

Hall-Ellis, Sylvia D. *Cataloging in the RDA Environment: Skill Sets, Expectations and Challenges.* Presentation delivered to the ALCTS Research and Publications Committee at the Midwinter Conference, American Library Association, Denver, Colo., January 24, 2009.

Hall-Ellis, Sylvia D. *LIS Cataloging Education for the 21st Century: Expectations and Challenges.* A panel discussion held at the 95th Annual Conference, Association for Library and Information Science Education, Denver, Colo., January 23, 2009.

Chu, Clara, Sylvia D. Hall-Ellis, and Mark Winston. *The Doctoral Degree & Building a Career.* A panel discussion delivered at the ALA Office of Diversity Spectrum Doctoral Fellows E.J. Josey Leadership Institute, Midwinter Conference, American Library Association, Denver, Colo., January 20, 2009.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Fundamentals of Cataloging Course: An Overview of the ALCTS Online Course.* Presentation delivered to the ALCTS Big Heads Group, 133rd Annual Conference, American Library Association, Anaheim, Calif., June 30, 2008.

Hall-Ellis, Sylvia D. *Employers' Expectations for Technical Services Librarians: What We Don't Know.* Presentation delivered to the ALCTS Research and Publications Committee Program, 133rd Annual Conference, American Library Association, Anaheim, Calif., June 28, 2008.

Hall-Ellis, Sylvia D., Virginia R. Maloney, and Mary Stansbury. *Institutional Responses to Engaged Scholarship: The Carnegie Foundation Engaged University Classification at Two Universities.* Presentation delivered to the 94th Annual Conference, Association for Library and Information Science Education, Philadelphia, Pa., January 11, 2008.

Hall-Ellis, Sylvia D. *Puzzles, Problems, and Predicaments.* Presentation delivered to the ALCTS Research Discussion Group, 132nd Annual Conference, American Library Association, Washington, D.C., June 23, 2007.

Hall-Ellis, Sylvia D. *Cataloging Education: A New Emphasis for the Library and Information Science Curriculum.* Presentation delivered to the ALCTS Pre-conference, 132nd Annual Conference, American Library Association, Washington, D.C., June 22, 2007. http://www.loc.gov/catdir/cpso/careercat.html

Ellett, Jr., Robert O. and Sylvia D. Hall-Ellis. *Copy Cataloging Done Smarter.* Presentation delivered to the International Conference on Interdisciplinary Information Sciences and Technologies (InSciT2006), October 25-28, 2006.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Cooperative Cataloging: Challenges and Opportunities for Defense Libraries.* Presentation delivered to the 1st Annual Conference of Defense Libraries, Spanish Ministry of Defense, Madrid, Spain, July 7, 2006.

Hall-Ellis, Sylvia D. *Cataloger Competencies: Do the Employers Require What the Professors Teach?* Presentation delivered to the ALCTS CCS Heads of Cataloging Discussion Group, 131st Annual Conference, American Library Association, New Orleans, La., June 26, 2006.

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *From Research to Practice: The Scholarship of Teaching and Learning in LIS Education.* Presentation delivered to the at the 92nd Annual Conference, Association for Library and Information Science Education, San Antonio, Tex., January 18, 2006.

Hall-Ellis, Sylvia D. *Employers' Expectations for Entry-Level Catalogers: What Position Announcement Data Indicate.* Research paper delivered to the Technical Services Special Interests Group, 91st Annual Conference, Association for Library and Information Science Education, Boston, Mass., January 12, 2005. http://dlist.sir.arizona.edu/

Hall-Ellis, Sylvia D. *Common Errors in MARC Records Prepared by LIS Students: What Does It Mean?* Research paper delivered to the ALCTS CCS Cataloging Norms Discussion Group, Mid-Winter Conference, 90th American Library Association, San Diego, Calif., January 10, 2004.

Hall-Ellis, Sylvia D. *Visual Arts as Foundation for Successful Library Automation: The Rocky Mountain College of Art & Design Experience.* Paper delivered at the 6th Annual Conference of Higher Education, Charleston, S. C., 1993.

Hall, Sylvia D. *Design Elements for Bibliographic Databases: An Overview.* Paper delivered at the 14th Online National Conference, New York, 1983.

Invited Regional Conference Presentations

Hall-Ellis, Sylvia D., Hudson, Christopher D., Brittany Cronin, and Kathryn Michaels. "The Colorado Law Project: Meeting the Public's Need for Legal Information." Panel discussion delivered at the Mountain Plains Library Association Conference, Billings, Mont., April 9, 2011.

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *Education for Information Professionals in New Mexico: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the New Mexico Library Education Summit, Las Vegas, N.M., September 26, 2005.

Hall-Ellis, Sylvia D. *Public Library-School Library Partnerships.* Presentation delivered at the 3rd Annual Colorado Association of Libraries Conference with the Mountain Plains Library Association, Denver, Colo., October 22, 2004.

Hall-Ellis, Sylvia D. *Learn All You Can – Educational Partnership Opportunities for the Lewis and Clark Bicentennial Commemoration.* Paper delivered at the 3rd Annual Lewis and Clark Bicentennial Council National Planning Conference, Bismarck, N.D., April 26, 1998.

Invited State Conference Presentations

Grealy, Deborah S. and Sylvia D. Hall-Ellis. *Academic Library Leadership Changes: Using Succession Planning and Mentoring*. Presentation delivered at the Minnesota Library Education Conference, St. Cloud, Minn., October 10, 2013.

Hall-Ellis, Sylvia D., Merrie Valliant, and Melissa Powell. *RDA: What Is It and What Do You Need To Do With It At Your Library?* Presentation delivered at the Colorado Library Consortium Spring Conference, Ft. Morgan, Colo., April 26, 2013.

Hall-Ellis, Sylvia D. *Service Learning and the Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 4th LEADS Scholars Orientation, Denver, Colo., August 5, 2009.

Hall-Ellis, Sylvia D. *Service Learning: Enhancement to Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 3rd LEADS Scholars Orientation, Denver, Colo., June 2008.

Hall-Ellis, Sylvia D. *Law Librarianship: A Community Conversation.* Sponsored by the Colorado Association of Law Libraries. Paper delivered at the Colorado Supreme Court Library, Denver, Colo., May 14, 2008.

Hall-Ellis, Sylvia D. *Opportunities and Challenges in Law Librarianship: A Community Conversation.* Presentation delivered at the Sturm College of Law, Denver, Colo., November 7, 2007.

Ellis, Sylvia D. *Grant Writing Resources for Nursing Professionals.* Presentation delivered at the Presbyterian / St. Luke's Health One Medical Center 1st Annual Research Symposium, Denver, Colo., October 17, 2007.

Hall-Ellis, Sylvia D. *Project Homeless Connect 4 Event Evaluation – Insights and Lessons Learned.* Presentation delivered at the Homelessness Research Symposium: What is DU Doing about Homelessness in Denver, Denver, Colo., September 14, 2007.

Hall-Ellis, Sylvia D. *Service Learning and the Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 2nd LEADS Scholars Orientation, Denver, Colo., August 10, 2007.

Hall-Ellis, Sylvia D. *Education for Information Professionals in a Digital Environment: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 15th Spring Mountains and Plains Parapros Conference, Denver, Colo., February 24, 2007.

Hall-Ellis, Sylvia D. *Public Library Service to Spanish-Speaking and Latino Residents in Denver: A Case Study.* Presentation delivered at the 4th Annual Colorado Association of Libraries Conference, Denver, Colo., November 10, 2005.

Hall-Ellis, Sylvia D. *Education for Information Professionals in a Digital Environment: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 14th Annual Mountains and Plains Parapros Conference, Aurora, Colo., July 29, 2005.

Hall-Ellis, Sylvia D. *Educational Opportunities: Library & Information Science Graduate Education at the University of Denver.* Presentation delivered at the 13th Annual Mountains and Plains Parapros Conference, Centennial, Colo., August 6, 2004.

Hall-Ellis, Sylvia D. *Library Education & Training: Focus on the West: An LIS Faculty Member's Personal Response*. Presentation delivered at the 1st Annual Colorado Association of Libraries Conference, Keystone, Colo., October 18, 2002.

Hall-Ellis, Sylvia D. *Grant Writing for School Librarians.* Presentation delivered at the 2002 Annual Colorado Education Media Association Conference, Colorado Springs, Colo., February 15, 2002.

Hall-Ellis, Sylvia D. *Grants – Opportunities for the Future.* Paper delivered at the Southeast Regional Accountability Annual Conference, Lamar, Colo., November 12, 1998.

Hall-Ellis, Sylvia D. *The Texas Library Connection and Interlibrary Loan: An Experiment in Resource Sharing.* Paper delivered at the Texas Computer Educators' Association Annual Conference, Austin, Tex., February 6, 1997.

Hall-Ellis, Sylvia D. *Finding Grant Sources on the Internet: A Guide for Librarians.* Paper delivered at the 2nd Annual Institute for School Library Personnel, Pharr-San Juan-Alamo North High School, Pharr, Tex., July 29, 1996**.**

Hall-Ellis, Sylvia D. *Mathematical and Logical Thinking: A Critical Intelligence.* Paper delivered at the 3rd Annual Paraprofessional Conference at the University of Texas - Pan American, Edinburg, Tex., March 8, 1996.

Hall-Ellis, Sylvia D. *Cataloging Trends and Issues: Update Session.* Paper delivered at the 1st Annual Institute for School Library Personnel, South Texas Community College, McAllen, Tex., July 19, 1995.

Hall-Ellis, Sylvia D. *Grant Writing: Tips and Encouragement for School Librarians.* Paper delivered at the 1st Annual Institute for School Library Personnel, South Texas Community College, McAllen, Tex., July 18 and 19, 1995.

Hall-Ellis, Sylvia D. *How to Become an Expert Grant Writer.* Paper delivered at the 3rd Annual High School Principals' Academy, South Padre Island, Port Isabel, Tex., June 19, 1995.

Texas Library Study: Results from Regions I and II. Paper delivered at the 3rd Annual Technology Conference, Texas A&M University, College Station, Tex., November 18, 1994.

Hall-Ellis, Sylvia D. *Academic Achievement and Middle School Students.* Paper delivered at the 8th Annual Young Adult Conference, Sam Houston State University, Huntsville, Tex., November 5, 1994.

Hall-Ellis, Sylvia D. *Multimedia Resources for Library Leaders.* Paper delivered at the Institute for Librarians in A Multicultural Environment, Sam Houston State University, Huntsville, Tex., June 10, 1994.

Hall-Ellis, Sylvia D. *Finding the Resource: Empowering the User, or, the Case for Curriculum Based Subject Access to Learning Resource Center Collections.* Paper delivered at the 81st Annual Texas Library Association Conference, Corpus Christi, Tex., April 12-16, 1994.

Hall-Ellis, Sylvia D. and William H. Pichette. *Sam Houston State University Makes Use of OCLC/AMIGOS Collection Analysis CD.* Paper delivered at the 81st Annual Texas Library Association Conference, Corpus Christi, Tex., April 12-16, 1994.

Hall, Sylvia D. *Funding and Library Development in Pennsylvania: A Symbiotic Relationship.* Paper delivered at the Annual Graduate Student Colloquia, University of Pittsburgh, School of Library and Information Science, 1982.

Hall, Sylvia D. *Leadership for Public Library Trustees.* Paper delivered for the Trustees Division, Pennsylvania Library Association Annual Conference, Lancaster, Penn., 1981.

Seminar and Professional Development Presentations

Taylor, Meredith, and Sylvia D. Hall-Ellis. *Talent Management and Succession Planning.* ALCTS eForum, held March 22, 2017.

Hirsh, Sandra, Heather O'Brien, Michelle Holschuh Simmons, Michael Krasulski, and Sylvia D. Hall-Ellis. *Information Services Today: An Introduction. Part 3: Information Services: Roles in the Digital Age*. Rowan and Littlefield in partnership with Library Journal webinar, recorded February 5, 2015.

Hall-Ellis, Sylvia D. and Jennifer Sweda. *Copy Cataloging in an RDA Environment.* ALCTS eForum, held May 14 and 15, 2013.

Hall-Ellis, Sylvia D. *Law Librarianship: A Community Conversation.* Sponsored by the Colorado Association of Law Libraries, presented at the Colorado Supreme Court Library, Denver, Colo., May 14, 2008.

Hall-Ellis, Sylvia D. and Beatrice Z. Gerrish. *Reading and Libraries: Recent Research in Reading.* Presentation at the Ricks Center for Gifted Education, Denver, Colo., March 4, 2008.

Hall-Ellis, Sylvia D. *Cataloger Competencies: Do the Employers Require What the Professors Teach?* Presentation for the School of Library and Information Science, San José State University, February 12, 2008.

Hall-Ellis, Sylvia D. and Robert O. Ellett, Jr. *Cooperative Cataloging: Rules, Tools, and Conventions for Building a Multi-institutional Catalog.* Sponsored for the Spanish Ministry of Defense, Madrid, Spain, July 10, 2006.

Hall-Ellis, Sylvia D. *Cash for Kids: Grant Writing Opportunities for Youth Services Librarians.* Sponsored by the Colorado Young Adult Librarians; presented at Bemis Memorial Library, Littleton, Colo., November 13, 2002.

Hall-Ellis, Sylvia D. *MARC Records and Authority Control: Planning for Bibliographic Database Migration.* Sponsored and held at the Douglas County Public Library, Castle Rock, Colo., May 28, 2002.

Grant Writing: A Refresher for Librarians. Sponsored by Library and Information Science Program, College of Education, University of Denver; presented at University Center at Chaparral, August 12, 2000.

Hall-Ellis, Sylvia D. *Shaking the Money Tree – Basic Grant Writing for Colorado Educators.* Sponsored by the Office of Educational Telecommunications of the Colorado Department of Education.
Pikes Peak Community College, Colorado Springs, Colo., November 16, 1998.
Pueblo School District 60, Pueblo, Colo., November 12, 1998.

University of Northern Colorado, Greeley, Colo., November 10, 1998.
United Technology Educational Partnership, Grand Junction, Colo., November 9, 1998.

Hall-Ellis, Sylvia D. *Cataloging Multimedia, Kits, Globes and Map Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 24, 1997 and December 12, 1996.

Hall-Ellis, Sylvia D. *New Standards for School Library Media Centers.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 15, 1997.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., April 4, 1997.

Hall-Ellis, Sylvia D. *Cataloging Sound Recordings and Audio Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., March 20, 1997 and November 21, 1996.

Hall-Ellis, Sylvia D. *Evaluating and Selecting CD-ROMS for School Library Media Collections.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., March 18, 1997.

Hall-Ellis, Sylvia D. *Cataloging Audiovisual Materials in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., February 27, 1997, November 7, 1996 and October 24, 1996.

Hall-Ellis, Sylvia D. *Introduction to Dialog: Basic Searching Strategies.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., February 14, 1997.

Hall-Ellis, Sylvia D. *Cataloging Books in USMARC.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., January 30, 1997, October 10, 1996, September 26, 1996 and August 8, 1996.

Hall-Ellis, Sylvia D. *Advanced Internet Searching Techniques for Librarians.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., January 21, 1997.

Hall-Ellis, Sylvia D. *Texas Library Connection Full-Text Searching.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., December 13, 1996 and October 25, 1996.

Hall-Ellis, Sylvia D. *Developing Evaluation Strategies for Grants and Proposals.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., December 10, 1996.

Hall-Ellis, Sylvia D. *Developing Needs Assessment for Grants and Proposals.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., November 12, 1996.

Hall-Ellis, Sylvia D. *Texas Library Connection Union Catalog Searching.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., November 8, 1996 and September 6, 1996.

Hall-Ellis, Sylvia D. *Grant Resources on the Internet.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., October 23, 1996.

Hall-Ellis, Sylvia D. *Preparing a Response to the Telecommunications Infrastructure Fund Board: Needs Assessment, Professional Development Framework, and Evaluation Strategies.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., October 16, 1996.

Hall-Ellis, Sylvia D. *Texas Library Connection: Building the Districtwide Bibliographic Database.* Sponsored and hosted by Mercedes Independent School District, Mercedes, Tex., September 13, 1996 and August 8, 1996. Sponsored and hosted by Los Fresnos Consolidated Independent School District, Los Fresnos, Tex., August 12, 1996.

Hall-Ellis, Sylvia D. *School-to-Work and Special Education: An Inclusive Partnership for Success.* Sponsored and hosted by the Office of Special Education, Region One Education Service Center, Edinburg, Tex., September 11, 1996.

Hall-Ellis, Sylvia D. *Telecommunications Infrastructure Fund Board: An Overview of Funding for Secondary Schools.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., August 31, 1996.

Hall-Ellis, Sylvia D. *Cataloging Books, Multimedia, and Realia in USMARC.* Sponsored and hosted by Edinburg Consolidated Independent School District, Edinburg, Tex., August 6, 1996.

Hall-Ellis, Sylvia D. *Internet Resources for Grant Writers.* Sponsored and hosted by Region One Education Service Center, Edinburg, Tex., April 20, 1996.

Hall-Ellis, Sylvia D. *Enhanced Grant Writing Skills for Mathematics Educators: Writing Skills for Campus Teams.* Sponsored and hosted by the Office of General Education, Region One Education Service Center, Edinburg, Tex., March 22, 1996.

Hall-Ellis, Sylvia D. *Internet Resources for Grant Writers.* Sponsored and hosted by the College of Education and Applied Science, Sam Houston State University, Huntsville, Tex., March 9, 1996.

Hall-Ellis, Sylvia D. *Grant Writing for Mathematics Educators: A Development Process for Campus Teams.* Sponsored and hosted by the Office of General Education, Region One Education Service Center, Edinburg, Tex., March 4, 1996.

Hall-Ellis, Sylvia D. *Shaking the Money Tree: Preparing Successful Technology Grant Applications.* Sponsored and hosted by the Office of Technology and Media Services, Region One Education Service Center, Edinburg, Tex., February 29, 1996 and April 29, 1996.

Hall-Ellis, Sylvia D. *District-wide Technology Planning: Technical Assistance for the Texas Education Agency Initiative.* Sponsored and hosted by the Office of Technology and Media, Region One Education Service Center, Edinburg, Tex., February 2, 1996.

Hall-Ellis, Sylvia D. *Enhanced Grant Writing Skills.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., January 27, 1996.

Hall-Ellis, Sylvia D. *United States Copyright Act of 1976, Video Transmissions, Computer Software and the Internet.* Sponsored and hosted by the Office of Technology and Media, Region One Education Service Center, Edinburg, Tex., January 24, 1996.

Hall-Ellis, Sylvia D. *The Grant Writing Development Process.* Sponsored and hosted by Pharr-San Juan-Alamo Independent School District, Pharr, Tex., January 20, 1996.

Hall-Ellis, Sylvia D. *MARC Cataloging of Materials for Library Media Centers.* Sponsored and hosted by the Office of Media Services, Region One Education Service Center for the Donna Independent School District, Donna, Tex., August 17, 1995.

Hall-Ellis, Sylvia D. *Classification.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., May 10, 1995.

Hall-Ellis, Sylvia D. *Library Technical Services.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., April 26, 1995.

Hall-Ellis, Sylvia D. *Grant Writing: An Introduction for Public School Administrators.* Sponsored and hosted by the Office of Administrative Services, Region One Education Service Center, Edinburg, Tex., April 19, 1995.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by the United Independent School District, Laredo, Tex., March 31, 1995.

Hall-Ellis, Sylvia D. *Using USMARC.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., March 29, 1995.

Hall-Ellis, Sylvia D. *Library Media Center Policies and Guidelines: How to Prepare for School Board Adoption.* Sponsored and hosted by the Office of Technology and Media Services, La Joya Independent School District, La Joya, Tex., March 10, 1995.

Hall-Ellis, Sylvia D. *Developing District-wide Policies and Guidelines for Library Media Centers.* Sponsored and hosted by the Office of Technology and Media Services, La Joya Independent School District, La Joya, Tex., January 10, 1995.

Hall-Ellis, Sylvia D. *MARC Cataloging of Audiovisual Materials for Library Media Centers.* Sponsored and hosted by the Office of Library Media and Technology Services, Cypress-Fairbanks Independent School District, Houston, Tex., December 1, 1994.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by United Independent School District, Laredo, Tex., October 14, 1994.

Hall-Ellis, Sylvia D. *The School Library Media Specialist in the 21st Century: Visions for the Future.* Sponsored and hosted by the Laredo Independent School District, Laredo, Tex., October 7, 1994.

Hall-Ellis, Sylvia D. *MARC Cataloging for Library Media Centers.* Sponsored by the Office of Library Media and Technology Services, Cypress-Fairbanks Independent School District, Houston, Tex., October 5, 1994.

Hall-Ellis, Sylvia D. *Jump to the Head of the Class: Undergraduate Library Resources Available at Sam Houston State University.* Sponsored by the Office of the Associate Vice President for Student Services, Sam Houston State University, Huntsville, Tex., October 4, 1994.

Hall-Ellis, Sylvia D. *CD-ROMs - 1994's Newest and the Best for Secondary Level Media Centers.* Sponsored and hosted by Clear Lake Independent School District, Houston, Tex., June 3, 1994.

Hall-Ellis, Sylvia D. *Introduction to Classification.* Sponsored by AJ Seminars, Rockville, Maryland; presented at Holiday Inn, Market Center, Dallas, Tex., May 18, 1994.

Hall-Ellis, Sylvia D. *Basic Descriptive Cataloging.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., May 4, 1994.

Hall-Ellis, Sylvia D. *Shaking the Money Tree - Part II: Writing Successful Grant Applications.* Sponsored by Donna Independent School District, Donna, Texas, and Region One Education Service Center Edinburg, Texas; presented at South Texas Community College Library, McAllen, Tex., April 29, 1994.

Hall-Ellis, Sylvia D. *Using MARC.* Sponsored by AJ Seminars, Rockville, Maryland; presented at Holiday Inn, Market Center, Dallas, Tex., April 6, 1994.

Hall-Ellis, Sylvia D. *Automated Authority Control.* Sponsored by AJ Seminars, Rockville, Maryland; presented at University Hilton Hotel, Houston, Tex., March 23, 1994.

Hall-Ellis, Sylvia D. *Automating the District School Library Media Centers: Choices and Opportunities.* Sponsored and hosted by the Office of Technology and Library Media Services, Fort Bend Independent School District, Sugar Land, Tex., March 4, 1994.

Hall-Ellis, Sylvia D. *Shaking the Money Tree - Part I: Preparing Successful Grant Applications.* Sponsored and hosted by the Office of Library Media Services, Donna Independent School District, Donna, Tex., February 4, 1994.

GRADUATE COURSES TAUGHT

San José State University, School of Library and Information Science
INFO 249 – Advanced Cataloging and Classification (Fall 2015, 2016; Summer 2016)
INFO 287 – Special Topics in Cataloging and Classification (Spring 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026; Fall 2020, 2021, 2022, 2023, 2024, 2025, 2026)
LIBR 248 – Beginning Cataloging and Classification (Summer 2002, 2003, 2004, 2005, 2006)
LIBR 249 – Advanced Cataloging and Classification (Summer 2003; Fall 2014; Summer 2015)

University of Denver, University College
Grant Writing Certificate Seminar for Non-Profit Organizations (Fall 2020, 2021; Spring 2021)

University of Denver, Morgridge College of Education HED
5991 – Grant Writing in Higher Education (Spring 2011)
LIS 4010 – Organization of Information (Fall 2002-2009; Winter 2005; Spring 2004-2006)
LIS 4020 – Professional Principles and Ethics (Summer 2000)
LIS 4040 – Management of Libraries and Information Centers (Fall 2010; Spring 2003, 2009 (DS); Winter 2005)
LIS 4070 – Cataloging and Classification (Winter 2008, 2009, 2010, 2011, 2012; Fall 2009 (DS)) LIS
4321 – Collection Management (Spring 2005)
LIS 4326 – LIS Research (Winter 2009 (DS); Spring 2009 (DS))
LIS 4350 – Adult Materials and Services (Summer 2006, 2009)
LIS 4379 – Social Sciences Resources (Spring 2009)
LIS 4400 – Cataloging and Classification (Spring 2000, 2001; Winter 2002-2009; Summer 2005, 2006 – course renumbered LIS 4070, September 2007)
LIS 4401 – Descriptive Cataloging (Winter 2001; Spring 2002, 2003, 2006-2009; Summer 2005)
LIS 4402 – Subject Cataloging (Spring 2001, 2009; Summer 2005, 2006, 2007, 2008)
LIS 4403 – Classification Schemes (Fall 2007, 2008, 2009 (DS)) LIS
LIS 4405 – Authority Control (Winter 2009)
LIS 4510 – Materials and Services for Children (Winter 2004; Summer 2005)
LIS 4620 – Grant Writing and Fundraising (Summer 2000, 2002, 2004, 2010; Winter 2006; Fall 2006-2009)
LIS 4700 – Seminar in Technical Services (Fall 2001)
LIS 4700 – Seminar in Public Libraries (Summer 2002)
LIS 4804 – Management of Electronic Records (Spring 2004; Fall 2005)
LIS 4902 – Capstone Projects (Winter 2003, Spring 2008, 2009, 2011)
LIS 4910 – Independent Study (every quarter Winter 2000 through Spring 2011)
LIS 4920 – Service Learning (every quarter Summer 2004 through Spring 2011)
RMS 4954 – Grant Writing (Summer 2013, 2014)
RMS 4959 – Content Analysis Methodology (Spring 2015)
QRM 4978 – Grant Writing (Summer 2011, 2012)

Rutgers University, School of Communication and Information
SC&I 522 – Cataloging and Classification (Summer 2013)

University of Arizona, College of Behavioral and Social Sciences
LIS 602 – Cataloging and Classification (Summer 1995)
LIS 612 – Advanced Online Search and Retrieval (Summer 1995)

Sam Houston State University, College of Education & Applied Science
LIS 532 - Cataloging and Classification (Fall 1993, 1994, 1995)
LIS 563 - Advanced Cataloging and Classification (Summer 1994)
LIS 567 - Research Methods (Spring 1994, Spring 1995)
LIS 591 - Educational Technology (Spring 1994, 1995)
LIS 596 - Networking and Computer Technologies in Education (Fall 1993, Summer 1994, Fall 1995)

Dissertations at the University of Denver

Bowers, Stacey L. *Library Anxiety of Law School Students: A Study Utilizing the Multidimensional Library Anxiety Scale.* Chair, May 5, 2010.

Fattor, Melissa M. *Student Engagement Differences by Ethnicity and Scale for Ninth Grade Students.* Chair, November 1, 2010.

Fulton, Roseanne. *A Case Study of Culturally Responsive Teaching in Middle School Mathematics.* Kent Seidel, Chair, June 18, 2009, Outside Chair.

Grealy, Deborah S. *Tribes and Territories in Library and Information Studies Education.* Bruce Uhrmacher, Chair, June 10, 2008, Committee Member.

McCord, J. Michael. *Developing a Standard of Care for Educational Malpractice.* Chair, April 15, 2011.

Priebe, Sarah J. *Distinguishing Effects of Domain and General Knowledge on Passage Fluency and Comprehension.* Jan Keenan, Chair. July 21, 2011, Outside Chair.

Snyder-Mondragon, Sandra M. *Institutional Factors that Impact the Retention of Graduate Students of Color in Schools of Library and Information Science: A Metaregression of Accredited Library School Statistics on Student Retention and Graduation Rates.* Kathy Green, Chair, July 24, 2009, Committee Member.

Taylor, Karen Pickles. *Effective Teaching.* Elinor Katz, Chair, July 15, 2009, Outside Chair.

Thompson, Jennifer. *Distinguishing a Western Women's College: A History of the Curriculum and Student Experience at Colorado Women's College.* Edith W. King, Chair, July 16, 2010, Committee Member.

Walker, Emelda. *Influence of Organizational Factors on Job Satisfaction of Disability Service Providers at Postsecondary Institutions.* Chair, April 29, 2010.

Dissertation Proposals at the University of Denver

Bowers, Stacey L. *Library Anxiety of Law School Students: A Study Utilizing the Multidimensional Library Anxiety Scale.* Chair, November 5, 2009.

McCord, J. Michael. *Developing a Standard of Care for Educational Malpractice.* Edith W. King, Chair. April 23, 2010.

Thompson, Jennifer. *History of Colorado Women's College.* Edith W. King, Chair, October 30, 2008. Committee Member.

Walker, Emelda. *Influence of Organizational Factors on Job Satisfaction of Disability Service Providers at Postsecondary Institutions.* Chair, July 21, 2009.

Dissertations at Other Institutions

Rodríguez-Mori, Howard. *The Information Behavior of Puerto Rican Immigrants to Central Florida, 2003-2009: Grounded Analysis of Six Case Studies Use of Social Networks during the Migration Process.* Kathleen Burnett, Chair, April 10, 2009, Florida State University, Committee Member.

Schwartz, Brian *More than a Look-up Skill: Medical Information Literacy Education in Osteopathic Medical Schools.* D. Mirah Dow, Chair, July 18, 2017. Emporia State University, Committee Member.

Snow, Karen. *A Study of the Perception of Cataloging Quality among Catalogers.* Shawne D. Miksa, Chair, August 1, 2011. University of North Texas, Committee Member.

Dissertation Proposals at Other Institutions

Schwartz, Brian *More than a Look-up Skill: Medical Information Literacy Education in Osteopathic Medical Schools.* D. Mirah Dow, Chair, December 4, 2015. Emporia State University, Committee Member.

Snow, Karen. *A Study of the Perception of Cataloging Quality among Catalogers.* Shawne D. Miksa, Chair, May 11, 2010. University of North Texas, Committee Member.

Master's Thesis at the University of Denver

Hemingson, Jeff. *Recital Paper.* Lamont School of Music, February 2010, Outside Chair.

Capstones at the University of Denver

Anthony, Alisa. *Correlation of Library and Information Science Program outcomes and Vacant Position Qualifications Listed on the Colorado State Library Jobline by Employers During the Period September 1, 2000 through August 31, 2002.* Chair, Winter Quarter, 2003.

Borden, Donna M. *Improving Emergency Communications Systems: Is a Radio Communications Network the Answer?* Fall Quarter, 2014.

Bowden, Heather L.M. *Exploring Biological Models for Long-term Data Preservation.* Chair, Spring Quarter, 2008.

Casenada, Cassandra Y. *Challenges to the Recruitment, Education, and Retention of Librarians of Color*. Chair, Spring Quarter, 2008.

Chang, Jennifer C. *Legal Research Practice and Preference: A Law Firm Perspective.* Chair, Spring Quarter 2011.

Ellis, Megan S. Fitzgerald. *Design of a Public Library Adult Volunteer Recruitment Program and Training Curriculum.* Chair, Winter Quarter, 2003.

Kircher, Kathy. *Development of a Library Pathfinder for Exobiology and Posting it on the Internet.* Chair, Winter Quarter, 2003.

Melhado, Loretta. *Design of St. John's Episcopal Church Library.* Chair, Spring Quarter, 2008.

Radcliff, Kathy. *Original Cataloging of Archival materials in the HERS Collection in Penrose Library.* Chair, Winter Quarter, 2003.

Sass, Carol Ann. *ACT Periodical Index: Access to Catholic Thinking Periodical Index: Web Index to Select Catholic Periodicals.* Spring Quarter 2000.

Stone, Sergio D. *Conducting Community Analysis for the Bemis Public Library (Littleton, Colorado) Using 2002 U.S. Census Data and the Online Outcome-Based Evaluation Toolkit.* Chair, Winter Quarter, 2003.

Tureson, Tamara. *Design and Use of an Information Audit Tool for Use in a Law Library.* Chair, Winter Quarter, 2003.

Tweed, Beth. *Evaluation of Email Reference Service in a Consumer Health Library Environment.* Chair, Winter Quarter, 2003.

GRANTS AND CONTRACTS

Student Learning in Agriculture STEM through Teacher Professional Development. Research team: Stanton Gartin (PI) and Cyndi Hofmeister, Northeast Junior College; Jeff Cash, Cheryl Sánchez, Anne-Marie Crampton, Lamar Community College; Suzanna Spears, Morgan Community College; Jack Wiley, Kerry Gabrielson, Trinidad State Junior College; Michael J. Miller, Colorado State University; Michael Womochil (Co-PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Agriculture, Agriculture and Food Research Initiative, Food, Agriculture, Natural Resources and Human Sciences Education and Literacy Initiative, $404,460 (2017-2020)

Leading and Achieving: the Colorado Agriculture Regional Consortium. Research team: Jack Wiley (PI), Kerry Gabrielson, Trinidad State Junior College; Jeff Cash (PI), Cheryl Sánchez, Anne-Marie Crampton, Lamar Community College; Suzanna Spears, Morgan Community College; Cyndi Hofmeister, Northeast Junior College; Michael Womochil (Co-PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Agriculture, Hispanic Serving Institutions Education Grants Program, $504,414 (2017-2020)

Cyber Prep Program Planning Grant. Research team: Debbie Sagen (PI), Brenda Lauer, Pikes Peak Community College; Gretchen Martin, Koiosa Insights; and, Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Commerce, Regional Alliances and Multi-stakeholder Partnerships to Stimulate (RAMPS) Cybersecurity Education and Workforce Development, $199,681 (2016-2018)

Career and Technical Education in Colorado: Pathways to Education and Employment. Research team: Heather McKay (PI), Rutgers University; Sarah Heath, Casey Sacks, Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Education, Institute of Education Sciences, $1,400,000 (2017-2021)

Pre-Alliance Planning Grant Colorado Community College Alliance. Research team: Victor Vialpondo (PI) and Janel Highfill, Community College of Aurora; Heidi Loshbaugh (Co-PI), Community College of Denver; Rick Reeves, Bill McGreevy, Liz Cox, and Kristin Aslin, Red Rocks Community College; Cathy Pellish, Front Range Community College; Samuel DeVries, Arapahoe Community College; Sylvia D. Hall-Ellis, Colorado Community College System. National Science Foundation, Louis Stokes Alliance for Minority Participation (LSAMP), $86,817 (2016-2017)

Towards Scalable Differentiated Instruction Using Technology-enabled, Competency-based, Dynamic Scaffolding. Research team: Karen Wilcox (PI) and Vijay Kumar, Center for Computational Engineering, Massachusetts Institute of Technology; Flora McMartin, Broad-based Knowledge; Quinsigamond Community College; and, Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Education, First in the World Developmental Grant, $2,891,882 (2015-2019)

Colorado Strategic Partnerships Emergency Grant. Research team: Elise Lowe-Vaughn (PI), Amy Hodson, Celia Hardin, Barbara McBride, James Newby, Christopher Dewhurst, Nina Holland, Kate Anderson, MaryAnn Roe, Chrystalynn Chrystalynn, Elaine Edon, Mona Barnes, Tom Morgan, Rob Hanni, and Marie Valenzuela, Colorado Department of Labor and Employment; Steve Anton, Joelle Brouner, and, Katie Griego, Colorado Department of Human Services; Rebecca Holmes, Judith Martinez, and Jennifer Jirous, Colorado Department of Education; Emily Templin Lesh, Colorado Workforce Development Council; Cory Everett, Colorado Department of Regulatory Agencies; and, Casey Sacks and Sylvia D. Hall-Ellis, Colorado Community College System. U.S. Department of Labor, Strategic Partnerships Emergency Grant, $5,000,000 (2015-2017)

CAEL Jump Start Program: Competency-Based Education. Research team: Jerry Migler (PI), Casey Sacks, Debra Cohn, Thomas Hartman, and Sylvia D. Hall-Ellis, Colorado Community College System; Matt Jamison, Front Range Community College; Mike Coste, Red Rocks Community College; Amanda Corum, Pueblo Community College; Janet Colvin, Pikes Peak Community College; and, MaryAnn Matheny, Community College of Denver. Council for Adult and Experiential Learning, $15,000 (2015)

Summit on the Redesign of Developmental Education. Research team: Jerry Migler (PI), Casey Sacks, and Sylvia D. Hall-Ellis, Colorado Community College System; Chip Nava, Pueblo Community College; Kim Moultney, Arapahoe Community College; Debbie Ulibarri, Trinidad State Junior College; and, Kris Bernard, Front Range Community College. American Association of Community Colleges, $15,000 (2015-2016)

Equity in Excellence at Colorado Community Colleges. Research team: Keith Howard (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Estela Mata Bensimon, Center for Urban Education, University of Southern California; and Kerry Gabrielson, Trinidad State Junior College. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $150,000 (2015-2016)

MBA High School of Business in Colorado. Research team: Laurie Urich (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Rudolph Sumpter and Beatrice Gerrish, Boulder Valley Schools; Keith Curry Lance, RSL Research Group. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $501,295 (2015-2016)

Fullbridge Program in Colorado. Research team: Keith Howard (PI) and Sylvia D. Hall-Ellis, Colorado Community College System; Suzanna Spears, Fort Morgan Community College; and, Cheryl Sánchez and Anne-Marie Compton, Lamar Community College. Colorado Department of Higher Education, Colorado Opportunity Scholarship Program, $300,000 (2015-2017)

Colorado Community College System Alternative Credit Program. Research team: Jerry Migler (PI), Keith Howard, and Sylvia D. Hall-Ellis, Colorado Community College System. American Council on Education, $13,000 (2015)

Internationalization in Higher Education. Researcher: Samuel D. Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $8,000 (2014-2015)

International Perspectives on Bilingual Education. Researcher: Sharolyn Pollard-Durodola. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $3,700 (2014-2015)

Cultivating Culturally Relevant and Responsive Curriculum and Pedagogy in College. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, iRise Grant, $5,000 (2014-2015)

Project EMERGE (Educational Model for Evaluation and Replicability in Gifted Environments). Research team: Norma Hafenstein (PI) and Bruce Uhrmacher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Lynde and Harry Bradley Foundation, $235,000 (2014-2015)

Collecting Asian American Refugee Stories. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. American Educational Research Association, Research Grant, $5,000 (2014-2015)

Developing Expertise in Teaching K-5 Mathematics. Research team: Julie Sarama (PI) and Douglas H. Clements (Co-PI), in partnership with the School of Education at the University of Michigan. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $130,344 (2013-2015)

Investigation of the Long-Term Outcomes for Special Education Students. Researcher: Antonio Olmos-Gallos. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Jefferson County School District, Office of Assessment, $40,000 (2014)

Refugee Community Collaboration. Researcher: Vicki Tomlin (PI) in partnership with the African Community Center and Jewish Family Service. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $14,854 (2014-2015)

Access to Mathematics for All. Research team: Richard S. Kitchen (PI), Nicole M. Russell (Co-PI), and Terrence Blackman (Co-PI), Curriculum Studies and Teaching Program, Morgridge College of Education; Álvaro Árias (Co-PI, Department of Mathematics); and, James Gray (Co-PI), Department of Mathematics, Community College of Aurora. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, The Robert Noyce Scholarship Program, Capacity Building Project, $349,926 (2014-2016)

Cognitive Test Battery for Intellectual Disabilities. Research team: Karen Riley (PI), Lyndsay Agans, Jessica Lerner, and Karin Dittrick-Nathan in partnership with David Hessl (PI), The MIND Institute at the University of California – Davis, and Elizabeth Berry-Kravis, Rush University Medical Center. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Institutes of Health, Outcome Measures for Use in Treatment Trials for Individuals with Intellectual and Developmental Disabilities (R01), $2,499,996 ($588,672 at DU) (2014- 2019)

Broadening Participation in Engineering among Women and Latino/as: A Longitudinal, Multi-Site Study. Researcher: Patton Garriott (PI) in partnership with the University of North Dakota and the University of Missouri. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, HER Core Research, $677,390 ($69,992 at DU) (2014-2019)

Designing a Teacher Evaluation System to Improve Teacher Effectiveness for Culturally and Linguistically Diverse Learners. Research team: María del Carmen Sálazar (PI), Jessica Lerner, and Kathy Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $29,988 (2014-2016)

Developing a College-Going Culture in Latina/O Families: Exploring the Influence of Funds of Knowledge on Family Outreach Programs. Researcher: Judy Marquez Kiyama. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $18,720 (2014-2016)

Assessment of Quality of Life in Neutral Implantation Surgery for the Treatment of Parkinson's Disease. Researcher: Cynthia McRae. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $3,967 (2014-2015)

Pura Vida: Cloud Forest, Curriculum and Cross-Cultural Study. Research team: Norma Hafenstein (PI) and Bruce Uhrmacher (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $8,000 (2014-2015)

Online Course Development for Curriculum and Instruction. Researcher: Ruth Chao. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: María del Carmen Sálazar. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: Jessica Lerner. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

Online Course Development for Curriculum and Instruction. Researcher: Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2014)

The Mathematics Education of African Americans, 1866 – 1954. Researcher: Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Academy of Education, Spencer Foundation Postdoctoral Fellowship, $55,000 (2014-2016)

Early Childhood Care and Education Study. Research team: Carrie Germeroth (PI), Melissa Mincic, and Douglas H. Clements. Technical reviewer for MCE: Sylvia D. Hall-Ellis. State of North Dakota, Department of Public Instruction, $73,500 (2013-2014)

Graduate Level Specialty in Addiction Counselor Training with Emphasis on Integration of Native American Specific Content. Research team: Ruth Chao (PI) and Michael J. Faragher (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. The Galena Foundation, $289,732 (2013-2016)

The Collecting Asian American and Pacific Islander Refugee Stories (CARS) Project. Researcher: Samuel Museus. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $15,000 (2014)

Parents in Transition: A Multiple Case Study of Parent and Family Orientation Programs. Researcher: Judy Marquéz Kiyama. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $1,500 (2014-2015)

The Sistah Network: Black Women Graduate Students Supporting and Retaining Each Other. Researcher; Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,708 (2014-2015)

Evaluation of the Northeast Denver Babies Ready for College Program. Research team: Carrie Germeroth (PI), Melissa Mincic, and Douglas H. Clements. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High Montessori, $9,922 (2013-2014)

Developing Teaching Expertise in K-5 Mathematics. Research team: Julie Sarama (PI) and Douglas Clements (University of Denver), in partnership with Timothy Boerst (PI), Meghan Shaughnessy, Deborah Ball, Hyman Bass (School of Education at the University of Michigan). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $449,827 ($130,344 at the University of Denver (2013-2015)

Early Learning Care and Education Study Program Grant for the State of North Dakota. Research team: Carrie Germeroth (PI), Melissa Mincic, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. State of North Dakota Department of Public Instruction, $73,500 (2013-2014)

Local Professional Learning Community for School Leaders. Research team: Susan Korach (PI), Kristina Hesbol, and Rebecca McClure. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Education Development Center, $10,950 (2013)

Healthy Eaters, Lifelong Movers 2: Implementing Evidence-Based School Environment, Policy, and Curricular Changes to Increase Opportunities for Healthy Eating and Physical Activity in Low Income, Rural Colorado. Research team: Elaine Berlansky, University of Colorado at Denver (PI), Nicholas Cutforth, University of Denver (Co-PI), and Allison Reeds. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $3,103,108 (2013-2017)

Hughes Rare Books Library Room Renovation in the Sturm College of Law. Project team: Patti H. Marks, Sylvia D. Hall-Ellis, and Leigh Elliott. Mabel T. Hughes Charitable Trust, $34,000 (2013-2014)

The Promise Center Partnership with the Marsico Institute for Early Learning and Literacy and the City and County of Denver. Research team: Karen Riley (PI), Douglas H. Clements (Co-PI), and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. The Piton Foundation, $223,468 (2013-2014)

Center of Excellence for Problem Gambling. Research team: Ruth Chao (PI) and J. Mike Faragher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $68,021 (2012-2013)

United Way Implementation and Validation Review. Research team: Douglas H. Clements (PI), Amanda Moreno, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High United Way, $19,737 (2013)

Math/Science Partnership in Rural Districts. Research team: Kristen Bunn (PI, Eagle County Schools), Paul Michalec (Co-PI), and Alegra Reiber. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Education, Colorado's Mathematics and Science Partnership Program, $750,000 (2013-2014)

Mathematics and Science Education of African Americans. Research team: Nicole Russell (PI), Sylvia D. Hall-Ellis, Steve Fisher (Penrose Library). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $29,994 (2013-2015)

Online Course Development for Curriculum and Instruction. Researcher: Nicole Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $3,000 (2013)

Discourse and Opportunity: Undocumented Students and Higher Education Policy. Researcher: Ryan Gildersleeve. Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Academy of Education, Spencer Foundation Postdoctoral Fellowship, $55,000 (2012-2014)

An Anthropological Study of the Latino Graduation Ceremony. Researcher: Ryan Gildersleeve. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Spencer Foundation, $39,900 (2012-2013)

Fragile-X and Pharmaceutical Company: Clinical Trial of AFQ056. University of California – Davis Children's Hospital MIND Institute (Sacramento), Children's Hospital Denver, and Rush Children's Hospital at Rush University Medical Center (Chicago). Karen Riley, PI. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Novartis Pharmaceuticals Corporation, $394,206 (2012-2014)

Project Engage, Phase 2, a DAPRA Grant in partnership with Total Immersion Systems, Inc., and Texas A&M University. Research team: Karen Riley (PI) and Lyndsay Agans (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Defense, $60,000 (2011-2013)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $14,951 (2012-2013)

Online Course Development for Curriculum and Instruction. Research team: Bruce Uhrmacher (PI) and Norma Hafenstein (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Teaching and Learning, $18,193 (2012-2014)

Writers in the Schools. Research team: Karen Riley (PI) and Amanda Moreno (Co-PI).Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Humanities, $4,965 (2012-2013)

Learning Ecosystem Validation Grant. Research team: Karen Riley (PI), Lyndsay Agans, Kent Seidel, and Shimelis Assefa. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Bill & Melinda Gates Foundation, $315,000 (2012-2013)

Project Words of Oral Reading and Language Development (WORLD). Research team: Jorge E. Gonzalez (PI), Texas A&M University; Laura Saenz (Co-PI), University of Texas – Pan American; and, Sharolyn Pollard-Durodola (Co-PI), University of Denver. Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $53,354 (2012-2015); award $640,718, transfer from Texas A&M University

Increasing the Efficacy of an Early Mathematics Curriculum with Scaffolding Designed to Promote Self-Regulation. Research team: Douglas H. Clements (PI) and Julie Sarama (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $1,445,315 (2008-2014); award $4,541,975, transfer from University at Buffalo, The State University of New York

Using Rule Space and Poset-based Adaptive Testing Methodologies to Identify Ability Patterns in Early Mathematics and Create a Comprehensive Mathematics Ability Test. Research team: Douglas H. Clements (PI) and Julie Sarama (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $323,791 (2010-2014); award $1,194,944, transfer from University at Buffalo, The State University of New York

Comprehensive Postdoctoral Training in Scientific Education Research. Researcher: Julie Sarama (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Education, Institute of Education Sciences, $133,458 (2010-2014); award $613,353, transfer from University at Buffalo, The State University of New York

Longitudinal Study of a Successful Scaling Up Project: Extending TRIAD. Research team: Douglas H. Clements (PI), Julie Sarama (Co-PI), and Abt Associates (Carolyn Layzer, Fatih Unlu, Laurie Bozzi, Lily Fesler, Alina Martinez, Cristofer Price, James van Orden). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Institute of Education Sciences, $384,940 (2011-2015; award $1,250,286, transfer from University at Buffalo, The State University of New York

Early Childhood Education in the Context of Mathematics, Science, and Literacy. Research team: Julie Sarama (PI), Douglas H. Clements (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. National Science Foundation, $990,020 (2010-2014; award $2,285,228, transfer from University at Buffalo, The State University of New York

Early Childhood Clearinghouse Information Center Redesign. Research team: Karen Riley (PI) and Amanda Moreno (Co-PI).Technical reviewer for MCE: Sylvia D. Hall-Ellis. Office of the Lt. Governor of Colorado, $12,000 (2012-2013)

Morgridge Rural Educational Leadership Initiative. Research team: Lyndsay Agans (PI), Linda Brookhart (Co-PI), Susan Korach, and Rebecca McClure. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Morgridge Family Foundation, $100,000 (2012-2014)

Center of Excellence for Problem Gambling. Research team: Patrick Sherry (PI) and J. Mike Faragher. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $55,000 (2012-2013)

Intermodal Transportation Institute Research Initiatives. Researcher: Patrick Sherry. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University Transportation Centers Program, Research and Innovative Technology Administration, U.S. Department of Transportation. $600,000 (2012-2014)

Mile High United Way Social Innovation Fund Early Literacy Initiative. Gloria L. Miller, PI, Amanda Moreano, Kim Hartnett-Edwards, and Sheridan Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Mile High United Way, $89,992 (2012-2013)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, $1,000 (2012-2013)

Refugee Student Art Outreach. Researcher: Karin Dittrick-Nathan. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $3,000 (2012-2013)

Resistance, Resilience, and Reciprocity: Centering the Voices of Black Doctoral Women with Faculty Aspirations. Researcher: Nicole M. Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,965 (2012-2013)

Assessing Learning through Student Notebooks. Research team: Keith Miller, Nancy Sasaki, and Kathy Green. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Professional Research Opportunities for Faculty, $30,000 (2012-2014)

International School Psychology Practicum Exchange. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $2,000 (2012-2013)

ELO in Colorado. Research team: Cynthia Hazel and Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Legacy Foundation, $150,000 (2012-2013)

Creating Online LIS Courses. Research team: Mary C. Stansbury (PI), Shimelis Assefa, Denise Anthony, Xiao Hu, and Krystyna Matusiak. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $15,000 (2011-2013)

Maritime Piracy Seminar. Researcher: Ved Nanda, The Nanda Center, Sturm College of Law. Technical reviewer for Sturm College of Law: Sylvia D. Hall-Ellis. Arsenault Family Foundation, $15,000 (2012-2013).

Early Childhood Librarianship: An Interdisciplinary, Experiential Learning MLIS. Researcher: Mary C. Stansbury (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Laura Bush's 21st Century Librarians Program, Institute for Museums and Library Services, $249,066 (2012-2014)

Learning Ecosystem Planning Grant. Research team: Karen Riley (PI), Lyndsay Agans, Kent Seidel, and Shimelis Assefa. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Bill & Melinda Gates Foundation, $281,217 (2011-2012)

Advanced Service Learning Practitioner Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Community Engagement and Service Learning, $400 (2011)

Evaluating and Enhancing the EspeciallyMe Program. Research team: Lori D. Patton and Nicole Russell. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, Public Good Fellowship Grant, $24,780 (2012)

Choosing Excellence: Let Every Child Bloom. Research team: Shimelis Assefa (PI) and Mary C. Stansbury (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Community Engagement and Service Learning, Public Good Grant, $7,657 (2012)

K-8 STEM Content Specific Professional Development to Improve Elementary Student Achievement. Research team: Kent Seidel (PI), Nicole Russell (Co-PI), Kimberly Hartnett-Edwards, Paul Michalec, Jeff Farmer, Keith Miller, Alegra Reiber, and Nancy Sasaki. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Education, Improving Teacher Quality Grant, (Title II ESEA), $307,299 (2011-2012)

Building a Better Principal Pipeline to Boost Student Achievement. Researcher: Susan Korach. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Denver Public Schools; a subcontract from the Wallace Foundation Grant, $170,000 (2011-2017)

Center of Excellence for Problem Gambling. Research team: J. Mike Faragher (Co-PI) and Bobbie Vollmer (PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Department of Behavioral Health, $79,999 (2011-2012)

An Exploration of Novice Teachers' Core Competencies: Impacts on Student Achievement, and Effectiveness of Preparation. Research team: Kent Seidel (PI), Kathy Green (Co-PI), Kimberly Hartnett-Edwards, and Duan Zhang. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Institute of Education Sciences, Effective Teachers and Effective Teaching, $990,987 (2012-2015)

Project Engage, a DAPRA Grant in partnership with Total Immersion Systems, Inc., and Texas A&M University. Research team: Karen Riley (PI) and Lyndsay Agans (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. U.S. Department of Defense, $49,964 (2011-2014)

User-centered Evaluation of Music Search Engines. Researcher: Xiao Hu. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Faculty Research Fund, $2,931 (2011-2012)

Educational Practicum in Vietnam and China to Promote the Inclusion of Young Children with Disabilities. Researcher: Gloria L. Miller. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Office of Internationalization, $5,000 (2011-2012)

Evaluation of Colorado's Enhancing Quality in Infant-Toddler (EQIT) Initiative. Research team: Virginia R. Maloney and Amanda Moreno. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Buell Foundation, $395,884 (2011-2013)

Creating Engaging Environments to Teach Pre-Algebra Mathematics to Elementary Students. Research team: Álvaro Arias, Mario López, María del Carmen Salazar, and Lyndsay Agans. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver Interdisciplinary Grant, $60,000 (2011-2012)

Morgridge Education Technology Accessible (META) Resource Project. Research team: Lyndsay Agans (PI) and Shimelis Assefa (Co-PI). Technical reviewer for MCE: Sylvia D. Hall-Ellis. Morgridge Family Foundation, $36,000 (2011)

MCE Connect: A 21st Century Framework for Faculty Development. Research team: Bruce Uhrmacher (PI), Shimelis Assefa (Co-PI), Lyndsay Agans (Co-PI), Kimberly Hartnett-Edwards, Norma Hafenstein, Xiao Hu, Paul Michalec (Co-PI), María del Carmen Salazar (Co-PI), and Sandra Snyder-Mondragon. Technical reviewer for MCE: Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $22,355 (2011-2012)

Parent Education and Parent Leadership and Advocacy. Research team: Virginia Maloney (PI) and Amanda Moreno, Marsico Institute for Early Learning and Literacy. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $27,358 (2010-2011)

Intentional School Culture. Researcher: Cynthia Hazel. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Denver Public Schools, $38,040 (2010-2011)

Healthy Eaters, Lifelong Movers: Implementing Evidence-Based School Environment, Policy, and Curricular Changes to Increase Opportunities for Healthy Eating and Physical Activity in Low Income, Rural Colorado. Research team: Elaine Berlansky, University of Colorado at Denver (PI), Nicholas Cutforth, University of Denver (Co-PI), and Allison Reeds. Technical reviewer for MCE: Sylvia D. Hall-Ellis. Colorado Health Foundation, $1,683,277 (2011-2014)

Second Life Learning Community. Research team: Don McCubbrey (PI), Sylvia D. Hall-Ellis (Co-PI), Walter LaMendola, and Paul Novak. University of Denver, Center for Teaching and Learning, $13,000 (2010-2011)

Reintroducing the Value of Law Librarians to Academic and Public Librarians in Colorado through the Identification and Use of Emerging Technologies. Research team: Sylvia D. Hall-Ellis (Co-PI), Stacey L. Bowers (PI), and Christopher Hudson, in partnership with Denver Public Library, Arapahoe Library District, and the Colorado State Supreme Court Library. University of Denver, Center for Community Engagement and Service Learning, $5,773 (2010-11)

Reintroducing the Value of Law Librarians to Public Librarians through the Identification and Use of Emerging Technologies and Resources. Research team: Stacey Bowers (PI) and Sylvia D. Hall-Ellis (Co-PI). American Association of Libraries, Wolters Kluwer Law & Business Grant Program, $2,725 (2010-2011)

Faculty Service Learning Pod. Research team: María del Carmen Salazar and Nicholas Cutforth (Curriculum and Instruction Program), Frank Tuitt (Higher Education Program), Cynthia Hazel and Gloria Miller (Child, Family, and School Psychology Program), and Sylvia D. Hall-Ellis (Library and Information Science Program). University of Denver, Center for Community Engagement and Service Learning, $8,000 (2010-2011)

Lincoln Collaborative. Research team: Antonio Esquibel (Principal, Lincoln High School), María del Carmen Salazar (Curriculum and Instruction Program), and. Sylvia D. Hall-Ellis. School Improvement Grant, Denver Public Schools, $375,000 (2010-2012)

Future LEADers of America: Leaders III. Research team: Denver Public Library (Kristen Svendson, PI), the University of Denver (Sylvia D. Hall-Ellis), the Colorado Chapter of REFORMA (Orlando Archibeque), and the Colorado Association of Libraries (Martin Garnar). Laura Bush's Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $988,366 (2009-2012)

Teaching for Success in the Library Environment: LIS 4030 in Library 2.0. Research team: Deborah S. Grealy (PI) and Sylvia D. Hall-Ellis (Co-PI). University of Denver, Center for Teaching and Learning, $ 9,350 (2009-10)

Writing Group Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Community Engagement and Service Learning, $750 (2008-2009)

Collaborative Learning Faculty Grant, Sylvia D. Hall-Ellis, University of Denver, Center for Teaching and Learning, $1,500 (2008)

Connecting Information Literacy to Learning. Research team: Lori Micho, Merrie Valliant, Amanda Samland, and Sylvia D. Hall-Ellis. Colorado State Library, LSTA Discretionary Grant Program, $19,548 (2008-2009)

Law Librarianship Fellows Program. Research team: Sylvia D. Hall-Ellis (PI), Stacey Bowers (Co-PI), and Christopher Hudson, Westminster Law Library. Laura Bush's 21st Century Librarians Program, Institute for Museums and Library Services, $999,370 (2008-2012)

Grant Writing in a Cooperative Learning Environment. Sylvia D. Hall-Ellis. University of Denver, Center for Teaching and Learning, $2,000 (2008-2009)

Project Homeless Connect 6 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $9,785 (2008)

Project Ecuador: International Learning Service Libraries – A Faculty Development Experience in Ecuador. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $600 (2007)

Project Ecuador: International Learning Service Libraries – A Faculty Development Experience in Ecuador. Sylvia D. Hall-Ellis, International Service Learning Office, University of Denver, $400 (2007)

Project Homeless Connect 5 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $1,000 (2007)

Project Homeless Connect 4 Event Evaluation. Research team: Sylvia D. Hall-Ellis and Duan Zhang. University of Denver Center for Community Engagement and Service Learning, $4,595 (2007)

Future LEADers of America: Leaders II. Research team: Denver Public Library (Kristen Svendson, PI), the University of Denver (Sylvia D. Hall-Ellis), and the Colorado Chapter of REFORMA (Orlando Archibeque). Laura Bush's Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $988,518 (2007-2010)

Strategic Planning Assistance for the Denver Medical Library. Sylvia D. Hall-Ellis. Denver Medical Library, Inc., $30,000 (2006-2007)

Destiny Software for JMAC Student Lab. Sylvia D. Hall-Ellis, gift from the Sagebrush Corporation, Minneapolis, Minnesota, $10,000 (2006)

Libraries: Tools for Education and Development Worldwide: A Faculty Development Experience in France. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $800 (2005)

Denver Public Library: Opportunities for Change. Sylvia D. Hall-Ellis, Colorado Community Based Research Network, $2,000 (2005)

Future LEADers of America. Research team: Denver Public Library (Letty Icolari and Steve Taylor, PIs), Emporia State University (Jim Agee), and the University of Denver (Sylvia D. Hall-Ellis). Recruiting Librarians for the 21st Century Program, Institute for Museums and Library Services, $670,315 (2005-2008)

American Association of University Professors Summer Institute Professional Development Grant. Sylvia D. Hall-Ellis, American Association of University Professors, $300 (2005)

Beta Phi Mu Alumni Tea. Sylvia D. Hall-Ellis, gift from the Office of Alumni and Parent and Relations, University of Denver, $2,000 (2005)

Spectrum Software for LIS Student Lab. Sylvia D. Hall-Ellis, gift from the Sagebrush Corporation, Minneapolis, Minnesota, $5,000 (2005)

Developing Research Capacity in Community Organizations and Residents through Training and Technical Assistance. Nicholas J. Cutforth (PI) and Sylvia D. Hall-Ellis. Piton Foundation, $25,000 (2005-2006)

Libraries: Tools for Education and Development Worldwide: A Faculty Development Experience in Argentina. Sylvia D. Hall-Ellis, Office of Internationalization, University of Denver, $500 (2004)

Developing Research Capacity in Community Organizations and Residents through Training and Technical Assistance. Research team: Nicholas J. Cutforth (PI), Gary Lichtenstein and Sylvia D. Hall-Ellis, Piton Foundation, $25,000 (2003-2004)

Increasing Spanish-Speaking and Hispanic Diversity among Library and Information Science Students at the University of Denver: Development of a Student Recruitment Model. Researcher: Sylvia D. Hall-Ellis (PI), Office of Multicultural Excellence, University of Denver, $2,750 (2003-2004)

Collection Development Enrichment to Support the Cataloging & Classification Specialization and School Librarianship within the Library & Information Science Program at the University of Denver. Research team: Sylvia D. Hall-Ellis (PI) and Deborah S. Grealy. Women's Library Association, University of Denver, $4,000 (2003)

Collection Development Enrichment to Support the Library & Information Science Program at the University of Denver. Research team: Deborah S. Grealy (PI) and Sylvia D. Hall-Ellis. Women's Library Association, University of Denver, $4,000 (2001)

Wireless LAN for Library Education. Research team: Deborah S. Grealy (PI) and Sylvia Hall-Ellis. University of Denver, Center for Teaching and Learning, $24,000 (2001-2002)

Upward Bound – A Program for South Texas Youth. Research team: Monte Churchill, Executive Director of Community Relations; Gary R. Sauceda, Outreach Coordinator; Raymond Hernandez, (PI) Associate Dean for Student Success; and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). U.S. Department of Education, Office of Postsecondary Education, $2,672,003 (1999-2003)

Write Now! Improving Elementary Students' Writing Skills. Research team: Caryl G. Thomason, Assistant Superintendent (PI); Karen Tankersley, Principal; and, Hal Anderson, Director of Technology, Cheyenne Mountain School District 12 (Colorado Springs, Colorado); and Sylvia D. Hall-Ellis. Colorado Department of Education, Educational Telecommunications Unit, $189,453 (1999-2001)

Operation Quick Start -- Distance Learning in Rural Colorado. Research team: Randal Weigum, Technology Coordinator (PI); Bonnie Barns, Director of Federal Programs and Staff Development; and, Adam "Joe" Raskop, Executive Director, Southeastern Board of Cooperative Educational Services (Lamar, Colorado); and Sylvia D. Hall-Ellis. Colorado Department of Education, Educational Telecommunications Unit, $400,000 (1999-2001)

Advanced Technological Training for Information Professionals for the 21st Century. Research team: Mario Reyna, Division of Business Director (PI) and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). Phi Delta Kappa and the National Science Foundation, $250,000 (1999-2001)

Working Connections – Training Information Technologies Professionals for the 21st Century. Research team: Mario Reyna, Division of Business Director (PI) and Sylvia D. Hall-Ellis, South Texas Community College (McAllen, Texas). Microsoft Corporation and the American Association of Community Colleges, $1,147,775(1999-2001)

The ROAD (Research Oriented Amplification of Development to Literacy) Program. Research team: Deborah J. Leong (PI), Metropolitan State University; Elena Bodrova, Metropolitan State University; Dmitri Semenov, Robert J. Marzano, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Foundation, $25,000 (1998-1999)

Press to Literacy. Research team: Deborah J. Leong (PI), Metropolitan State University; Elena Bodrova, Metropolitan State University; Dmitri Semenov, Robert J. Marzano, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). The Denver Post and the Robert S. McCormick Foundation, $49,818 (1998-1999)

International Telementor Center. Research team: David Neils, David B. Frost (PI), and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Philanthropy, $100,000 (1998-1999)

America Reads: Providing Tutor Training for the America Reads Challenge. Research team: Louis F. Cicchinelli (PI) and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Department of Education, Office of Educational Research and Improvement, $306,000 (1998-1999)

Comprehensive School Reform. Research team: Louis F. Cicchinelli (PI), J. Timothy Waters, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Department of Education, Office of Educational Research and Improvement, $285,000 (1998-1999)

Sustainable Energy Education (SEE) Program for Grades 4-8: Preparing Today's Youth for Lifelong Learning and Responsible Actions in Energy Conservation. Research team: Mary Gromko, Colorado Department of Education; Gene McCarthy, Rocky Flats Field Office, U.S. Department of Energy; Gina Kissell, National Renewable Energy Laboratory; and Barbara L. McCombs (PI), Janet L. Bishop, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). State of Colorado Governor's Office for Energy Conservation, $499,936 (1997-1999)

Review of Kansas Curriculum Standards in Mathematics and Language Arts. Research team: Robert J. Marzano (PI), John S. Kendall, David B. Frost, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Submitted to the Kansas State Department of Education, $25,903 (1998)

International Telementor Center. Research team: David Neils, John Kuglin, Chris Rapp, David B. Frost (PI), and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). Hewlett-Packard Company, $54,752 (1998)

Genesis Mission: Education Public Outreach. Developed in partnership by the Jet Propulsion Laboratory, California Institute of Technology, Los Alamos National Laboratory, Lockheed Martin Astronautics, and the Mid-continent Regional Educational Laboratory (Aurora, Colorado). Research team: John T. Sutton (PI), Alice Krueger, Martha Henry, Greg Rawls, Shae Isaacs, Jeff Johnson, Deb Jordan, Arlene Mitchell, David B. Frost, Jana Caldwell, J. Timothy Waters, and Sylvia D. Hall-Ellis. National Aeronautics and Space Administration, $139,700,000; subcontract award, $4,750,000 (1997-2007)

North Dakota Mathematics Assessment Project. Developed in partnership by the North Dakota Department of Education and Mid-continent Regional Educational Laboratory (Mid-continent Regional Educational Laboratory). Research team: Ann Clapper, Clarence Bina, Greg Gallagher, North Dakota Department of Education; Don Burger (PI), Hillary Michaels, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Office of Education, $1,618,214; subcontract award, $389,076 (1997-2001)

Pacific Resources for Education and Learning Distance Education: Project Evaluation. Developed in partnership by the Pacific Educational Community, the Pacific Resources for Education and Learning (PREL), and Mid-continent Regional Educational Laboratory (McREL). Research team: John W. Kofel (PI), Executive Director, PREL; J. Timothy Waters, Executive Director; Joan Buttram, Robert Keller, and Sylvia D. Hall-Ellis, Mid-continent Regional Educational Laboratory (Aurora, Colorado). U.S. Office of Education, Star Schools Program, $10,000,000; subcontract award, $500,000 (1997-2002)

Identification of Bilingual Gifted and Talented Children: A Comprehensive School Grants for Bilingual Education. Developed in partnership by Hidalgo (Texas) ISD, Los Fresnos (Texas) CISD, Progreso (Texas) ISD, University of Texas – Pan American (Edinburg, Texas), and Education Service Center, Region One (Edinburg, Texas). Research team: Hilda Medrano, Dean, College of Education, University of Texas – Pan American; Linda Phemister (PI), Janie Navarro, and Sylvia D. Hall-Ellis, Education Service Center, Region One. U.S. Department of Education, Office of Bilingual Education and Minority Languages Affairs, $1,670,633 (1997-2002)

Academics 2000: First Things First -- The Texas Goals 2000. Developed for Jim Hogg (Hebbronville, Texas) County ISD, Mirando City (Texas) ISD, and San Isidro (Texas) ISD. Research team: Hilda Medrano, Dean, College of Education, University of Texas - Pan American (Edinburg, Texas); Angie Lehmann, Amy Mares, Ellen Gonzalez (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg, Texas). Texas Education Agency, $339,987 (1997-2000)

Southwestern Bell's Learning Communities Initiative. Developed for Tech Prep of the Rio Grande Valley, Inc. (Harlingen, Texas); the Center for Professional Teacher Development, University of Texas – Brownsville; Teach for America – Rio Grande Valley (McAllen, Texas); and Education Service Center, Region One (Edinburg, Texas). Research team: Patricia G. Bubb, Executive Director (PI), Tech Prep of the Rio Grande Valley; Martin Winchester, Executive Director, Teach for America – Rio Grande Valley; Aileen Johnson, Director, School of Education, University of Texas – Brownsville; and Sylvia D. Hall-Ellis. Southwestern Bell Foundation, $100,000 (1997-1998)

Texas School to Work: Regional Implementation. Developed for Tech Prep of the Rio Grande Valley, Inc. (Harlingen), South Texas Community College (McAllen), Texas State Technical College (Harlingen), Texas Southmost College (Brownsville), Empowerment Zone of the Rio Grande Valley (Mercedes), Project VIDA (Weslaco), Youth Fair Chance (McAllen), and Education Service Center, Region One (Edinburg). Research team: Patricia G. Bubb (PI), Tech Prep of the Rio Grande Valley; Stephen Vassberg, Texas State Technical College; Ellen Trevino, Youth Fair Chance; Wanda Garza, Project VIDA; Leonardo Olivares, University of Texas – Pan American; Michael Bell, South Texas Community College; and Sylvia D. Hall-Ellis. Texas Workforce Commission, $4,250,000 (1997-2002).

Comprehensive Bilingual Education Grant for Hidalgo ISD and Roma ISD. Developed for Hidalgo (Texas) ISD, Roma (Texas) ISD, College of Education, University of Texas – Pan American (Edinburg, Texas), and Education Service Center, Region One (Edinburg, Texas). Research team: Tomas Thomas (PI), Director, Office of Bilingual Education and Sylvia D. Hall-Ellis. U.S. Department of Education, Office of Bilingual Education and Minority Languages Affairs, $1,531,361 (1997-2002)

Lopez High School, Porter High School, Rivera High School, Central Middle School, and Perkins Middle School, Brownsville (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $1,473,611 (1997-1998)

Donna High School, Todd Middle School, and Solis Middle School, Donna (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $704,052 (1997-1998)

Memorial Middle School and Nellie Schunior Middle School, La Joya Independent School District (Texas). Telecommunications Infrastructure Fund Board, $293,641 (1997-1998)

Martin High School, Christen Middle School, Cigarroa Middle School, Lamar Middle School, Laredo (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $1,200,000 (1997-1998).

Lasara Middle School, Lasara (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $246,210 (1997-1998)

Los Fresnos High School and Resaca Middle School, Los Fresnos (Texas) Consolidated Independent School District. Telecommunications Infrastructure Fund Board, $500,000 (1997-1998)

Lyford Junior High School, Lyford (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $354,997 (1997-1998)

Travis Middle School, McAllen (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $269,139 (1997-1998)

Mission High School, Mission (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $297,010 (1997-1998)

Progreso High School, Progreso (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $300,000 (1997-1998)

San Perlita High School, San Perlita (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $293,490 (1997-1998)

Myra Green Junior High School, Raymondville (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $225,000 (1997-1998)

Rio Grande City High School, Ringgold Middle School, Gruella Middle School, Rio Grande City (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $809,934 (1997-1998)

Rio Hondo Junior High School, Rio Hondo (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $297,024 (1997-1998)

Roma High School, Roma (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $333,178 (1997-1998)

San Benito High School, Miller Jordan Junior High School, San Benito (Texas) Consolidated Independent School District. Telecommunications Infrastructure Fund Board, $547,000 (1997-1998)

Santa Maria High School and Santa Maria Middle School, Santa Maria (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $400,000 (1997-1998)

Salvador High School, United Independent School District (Laredo, Texas). Telecommunications Infrastructure Fund Board, $250,879 (1997-1998)

Weslaco High School, Cabaza Middle School, Cuellar Middle School, Weslaco (Texas) Independent School District. Telecommunications Infrastructure Fund Board, $874,242 (1997-1998)

Principals' Assessment and Training Center. Developed for Education Service Center, Region One (Edinburg, Texas). Research team: Roberto Zamora, Leonel Barrera, William H. Parry, and Sylvia D. Hall-Ellis. Texas Principals' Leadership Initiative, Texas Association of Secondary School Principals, Texas Association of Elementary School Principals, and the Sid Richardson Foundation. $461,439 (1996-1998)

The Texas Library Connection -- Integrating and Sharing Resources. Developed for Hidalgo County Library System (McAllen), Cameron County Library System (Brownsville), South Texas Community College (McAllen), the University of Texas - Pan American (Edinburg), University of Texas – Brownsville, and Education Service Center, Region One (Edinburg). Research team: William R. McGee, Coordinator, Hidalgo County Library System; Joe Garcia, Director, Cameron County Library System; Michael D. Bell, Library Director, South Texas Community College; Eleanor Folger Foster, University Library, University of Texas - Pan American; Jaime Vela (PI), Director of Instructional Technology and Media Services, Ron Pontius, Instructional Technology, and Fabiola Fuentes, Media Services, Education Service Center, Region One; and Sylvia D. Hall-Ellis. Office of Library Media Services, Technology Services, Texas Education Agency. $8,000 (1996-1997)

Developing Leadership Communities for Improving Algebra I for All Students. Developed for a partnership of the Region One Statewide Systemic Initiative Team. Research team: Noel Villarreal (PI), Eduardo Cancino, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Statewide Systemic Initiative for Reform in Mathematics, Science and Technology Education to The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin. $25,000 (1996-1997)

Academics 2000: First Things First -- The Texas Goals 2000. Developed for Edinburg (Texas) CISD. Research team: Hilda Medrano, Dean, College of Education, University of Texas - Pan American (Edinburg); Helen Jones, Director (PI), Gifted and Talented Education, Edinburg CISD; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $750,000 (1996-2001)

Texas Teachers Empowered for Achievement in Mathematics (TEXTEAM) Institute for Algebra I. Developed for Hidalgo ISD, Jim Hogg (Hebbronville) County ISD, La Joya ISD, La Villa ISD, Lyford ISD, Mission CISD, Pharr-San Juan-Alamo ISD, Rio Hondo ISD, San Isidro ISD, San Perlita ISD, Santa Maria ISD, Santa Rosa, Sharyland ISD, Valley View ISD, Webb (Laredo) CISD, Weslaco ISD, and Zapata County (Zapata) ISD. Research team: Noel Villarreal (PI), Chuck McInteer, Ellen M. Gonzalez, Education Service Center, Region One (Edinburg); and Sylvia D. Hall-Ellis. Charles A. Dana Center for Mathematics and Science Education, University of Texas - Austin, $15,975 (1996)

Community Learning Center for La Villa, Texas. Developed for Edcouch-Elsa Independent School District. Research team: Noe Gonzalez (PI), Assistant Superintendent, Edcouch-Elsa Independent School District, and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $325,000 (1996-1997)

Monte Alto (Texas) Community Learning Center. Developed for Monte Alto Independent School District. Research team: Homero A. Diaz (PI), Superintendent, Monte Alto Independent School District, and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $300,000 (1996-1997)

Community Learning Center for La Villa, Texas. Developed for La Villa Independent School District. Research team: Sam Gonzalez (PI), Assistant Superintendent, La Villa Independent School District; and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $325,000 (1996-1997)

Building Project for Taylor Elementary. Developed for Mercedes (Texas) Independent School District. Research team: Mrs. Denise Rivera, Librarian, and Eduardo Infante, Principal, Taylor Elementary School; Ismael S. Cantu (PI), Federal Programs Director, Mercedes Independent School District; and Sylvia D. Hall-Ellis. Delta Region Subzone, Rio Grande Valley (Texas) Rural Empowerment Zone, $375,000 (1996-1997)

Border Education Network (BEN) - Distance Education through Cable Television. Developed for Edinburg (Texas) Consolidated Independent School District. Research team: Noe Torres (PI), Library Media Specialist, Magdalena Rosas, Library Media and Technology Coordinator, Edinburg Consolidated Independent School District; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Edinburg (Texas) Consolidated School District, $250,000 (1996-1997)

Multiservice One-Stop Open Enrollment Charter School. Developed for the Information Referral Resource Assistance, Inc. (McAllen, Texas). Research team: Pablo Perez and Aguie Pena (PI), Executive Director, Information Referral Resource Assistance, Inc.; Roberto Zamora and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $3,066,000 (1996-2001)

Project OK: A Community Youth Opportunities Grant for Summer, 1996. Developed for McAllen (Texas) Independent School District, St. Joseph the Worker Catholic Church, and the Office of Adult Education, Education Service Center, Region One. Research team: Father Bart Flatt, St. Joseph the Worker Catholic Church; Noe Calvillo (PI), Office of Adult Education; Maria Louisa Garcia, McAllen Independent School District; and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Protective and Regulatory Agency through the Office of the Mayor, City of McAllen, $350,000 (1996-2001).

Early Childhood: a Time of Discovery. Developed for a partnership of Lasara ISD, Rio Hondo ISD, San Perlita ISD, the School of Education, University of Texas - Brownsville, and Education Service Center, Region One (Edinburg). Research team: Hugo Rodriguez, Dean, School of Education, University of Texas - Pan American; Leonel Barrera and Jack Damron, Field Service Agents, Ellen M. Gonzalez (PI), Administrator for Student Instructional Services, Ruth Solis, Education Specialist in Special Education, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $722,090 (1996-2001)

Innovative Gifted and Talented Programs for Early Childhood and Elementary Education Students. Developed for a partnership of Edinburg (Texas) CISD, the School of Education, University of Texas - Pan American (Edinburg), and Education Service Center, Region One (Edinburg). Research team: Hilda Medrano, Dean, School of Education, University of Texas - Pan American; Helen de la Garza (PI), Director of Elementary Curriculum and Instruction, Edinburg CISD; and Sylvia D. Hall-Ellis. Texas Education Agency, $750,000 (1996-2001)

Reading Recovery in Early Elementary Grades. Developed for a partnership of La Villa (Texas) ISD the School of Education, University of Texas - Pan American (Edinburg), and Education Service Center, Region One (Edinburg). Research team: Hilda Medrano, Dean, School of Education, University of Texas - Pan American; Marcario Salinas (PI), Supervisor of Elementary Curriculum and Instruction, La Villa ISD; and Sylvia D. Hall-Ellis, Education Service Center, Region One. Texas Education Agency, $750,000 (1996-2001)

Connected Mathematics Project for Middle and Junior High Students. Developed for a partnership of Michigan State University, The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin and Region One Statewide Systemic Initiative Team. Research team: Jack Damron, Chuck McInteer, Noel Villarreal (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). National Science Foundation through Michigan State University to the Charles A. Dana Center at the University of Texas - Austin, $539,610 (1996-1999)

Sharing Resources: Testing the Interlibrary Loan Potential of the Texas Library Connection -- Integrating Media Resources. Developed under the sponsorship of the Hidalgo County Library System (McAllen) and Education Service Center, Region One (Edinburg). Research team: William H. McGee, Hidalgo County System Coordinator; Fabiola Fuentes, Library Media; Ronald Pontius (PI), Instructional Technology, Education Service Center, Region One; and Sylvia D. Hall-Ellis. Library Media Services Program, Office of Technology Services, Texas Education Agency, $25,000 (1996-1997)

State and Federal Adult Education JOBS Program. Developed for Education Service Center, Region One (Edinburg). Research team: Noe Calvillo (PI), Director, Adult Education Program, and Sylvia D. Hall-Ellis. Adult Education Program, Texas Education Agency, $532,846 (1995-1996)

Creating Safe and Drug-Free Schools and Communities. Developed for a partnership of the Region One Consortium for Safe and Drug-Free Education Environments. Research team: Clara Contreras (PI), Health Specialist, and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Education Agency, $150,000 (1995-1996)

Developing Leadership Communities for Improving Mathematics Performance for All Students on Title I Campuses. Developed for a partnership of the Region One Statewide Systemic Initiative Team. Research team: Jack Damron, Chuck McInteer, Noel Villarreal (PI), and Sylvia D. Hall-Ellis, Education Service Center, Region One (Edinburg). Texas Statewide Systemic Initiative for Reform in Mathematics, Science and Technology Education to The Charles A. Dana Center for Mathematics and Science Education, The University of Texas at Austin, $50,669 (1995-1996)

The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas. Sylvia D. Hall-Ellis (PI). Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville). Texas Association of School Librarians, Children's Services Round Table, and Young Adults Round Table (Austin, Texas), $2,500 (1995)

School Library Media Specialists Fellowship Program. Sylvia D. Hall-Ellis (PI). Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville, Texas). U.S. Department of Education, HEA Title II-B, Library Education and Human Resource Development Program, $44,000 (1995-1996)

Planning for Educational Technology. Research team: Ruth Ann Riggins (PI), Director of Library Media and Technology Services, Donna (Texas) Independent School District; Noe Torres, Education Service Center, Region One; Patricia G. Bubb, Tech Prep of the Rio Grande Calley, Inc; Michael D. Bell, South Texas Community College; and Sylvia D. Hall-Ellis, Sam Houston State University. Developed under the sponsorship of Donna (Texas) Independent School District, Education Service Center, Region One (Edinburg), Tech Prep of the Rio Grande Valley, Inc. (Harlingen), South Texas Community College (McAllen), and the Department of Library Science, Sam Houston State University (Huntsville). Funded through Infusion of Educational Technology Planning Grant Program (H.B. 18: Models). Texas Education Agency, $18,000 (1993-1994)

The Impact of Library Resource Centers on Academic Achievement in Selected Public Schools in South Texas. Sylvia D. Hall-Ellis (PI) and Mary Ann Berry. Developed under the sponsorship of the Department of Library Science, College of Education and Applied Science, Sam Houston State University (Huntsville). Sam Houston State University Research Enhancement Fund, $7,500 (1993-1994)

Electronic Mail Resource Sharing System: Management and Operation of the Iowa Computer-Assisted Network. State Library of Iowa, $294,000 (1986-1993)

The Iowa Locator: A CD-ROM Resource Sharing Tool. State Library of Iowa, $567,000 (1986-1992)

Statewide Database Development: An OCLC Tape Analysis To Determine Feasibility. State Library of South Dakota, $15,000 (1987)

The Iowa Locator: A Feasibility Study. State Library of Iowa, $50,000 (1986)

Electronic Mail Resource Sharing System: A Feasibility Study for Libraries in the State of Iowa. State Library of Iowa, $5,000 (1985)

Access Pennsylvania: A Feasibility Study. State Library of Pennsylvania, $50,000 (1984)

Automating Library Administrative and Management Tasks: Procurement and Distribution of Microcomputer Systems for District Library Centers in the Commonwealth of Pennsylvania. State Library of Pennsylvania, $495,000 (1982)

Sharing Serial Titles Resources: Procurement and Distribution of Microfiche Readers for 550 Libraries in the Commonwealth of Pennsylvania. State Library of Pennsylvania, $500,000 (1982)

Electronic Mail System: A Pilot Project for Libraries throughout the Commonwealth of Pennsylvania. State Library of Pennsylvania, $125,000 (1982)

Literacy Program for Adults in Rural Upstate New York State: Program Outreach and Evaluation - Phase 3. Appalachian Regional Commission, $50,000 (1981)

Database Building: A Cooperative Project of the Finger Lakes Library System (Ithaca), Four County Library System (Binghamton), and the Southern Tier Library System (Corning). New York State Library, $450,000 (1980-1985)

Faces of the Southern Tier: A Professional Photographer-in-Residence. New York State National Endowment for the Humanities, $25,000 (1980)

Literacy Program for Adults in Rural Upstate New York State: Program Implementation - Phase 2. Appalachian Regional Commission, $50,000 (1980)

Small Business Resources Center: A Pilot Project for Rural Public Libraries. New York State Library, $50,000 (1980)

Media Programming: A Professional Development Program for Public Librarians in Upstate New York: A Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $35,000 (1979)

Information and Library Resources for Inmates and Prisoners in Selected Upstate New York Facilities: A Cooperative Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $25,000 (1979)

Library Resources for Homebound Adults in Upstate New York: An Outreach Program in Allegheny, Chemung, Schuyler, Steuben, and Yates Counties. New York State Library, $40,000 (1979)

Literacy Program for Adults in Rural Upstate New York State: Program Initiation and Establishment - Phase 1. Funded by the Appalachian Regional Commission. Awarded to the Corning (New York) Public Library, $50,000 (1979)

Information Reference Services to Homebound Adults. New York State Library, $31,000 (1978)

Books-By-Mail Services to Homebound Adults. New York State Library, $31,000 (1978)

System Headquarters Services and Programs for Public Libraries in District 10. Funded through Library Services and Construction Act Title I. Texas State Library and Historical Commission, $880,000 (1976)

County Library Development Grant for Atascosita County. Funded through Library Services and Construction Act Title I. Texas State Library and Historical Commission, $15,000 (1976)

Spanish Language Materials Collection Development Program. Texas State Library and Historical Commission, $40,000 (1975)

Establishment of System Headquarters for Alamo Regional Library System (District 10) Headquartered at the San Antonio (Texas) Public Library. Texas State Library and Historical Commission, $800,000 (1975)

SELECTED CONSULTANTSHIPS

Project Strategic Planning & Funding Proposal Development

Walden University, 2015.
Pikes Peak Library District, 2014.
Douglas County Public Libraries, 2011-2012.
Denver School for Science and Technology, 2008-2011.
Johnson & Wales University, Denver Campus, 2007-2009.
Challenges, Choices, and Images K-12 Charter School, Denver Public Schools, 2007.
Denver Medical Library, Inc., 2006-2010.
Bemis Public Library (Littleton), Ergonomic Design and Facilities Enhancement Consultant, 2003.
Curtis Park Community Center (Denver), Community Technology Center Evaluation and Proposal Development Consultant, 2003.
Colorado Community Based Research Network (Denver), Funding Research Associate, 2002.
Our Lady of the Rosary Academy (Edgewater), Learning Resource Center Development Project Consultant, 2001-2003
University of Southern Colorado (Pueblo). Technology Integration and Curriculum Enhancement into Higher Education Learning Environment. Proposal Development Consultant, 2000.
Jefferson County Library System (Lakewood), 1999-2000.
Southeastern BOCES (Lamar, CO). Distance Learning Curriculum Content Development Project. Proposal Development Consultant, 1998-2004.
Cheyenne Mountain School District 12 (Colorado Springs, CO). Technology Integration into Elementary Writing Curriculum Project. Proposal Development Consultant, 1998.
Telecommunications Infrastructure Fund Board Round #2 Application, 1997. Technical assistance to the following: La Villa (Texas) Independent School District; Mirando City (Texas) Independent School District; Monte Alto (Texas) Independent School District; San Isidro (Texas) Independent School District.
Telecommunications Infrastructure Fund Board Round #1, 1996. Technical assistance to the following: Brownsville (Texas) Independent School District; Donna (Texas) Independent School District; Edinburg (Texas) Consolidated Independent School District; Harlingen (Texas) Consolidated Independent School District; Jim Hogg County Independent School District (Hebbronville, Texas); La Feria (Texas) Independent School District; La Joya (Texas) Independent School District; La Villa (Texas) Independent School District; Los Fresnos (Texas) Consolidated Independent School District; Progreso (Texas) Independent School District; Raymondville (Texas) Independent School District; Rio Hondo (Texas) Independent School District; San Benito (Texas) Independent School District; Sharyland Independent School District (Mission, Texas); Weslaco (Texas) Independent School District; Zapata (Texas) County Independent School District.
South Texas Community College (McAllen). Strategy Development to Meet the Technology Instructional Needs for Vocational, School-To-Work and Academic Programs, 1994-2000. Development Consultant.
Donna (Texas) Independent School District. Planning for the Infusion of Technology in Middle Schools Serving High At-Risk Students, 1994-1995. Research Associate.
Pettus (Texas) Independent School District. Planning for District-wide Automation in School Library Media Centers: Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1994. Principal Investigator.
Fort Bend Independent School District (Sugar Land, TX). Planning for District-wide Automation in School Library Media Centers, Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1994-1995. Principal Investigator.
Northern Waters Library Services (Ashland, WI). Professional Consulting Services to Make Recommendations on the Development of System-Wide Efforts of the Northern Waters Library Service, 1988-1989. Research Associate.
State Library of Iowa (Des Moines). The Iowa Locator Compact Disc to Support Multi-Type Libraries Resource Sharing including Database Design, Building, Production, and Distribution, 1986-1991. Project Director.
State Library of Iowa (Des Moines). Iowa Computer-Assisted Network Development, Enhancement, and Operation, 1985-1992. Technical Director.
State Library of South Dakota (Pierre). Statistical Sampling and Analysis of Multi-Institutional OCLC Archive Tape for Statewide Online Database Building, 1985-1986. Research Associate.
District of Columbia Public Library (Washington, DC). Planning Document for the Retrospective Conversion of Bibliographic Records and Automation Issues in the 1990's, 1984-1985. Research Associate.

State Library of Pennsylvania (Harrisburg). Database Development for High School Libraries, 1984-1985. Research Associate.
MINITEX (Minneapolis, MN). Workshops for Retrospective Conversion, Bar Coding, Library Statistics, and OCLC Serials Format, 1985. Presenter and Research Associate.
ABC Film Consortium (Altoona, Bellefonte, Johnstown, PA). Database Building, System Design, and Implementation of Online Film Booking System, 1983-1985. Database Manager.

Library Automation -- System Design & Implementation

Douglas County Library District (Castle Rock, CO). Library Automation Technical and System Performance Specifications, 2001.
Pharr-San Juan-Alamo Independent School District (Pharr, TX). Library Automation Technical and System Performance Specifications, 1997. Project Development Consultant.
Harlingen (Texas) Independent School District. Planning for District-wide Automation in Junior High School Library Media Centers: Preparation of Data, and CD-ROM Hardware/Software Configuration Evaluation, 1996. Principal Investigator.
Sharyland (Texas) Independent School District. Design and Construction of New Elementary School Library and Technology Resources Center, 1995-1996. Principal Investigator.
South Texas Independent School District (Mercedes, TX). Design and Construction of a New High School Library and Technology Resources Center, 1995-1996. Principal Investigator.
Citizens' Library (Washington, PA). Online Community Resources Files: Design and Implementation, 1984. Research Associate.
Altoona (Pennsylvania) Hospital. Integrated Online System Upgrade Study, 1984. Research Associate.
State Library of South Dakota (Pierre). Automation Plan and State Database Development, 1982-1983. Principal Investigator.
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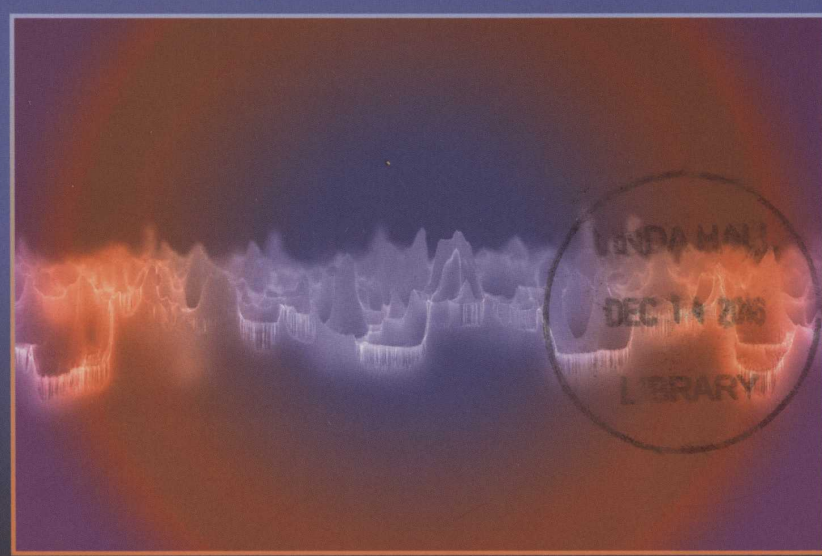


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On The Cover: *Yuan-Hung Tseng and Bing-Yue Tsui, JVST A **34**(6), p. 061305-1 (2016). Cover shows SEM photo of silicon surface after etched by Cl2/O2 plasma.*

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Combinatorial survey of fluorinated plasma etching in the silicon-oxygen-carbon-nitrogen-hydrogen system

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New multipass optical lithography patterning methods needed to print features for future <10 nm technologies will demand an increasingly complex combination of hardmasks, antireflection coatings, spacers, and etch stopping materials with distinct yet complementary properties. Finding the right mix, however, has proven particularly challenging given that the materials most commonly used are drawn from a limited set of Si- and C-based solids comprising Si, C, O, N, and H. To understand and maximize the limits of this composition space, the authors have performed a combinatorial survey of the dry etch characteristics for the Si-C-O-N-H system with the goal of understanding material composition–etch interactions and identifying material subclasses with distinct etch properties. Over 50 thin films sampling Si-C-O-N-H composition space were surveyed using two fluorinated etches commonly utilized for selective patterning of SiO_2 and a-SiN:H dielectrics (CHF_3 and CF_4/O_2, respectively). It was found that the incorporation of oxygen in a-SiN:H allowed for significant tuning of the etch rate of a-SiON:H materials relative to SiO_2. Additionally, increasing hydrogen content and nanoporosity significantly increased the etch rate of the various dielectric materials independent of the Si, C, O, and N content. The influence of carbon depended on whether it was incorporated as terminal organic groups, where it resulted in increased etch rates, or directly within the network of the material, where it resulted in decreased etch rates. Silicon- and carbon-rich materials exhibited very low etch rates in both etches and were found to have the most distinct and potentially complementary etch properties relative to SiO_2 and a-SiN:H. Accordingly, a-C:H, a-Si:H, and a-SiC:H merit further examination as hardmask or spacer materials in future multipass patterning processes. © *2016 American Vacuum Society*.
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I. INTRODUCTION

For five decades, transistor area count has doubled roughly every two years in accordance with Moore's Law.[1,2] During this time frame, gains in transistor density have come mostly through Dennard dimensional scaling,[3] which has allowed both a reduction in the transistor areal footprint and tremendous gains in device performance.[4] However, Dennard-style transistor scaling has in the recent decade stalled or come to a halt[5,6] due to numerous physical limitations such as an inability to continue gate dielectric thickness scaling beyond a few atomic layers.[7] Nevertheless, gains in transistor areal density and performance have continued as a result of the implementation of high-k gate dielectric materials[8] and novel trigate or fin field effect transistor (FET) architectures.[9] Further, a long bench of new and upcoming Omega-FET, Pi-FET, and nanowire transistor devices exist that offer the potential for transistor scaling down to low single nanometer dimensions.[10,11] Beyond these charge-based devices, an equally vast array of novel devices exist that are based on other non-charge-based computational states that offer the potential for further scaling and reduced energy consumption.[12,13]

Unfortunately, the optical lithography techniques utilized to define the shape and dimensions of a transistor (as well as the associated metal interconnect) have faced serious physical scaling limitations of their own.[14] For an optical projection system, resolution (R) is defined by the Rayleigh criterion, $R = \lambda/\mathrm{NA}$, where λ is the wavelength of the imaging light and NA is the numerical aperture of the projection assembly.[15] For current industry-standard 193 nm deep UV projection systems, the predicted minimum achievable resolution is correspondingly ~80–90 nm.[6,15] To achieve the greater resolution needed to print smaller feature sizes, the semiconductor optical lithography roadmap has for over a decade called for implementation of a shorter wavelength light referred to as extreme UV (EUV).[16,17] However, new EUV light sources have faced significant technical challenges that have delayed the target insertion point for EUV lithography numerous times.[18–20] In order to print feature sizes well below the wavelength of light, computational lithography[21] has been utilized extensively, and more recently, pitch division and double-quadruple multiple patterning techniques have allowed features <20 nm to be

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achieved.[22,23] These latter multipatterning approaches break up the targeted pattern to be printed into reduced symmetry segments and rely on multiple combined lithography and etch transfer passes to achieve the final desired feature. The numerous litho and etch iterations, in turn, require a complex stack of hardmask, antireflection, spacer, and photoresist coatings with stringent optical, physical, and etch selectivity requirements.

Because of the likely continued delays in EUV technology, additional complementary processes have been sought to increase the number of degrees of freedom for <10 nm optical lithographic processes. These have included increased usage of self-aligned patterning techniques,[23] implementation of directed-self-assembled block-*co*-polymer photoresists,[24,25] and selective deposition of materials on preformed patterns.[26] While several proof of concepts have been demonstrated in these areas,[27–29] it is likely that multipatterning techniques will continue to be heavily relied on to bail out the lack of optical lithography scaling for single digit nanometer technologies and beyond. This will in turn further increase the complexity and already stringent etch selectivity requirements for multipatterning approaches and essentially require unique combinations of spacer, hardmask, and etch stopping materials that exhibit near perfect etch selectivity to one another in various plasma etch chemistries. As one example,[23,30] a typical multipattern process may employ up to five or more patterning assist materials that must be etched through with varying degrees of selectivity, not including the target material to which the final pattern is to be transferred. Fortunately, this level of complexity can be reduced by consideration of the four color theorem of map topology.[31]

The four color map theorem states that only four colors are needed for coloring any map such that no two countries with a common border will have the same color.[31] Whereas proof of the four color theorem required the invention of the modern day computer,[32] the theorem may in turn be applied to reducing the complexity of multipatterning processes for next-generation microprocessors. Specifically, a multipatterned wafer may be viewed as a checkerboard array of different materials that are exposed simultaneously during any plasma etch transfer step.[33,34] For pure pattern transfer fidelity to be maintained, only one of the exposed materials may be etched by the plasma chemistry while the others must exhibit near perfect etch resistance. This scenario and the associated requirements are analogous to the four color map theorem, which suggests that only four unique material/etch chemistry combinations are needed to enable even the most complex multipatterning process. Unfortunately, even within this simpler framework, the current combination of largely halogenated etch chemistries and pattern stack materials (predominantly all from the Si-O-C-N-H phase diagram) at best present only two unique "colors."[35,36] The few materials from outside the Si-O-C-N-H system that have been identified as viable third color materials [e.g., TiN (Ref. 37)] present additional challenges related to optical transparency, mechanical stability, and defects.[38,39] Thus, new materials that could be viable third or fourth colors are highly desired to increase the flexibility of designing new material stacks to assist future multipatterning processes.

Toward this end, we have begun a search for new materials and material subclasses that, in combination with typical plasma etch chemistries, will allow the identification of potential third and fourth colors. We report a combinatorial plasma etch survey of over 50 different materials commonly utilized in microelectronic processing that have been treated with two fluorinated etches typically used for the selective patterning of SiO_2 interlayer and SiN:H etch stop (ES) dielectrics, CHF_3 and CF_4/O_2, respectively. In contrast to previous etch selectivity studies that typically only survey a limited number of materials and do not consistently report the specific composition of these materials,[40–46] the study described here enables a direct analysis of the influence of material stoichiometry and mass density on blanket/unpatterned etch rates and thus allows a more thorough survey of the etch rate ranges and selectivities possible within a given composition space. It is acknowledged that this study neglects many different pattern-dependent effects that are also important considerations for plasma etch optimization including: fin/trench sidewall tapering,[47,48] faceting,[49] necking,[49] bowing,[50] microtrenching,[50,51] microloading,[52] and reactive ion etch (RIE) lag[53] resulting from topography driven shadowing[54] and/or differential charging.[55] However, we view this approach as an important first step in beginning to understand the role that material composition may play in influencing these effects. It is anticipated that this screening study will thus allow for a more rational selection of a subset of materials from this study for future pattern-dependent-focused etch–material interaction studies.

In this article, we specifically focus on the Si-C-O-N-H phase space that comprises the majority of materials typically involved in multipattern processing. A wide variance in etch rate with composition is observed and points to both Si-C-O-N stoichiometry and mass density/hydrogen content being significant considerations for tuning etch selectivity and identifying potential third and fourth color dielectrics. In a companion article,[56] we focus on several high-dielectric-constant materials (Al_2O_3, AlN, HfO_2) and up-and-coming low-*k* dielectric materials (a-B:H, a-BC:H, a-BN:H, a-BP) that lie completely outside the Si-C-O-N system and represent additional third and fourth color materials.[39] Beyond advancing current state-of-the-art pitch division/multipatterning processes within the nanoelectronics industry, we believe these combined studies will additionally benefit nanoscale fabrication processes for electromechanical, energy storage/harvesting, photovoltaic, optoelectronic, and other micro/nanoelectronic devices.

II. EXPERIMENT

The materials investigated in this study were all deposited on Si (001) substrates using a variety of chemical vapor deposition (CVD), plasma-enhanced CVD (PECVD), and spin-on deposition techniques, the details of which have been provided elsewhere.[57–62] Table I provides a summary

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TABLE I. Summary of properties for the various materials in the Si-C-O-N-H system utilized in this study.

Film type	Deposition	Composition range	Density range (g/cm^3)
C:H, CF_x	PECVD, spin-on	H = 25%–50%, F = 0%–44%	0.7–2.2
Si, Si:H	CVD, PECVD	H = 0%–12%	2.2–2.3
SiO_x:H	CVD, PECVD	x = 1.8–2.2, H = 0%–14%	2.2–2.3
SiN_x:H	CVD, PECVD	x = 0.9–1.5, H = 0%–40%	2.0–2.5
SiC_x:H	PECVD	x = 1–4, H = 30%–55%	1.1–2.5
SiO_xN_y:H	PECVD	O = 0%–26%, N = 0%–37%, H = 0%–20%	2.2–2.5
SiN_xC_y:H	PECVD	N = 4%–18%, C = 20%–30%, H = 0%–50%	1.5–2.5
SiO_xC_y:H	PECVD, spin-on	O = 12%–25%, C = 8%–35%, H = 0%–40%	0.9–2.2

of the various films investigated, including their nominal composition and deposition method. The thickness of the films utilized in this study ranged from as thin as 100 nm to as thick as several microns.

The full elemental composition of all films was determined by combined nuclear reaction analysis (NRA) and Rutherford backscattering (RBS) measurements performed at the University of Albany Dynamitron Accelerator Laboratory. This analysis has been described in detail previously.[63] Briefly, the H content was determined using the ^{15}N nuclear reaction method, and the C, N, and O content was determined using deuteron nuclear reactions. The Si content was determined by 2 MeV ^4He RBS. Given the determined H, C, N, O, and Si composition of the films, parameter-free simulations of the full RBS spectra were performed using the program RUMP.[63] These RUMP simulations were then compared to the data to provide a powerful check on the analysis. As an additional consistency check, the mass density for all of the films was determined using both NRA-RBS and previously described x-ray reflectivity measurements.[59] The two techniques were found to be in agreement to within ± 0.1 g/cm^3.

To allow for a direct comparison of the dry plasma etch characteristics of each thin-film material, the samples were all etched simultaneously in a single plasma etch tool. This was accomplished by cleaving $\sim\frac{1}{2} \times 1$ in. coupons of each material from its respective substrate. These coupons were then loaded onto a handler wafer and etched simultaneously in a 300 mm diameter single wafer Oxford Instruments PlasmaLab μEtch 300 RIE system. Portions of each coupon were protected from the plasma etch using a thin Si beam cleaved from a 300 mm diameter Si (001) wafer and physically placed across each row of coupons (see Fig. 1). After etching, the etch rate of each material was determined by either measuring the thickness difference or step height across the exposed and unexposed portions of the coupon. For the former, the thickness of each portion of the coupons was determined using spectroscopic ellipsometry. For the latter, a surface profilometer was used to measure the step height created between the etched and unetched portions of the sample. The surface profilometer was utilized primarily for samples where the unexposed and exposed portions of the films exhibited low color/thickness contrast that complicated the etch rate measurements using the ellipsometer. In several cases, the exposed portion of the film was completely etched away, thus preventing an accurate measurement of the film etch rate. These results were either excluded from the final analysis or marked as a minimum possible etch rate. In other cases, no transition between the exposed and unexposed portions of the samples could be measured. For these samples, the etch rate was concluded to be zero.

To screen the etch selectivity of the various materials under consideration, the samples were exposed to two different plasma etches typically used for selective SiO_2 and a-SiN:H etching. The first plasma etch was a common CHF_3-based chemistry used for selectively etching SiO_2 and low-dielectric-constant (i.e., low-k) a-SiOC:H interlayer dielectrics (ILD) with a a-SiN:H etch stop (hereafter designated as the "ILD" etch). The second plasma etch was a common CF_4/O_2-based chemistry typically utilized to selectively etch a a-SiN:H ES relative to SiO_2 (hereafter designated as the "ES" etch). A summary of the nominal process conditions used for both capacitively coupled plasma etches is provided in Table II. We note that while other etch chemistries might be more typically utilized in pitch division patterning processes, the details of these recipes are not typically published in the open literature. In this regard, the CF_4/O_2 and CHF_3 etch chemistries were specifically selected due to both their complementary selective etching capabilities and the fact that detailed etch process conditions for these

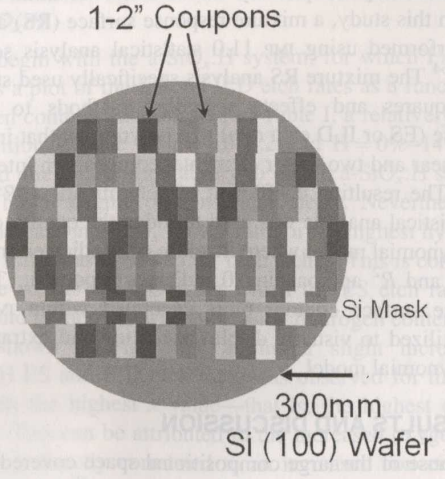


FIG. 1. (Color online) Schematic of wafer carrier and sample geometry for the plasma etch study.

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TABLE II. Summary of the RIE process conditions utilized for both the ILD and ES etches.

Process variable	ILD etch	ES etch
CHF_3 (sccm)	38	0
CF_4 (sccm)	0	60
O_2 (sccm)	4	38
Ar (sccm)	38	75
Pressure (Torr)	30	400
RF power (W)	600	280

chemistries are frequently published in the public domain.[39–55]

To account for possible run–run and within chamber variability, each dry etch run was repeated three times and typically included 2–3 replicates of each sample positioned at opposing sites within the chamber. The three runs were performed using different etch times to accommodate the wide variation in thicknesses and etch rates exhibited by the samples in an attempt to avoid having all of the films of a given type be completely etched through or not etched at all. For additional statistical control, six or more CVD SiO_2 samples were also included in each run and randomly distributed within the chamber. The variability/error for the various thickness or step height measurements was generally $\ll$1 nm and taken to be significantly lower than any sample–sample etch rate variability arising from spatial variations in etch rates within the etch chamber (>1 nm). Additional variability arising from sample–sample composition variability was excluded by utilizing thin film samples with <3% across wafer composition variability and cleaving replicate samples only from the center of the 300 mm diameter Si (001) wafer. In the results to be presented, we have chosen to plot the results for each individual sample (as opposed to the mean) to more clearly illustrate the number of samples characterized and to highlight any significant sample–sample variability.

In cases where the composition space of a ternary system was sufficiently sampled by the Si-C-O-N-H films investigated in this study, a mixture response surface (RS) analysis was performed using JMP 11.0 statistical analysis software (SAS).[64] The mixture RS analysis specifically used standard least squares and effects screening methods to fit the response (ES or ILD etch rate) to a polynomial that included both linear and two factor elemental composition interaction terms. The resulting coefficient of determination (R^2) from the statistical analysis was used to judge the quality of fit to the polynomial model where R^2 close to 1 indicates an excellent fit and R^2 approaching 0 indicates a poor fit. Ternary response surface contour plots generated within JMP 11.0 were utilized to visually display the fitted and extrapolated RS polynomial model.

III. RESULTS AND DISCUSSION

Because of the large compositional space covered in this study, we begin by first examining the dry etch behavior of the pure elements (i.e., a-C:H, a-Si:H, and a-Si) and a few stoichiometric, low-hydrogen-content compounds present within the Si-C-O-N composition space [i.e., a-SiO_2, a-Si_3N_4:H (20% H) and a-SiC:H (30% H)]. We initially compare the etch rates of the different materials as a function of their mass density. This is both for clarity of presentation and due to an expected intuitive correlation between the etch rate and mass density of a material (i.e., for a fixed number of reactive etch species and fixed composition, etch rate should decrease as the mass/atomic density of the etched material increases). In this regard, etch rate versus mass density comparisons for amorphous thin-film materials are particularly relevant as differences in deposition methods and process conditions can produce materials with significantly different mass/atomic densities.[65] In many cases, the variations in mass density are largely due to differences in the amount of incorporated hydrogen and other hydrogenated terminal groups (e.g., CH_x, NH_x, and OH) which can act as network modifiers and result in more open/lower density network structures with reduced properties.[66–68]

After establishing general trends in dry etch behavior for the elements and stoichiometric compounds, we next probe more complex compositional effects by examining nonstoichiometric materials (SiO_x:H, SiC_x:H, SiN_x:H, SiO_xN_y:H, SiN_xC_y:H, and SiO_xC_y:H) and more closely scrutinizing the influence of hydrogen and carbon content on some of the examined material systems. We place a particular emphasis on comparing the etch behavior of the different material composition classes and conclude by seeking to establish clouds of materials with distinctive etch characteristics that might represent unique etch colors.

A. Pure elements and compounds

Figure 2 summarizes the measured etch rates as a function of mass density for the elemental and stoichiometric compound films exposed to the ES (CF_4/O_2) and ILD (CHF_3) etches. As a reminder, each data point represents the result from a single sample in order to more clearly illustrate the number of samples characterized and highlight any sample–sample variability.

For the ES etched samples, etch rates ranging from <1 Å/s to as high as 24 Å/s were observed. For the a-C:H samples, which were sampled across a range of mass densities from 0.7 to 2.2 g/cm^3, etch rates were found to scale as a function of density. For the highest density a-C:H film (2.2 g/cm^3), a low etch rate of ~1 Å/s was observed, similar to the values for the a-Si, a-Si:H, and SiO_2 films with comparable mass densities. As the mass density of the a-C:H films decreased, the ES etch rate increased substantially up to a value of ≥20 Å/s for the film with a mass density of 0.7 g/cm^3 (note that this value is a minimum value due to the film being completely etched through). Thus, the a-C:H results clearly illustrate the intuitive correspondence between increasing etch rate and decreasing mass/atomic density. For the a-C:H films examined here, the decrease in mass density is a direct result of hydrogen content steadily increasing from 27% for the highest density film to 53% for the lowest density film. The increasing etch rate with

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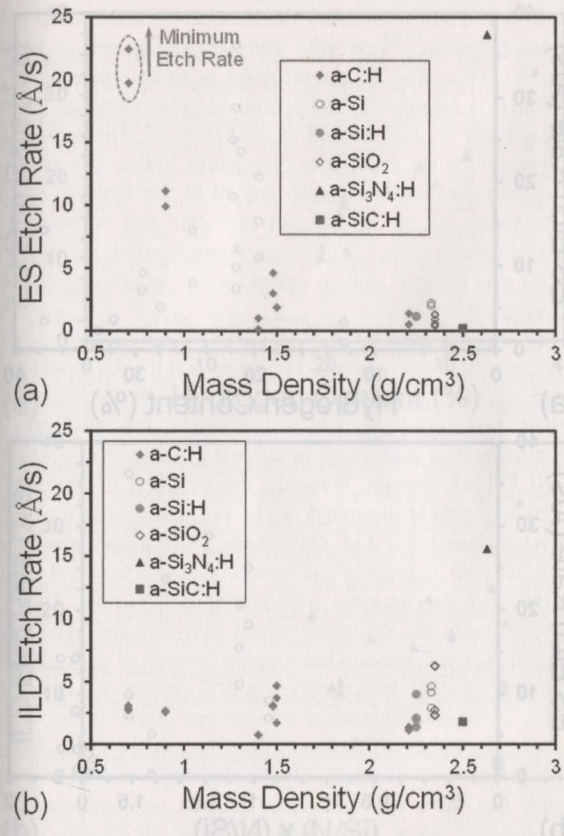


FIG. 2. (Color online) (a) ES (CF_4/O_2) and (b) ILD (CHF_3) etch rates as a function of mass density for a-C:H, a-Si, a-Si:H, a-SiO_2, a-Si_3N_4:H, and a-SiC:H thin films.

hydrogen content can be further rationalized based on the development of interconnected nanoporosity (~25%)[69] in the lowest density a-C:H film that allowed the plasma-activated etch species to penetrate further into the surface of the a-C:H dielectric.[70,71] A similar trend would be expected for a-Si:H, but unfortunately, a-Si:H films with a similarly wide range of hydrogen content could not be obtained for this study.

For all of the Si- and C-based materials in Fig. 2(a), the ES etch rates decreased as a function of material density, with the exception of Si_3N_4:H, which simultaneously exhibits the highest etch rate (24 Å/s) and highest mass density (2.65 g/cm^3). Although perhaps counterintuitive, this result is consistent with the ES etch chemistry being specifically optimized for materials of SiN_x:H composition, and illustrates the additional role of chemical composition/bonding in determining etch rates. Such compositional effects will be further illustrated in more detailed examinations of the ES and ILD etch rates of a-SiO_x:H, a-SiN_x:H, and a-SiC_x:H (vide infra).

For the ILD (CHF_3) etched samples, all of the films exhibited slightly higher but comparable etch rates, with the exception of the PECVD a-Si_3N_4:H film, which—interestingly—again exhibited an etch rate approximately three times as high (~15 Å/s) as that of the CVD SiO_2 film (~5 Å/s) [see Fig. 2(b)]. As we will show later, this difference becomes less apparent for the nonstoichiometric PECVD equivalents of these films (i.e., a-SiN_x:H and a-SiO_x:H). In addition, unlike in the case of the ES etch, the a-C:H films do not exhibit a significant difference in etch rate as a function of mass density for the ILD etch. This can be attributed to the CHF_3 etch being a polymerizing chemistry[35] that, during etching, codeposits surface CF_x that prevents greater subsurface penetration of the plasma-activated etch species.[70,71] In this regard, we note for additional insight that measurements on PECVD CF_x films included with the above samples (but not included in Fig. 2) did show a high etch rate of ~30 Å/s in the CF_4/O_2 ES etch and a substantially lower etch rate of 6 Å/s in the CHF_3 ILD etch. This confirms the partial etch resistance of any surface CF_x residues potentially produced in the CHF_3 chemistry.

B. Nonstoichiometric compounds

We next examine the etch characteristics of several off-stoichiometric materials in the Si-O-C-N-H system. For the ternary and quaternary systems investigated, we initially look at how the etch properties vary in response to a change in concentration for a single element. However, due to limitations associated with the deposition processes, it was difficult in all cases to generate a sample set where the concentration of one element was systematically varied in relation to the concentration of the others. This is particularly true in the case of the plasma-deposited hydrogenated materials where variations in oxygen, nitrogen, and carbon content can cause wide fluctuations in hydrogen content. This point was partly addressed by performing a RS analysis where, for many of the ternary systems investigated, a sufficiently large sampling of the composition space allowed for this. While several RS analysis examples of dry plasma etching have been previously reported in the literature,[72–74] the results presented here differ in that the composition of the material being etched serves as the input variable whereas in prior studies the composition of the plasma etch chemistry and other plasma etch process variables were utilized as inputs.

1. a-SiO_x:H

We begin with the a-SiO_x:H system, for which Fig. 3(a) presents a plot of the ES and ILD etch rates as a function of hydrogen content. As indicated in Table I, a relatively small compositional space of $x = 1.8–2.2$ and H = 0%–14% was explored due to a limited ability to obtain a-SiO_x:H samples with a larger degree of nonstoichiometry. Nevertheless, a slight increase in a-SiO_x:H etch rate for the highest hydrogen content films was observed for both etches. This is consistent with the results for a-C:H for which the ES etch rate was also found to increase with increasing hydrogen content.

As shown in Fig. 3(b), a similar slight increase in a-SiO_x:H ES and ILD etch rates was observed for the samples with the highest x value—that is, the highest oxygen content. This can be attributed to the increased oxygen content being directly correlated to an increased concentration of OH groups.[75] Several previous investigations of the wet etch behavior of a-SiO_2 in hydrogen fluoride (HF) based

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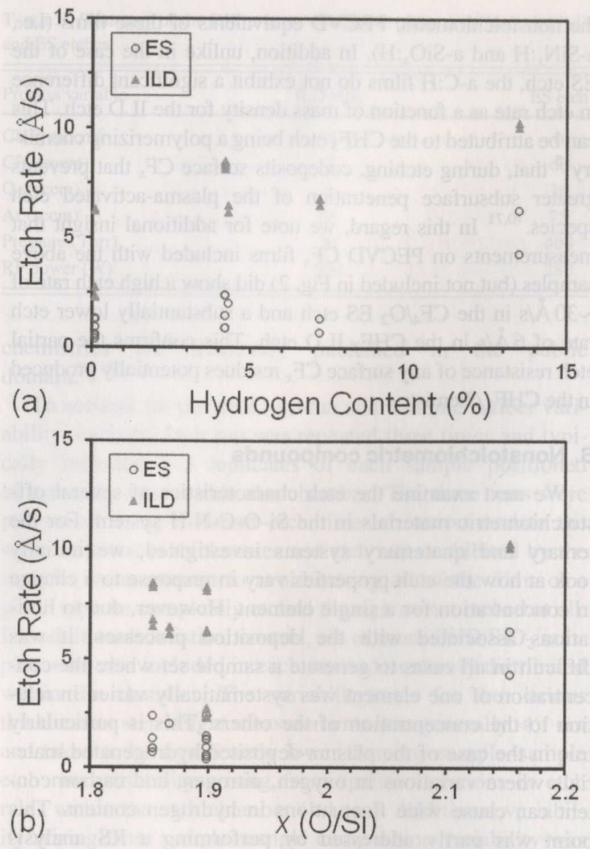


FIG. 3. (Color online) ES and ILD etch rates for a-SiO_x:H thin films as a function of (a) hydrogen content (%) and (b) x (O/Si).

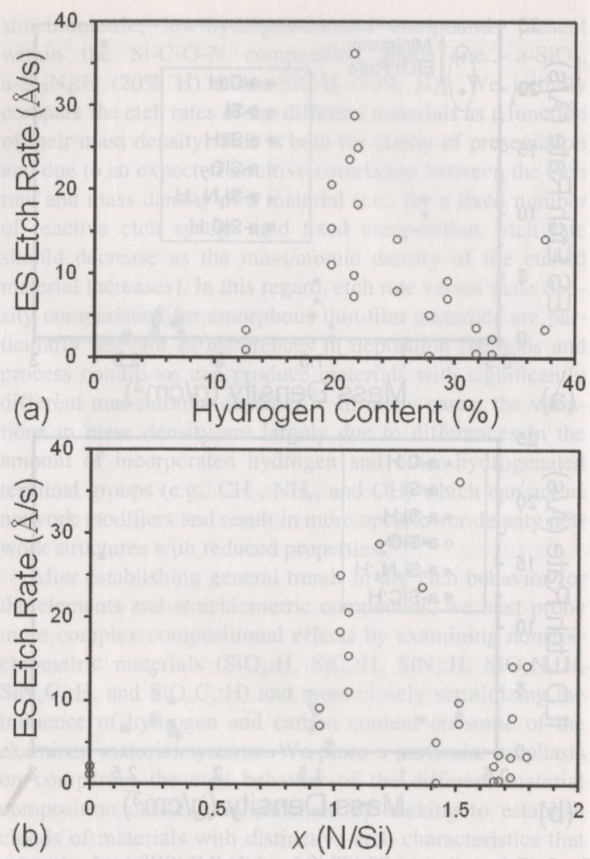


FIG. 4. (Color online) a-SiN_x:H ES etch rates as a function of (a) H content (%) and (b) x (N/Si).

solutions have shown a strong relationship between hydrogen content and HF etch rates.[75,76] However, studies of dry plasma etching of SiO_2 have shown a much weaker effect on hydrogen content.[76]

Since a fairly limited range of x and hydrogen content were investigated in this study, it is possible that a more prominent response between etch rate and composition may exist within the a-SiO_x:H system. However, based on the relatively small differences in etch rate observed in Fig. 2 for a-Si:H and a-SiO_2, one would expect only a rather weak response between x (O/Si) and etch rate. The density trend observed for a-C:H in Fig. 2 does suggest that hydrogen content may have a strong influence on a-SiO_x:H etch rate, but to more clearly observe such an effect would require additional higher hydrogen content samples beyond those available to this study. Due to the limited sampling of the Si-O-H composition space, a more detailed ternary response surface analysis for this system was not attempted.

2. a-SiN_x:H

Figures 4 and 5 present the ES and ILD etch rates, respectively, for a-SiN_x:H as a function of both hydrogen content and N/Si ratio, x. For the ES etch, the a-SiN_x:H etch rate was found in many cases to depend on the etch time, with longer etch times generally leading to higher etch rates (up to 2× in some cases). This is attributed to the formation of a native oxide (SiO_2) surface layer on the a-SiN_x:H films. As shown in Sec. III B 1, SiO_2 exhibits a relatively low ES etch rate and therefore the presence of a thin SiO_x surface layer could be expected to initially impede or delay etching of the underlying a-SiN_x:H film. Similar delayed etch effects have also been reported for plasma etching of silicon and other nitride materials.[77–79] For short etch times, this effect would thus make the measured etch rate appear lower. While this effect increased the variability in the observed a-SiN_x:H ES etch rates, it did not influence the general trends to be discussed.

Focusing on Fig. 4(a), we observe a general decrease in a-SiN_x:H ES etch rate with increasing hydrogen content. This behavior runs counter to the previously observed increasing hydrogen content/increasing etch rate correlation shown in Fig. 2. We also note that the lowest hydrogen content a-SiN_x:H film in Fig. 4(a) actually exhibits a very low ES etch rate in contrast to the observed broader trend. Both of these contradicting observations can be partially understood by examining the ES etch rate dependence on N/Si ratio (x) shown in Fig. 4(b). In this case, a gradual increase in ES etch rate is observed as the N/Si ratio increases from <1 to roughly 1.3–1.4, before it again decreases to low values (note data points for a-Si:H have also been included to allow the full dependence on N/Si ratio to be assessed).

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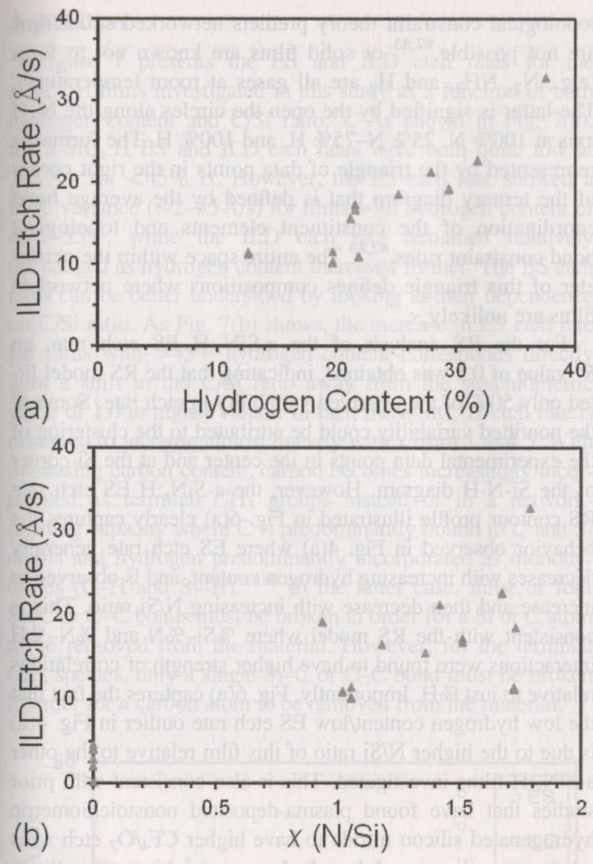


FIG. 5. (Color online) a-SiN_x:H ILD etch rates as a function of (a) H content (%) and (b) x (N/Si).

Thus, the observed maximum in ES etch rate occurs at approximately the same x value as for stoichiometric Si_3N_4 (1.33). This suggests that Si–N bonds are perhaps preferentially attacked/etched by the CF_4/O_2 chemistry relative to the Si–Si, Si–H, and N–H bonds present in higher concentrations in the nonstoichiometric a-SiN_x:H films. In this regard, we note that preferential CF_4/O_2 etching of Si_3N_4 over Si and a-Si:H has been previously reported in the literature.[40,77,80] Thus, the outlier behavior of the lowest hydrogen content a-SiN_x:H film in Fig. 4(a) can be partly attributed to the high N/Si ratio (1.7) exhibited by this film relative to the others. The competing behavior between %H and N/Si on a-SiN_x:H ES etch rate will be more clearly discussed in the response surface analysis described later.

For the CHF_3 ILD etch, the a-SiN_x:H etch rates are slightly higher on average than those observed for the CF_4/O_2 ES etch. This could be due to the higher CHF_3 SiO_2 etch rate and the ability for this etch to more easily break through any SiO_x surface layer present on the a-SiN_x:H films. Interestingly, the ILD etch rate for a-SiN_x:H also shows a strong dependence on hydrogen content, opposite to that found in the case of the ES etch but consistent with the intuitive density/etch rate correspondence, where it increases from ~10 Å/s for 10%–20% H to >30 Å/s for 38% H (see Fig. 5). A similar increase in ILD etch rate with increasing N/Si ratio is also observed, which is rendered even more apparent when including the ILD etch results for a-Si and a-Si:H [see Fig. 5(b)]. This may indicate a weaker selectivity to Si–N bonding for the CHF_3 relative to the CF_4/O_2 chemistry or suggest a stronger dependence on H or Si content for the ILD etch rate.

The strong a-SiN_x:H ILD etch rate dependence on hydrogen content is particularly interesting, given the lack of such an observed dependence for the ILD etch rate of all the other materials discussed so far. As mentioned previously, the lack of a hydrogen content/density trend for the CHF_3 ILD etch in a-C:H and other materials has been attributed to the propensity of this etch to form a comparatively thick CF_x surface layer. In fact, studies by Kuo and others have attributed the selective CHF_3 etching of SiO_2 relative to a-SiN_x:H to the enhanced growth of a CF_x surface layer on a-SiN_x:H.[40,44,45] In this regard, we do note that the a-SiN_x:H film in the Kuo study had a N/Si ratio of 1.6 and hydrogen concentration of 15%, similar to the lowest hydrogen content a-SiN_x:H film examined in this study that also exhibited a relatively low CHF_3 ILD etch rate. Thus, these observations suggest that the CF_x surface layer thickness formed during CHF_3 etching of a-SiN_x:H and other materials is likely dependent on stoichiometry (N/Si), concentration of hydrogen, and/or the presence of specific chemical bonds in the etched film (i.e., C–C, Si–Si, Si–N, Si–C, Si–H, N–H, or C–H).

The contrasting ES and ILD etch behavior may be attributed to differences in the propensity of the two chemistries to etch through a native oxide layer, codeposit CF_x during etching, and the stability of these and other fluoride species on the a-SiN_x:H surfaces. The contrasting dependencies on N/Si and hydrogen content, in particular, suggest variances in sensitivity to different elements or chemical bonds in a-SiN_x:H for the two different etches. Disentangling such effects in a ternary system like a-SiN_x:H can be difficult using simple x–y plots. However, as we will show later, some of these effects can be more clearly analyzed and visualized via a ternary response surface analysis.

To the authors' knowledge, relatively few investigations correlating dry plasma etch rates to variations in a-SiN_x:H properties have been previously reported. However, one detailed investigation worth noting was reported by Hahn *et al.* where the dry etch rates of inductively coupled plasma (ICP) deposited a-SiN_x:H were investigated primarily as a function of film stress and SF_6/Ar ICP etch process conditions.[81] When etch conditions with a strong chemical component were utilized, the authors observed that the measured etch rates increased substantially when the intrinsic film stress increased above 500 MPa. When more physical etch conditions were utilized, the authors observed no apparent dependence of etch rate on film stress. While Hahn *et al.* report only that the refractive index (RI) of the a-SiN_x:H films was ~2.0 and do not report the exact elemental composition, the authors' experience with the a-SiN_x:H films in this study suggests that films with higher compressive stress tend to be closer to the stoichiometric value of $x = 1.33$. In this regard, the increase in SF_6/Ar etch rate with a-SiN_x:H film

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stress observed by Hahn is consistent with the maximum in CF_4/O_2 etch rate observed at $x \approx 1.3$ in this study.

To more clearly visualize how both the a-SiN_x:H ES and ILD etch rates vary with composition, a statistical RS analysis was performed. To improve the a-SiN_x:H composition space covered in the analysis, the previously presented results for PECVD a-Si:H and CVD a-Si were also included. The resulting ES and ILD etch rate ternary contour plots predicted from the RS model are depicted in Fig. 6. The filled circular points present in each ternary plot represent the compositions for the individual films utilized in the RS modeling. Each side of the triangle represents the axis for one of the three elemental components of the system (i.e., % Si, N, and H in this case) with the three corners signifying a composition of 100% for each element. The illustrated data points are plotted such that each elemental concentration decreases in proportion to the distance from the corner of the triangle representing that element. The color shading illustrates the ES and ILD etch rates predicted by the RS model as a function of composition.

As evident in Fig. 6, only a portion of the full Si-N-H ternary diagram was sampled in this study. However, a significant portion of this diagram is either experimentally or theoretically known as non film or solid forming. These regions are signified in Fig. 6 by the additional open circle data points which represent compositions where either

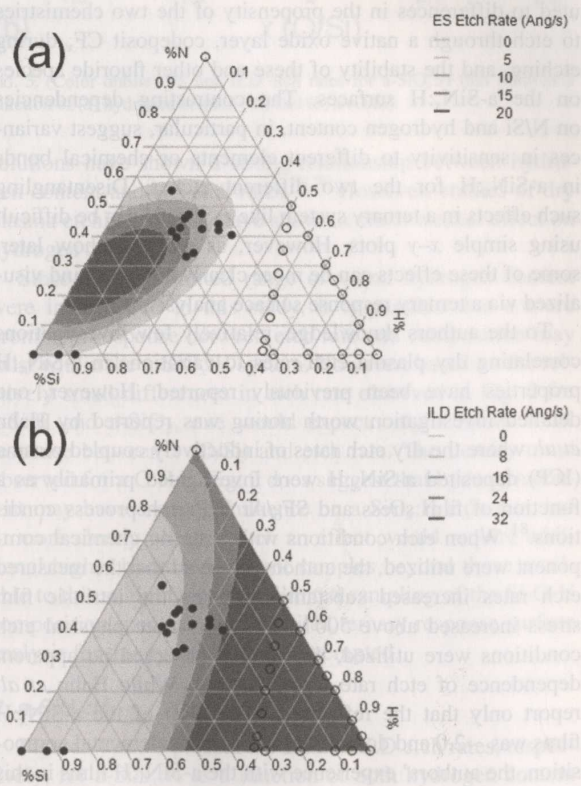


FIG. 6. (Color online) (a) ES and (b) ILD etch rates for a-SiN_x:H as a function of silicon, nitrogen, and hydrogen content (%). Filled circles represent experimental data points and open circles non-film-forming compositions.

topological constraint theory predicts networked solid films are not possible,[82,83] or solid films are known not to form (e.g., N_2, NH_3, and H_2 are all gases at room temperature). The latter is signified by the open the circles along the N–H axis at 100% N, 25% N–75% H, and 100% H. The former is represented by the triangle of data points in the right corner of the ternary diagram that is defined by the average bond coordination of the constituent elements and topological bond constraint rules.[82,83] The entire space within the perimeter of this triangle defines compositions where networked films are unlikely.

For the RS analysis of the a-SiN_x:H ES etch rate, an R^2 value of 0.5 was obtained, indicating that the RS model fitted only 50% of the observed variability in etch rate. Some of the nonfitted variability could be attributed to the clustering of the experimental data points in the center and at the Si corner of the Si-N-H diagram. However, the a-SiN_x:H ES etch rate RS contour profile illustrated in Fig. 6(a) clearly captures the behavior observed in Fig. 4(a) where ES etch rate generally decreases with increasing hydrogen content, and is observed to increase and then decrease with increasing N/Si ratio. This is consistent with the RS model where %Si–%N and %N–%H interactions were found to have higher strength of correlations relative to just %H. Importantly, Fig. 6(a) captures the fact that the low hydrogen content/low ES etch rate outlier in Fig. 4(a) is due to the higher N/Si ratio of this film relative to the other a-SiN_x:H films investigated. This is also consistent with prior studies that have found plasma-deposited nonstoichiometric hydrogenated silicon nitride to have higher CF_4/O_2 etch rates relative to silicon and low hydrogen stoichiometric silicon nitride deposited by chemical vapor deposition.[84]

The maximal ES a-SiN_x:H etch rate predicted by the RS model actually occurs at roughly 60% Si, 30% N, and 10% H. Unfortunately, the predicted maximum falls outside the experimentally sampled portion of the Si-N-H ternary diagram. It is unclear whether such a maximum truly exists or is simply an artifact of the reduced model fit and/or the nonuniform sampling of composition space. Any attempts to extrapolate the results of the a-SiN_x:H ES RS model outside the experimentally sampled regions should be taken with some caution, but this result suggests a composition space worthy of future investigation.

For the RS analysis of the a-SiN_x:H ILD etch rate, a much higher R^2 value of 0.97 was obtained, indicating that the model fitted 97% of the observed variability in etch rate. The RS contour profile [Fig. 6(b)] captures the trends observed in Fig. 5, where ILD etch rate increases as a function of both hydrogen content and N/Si ratio. This is consistent with the RS model where %H, Si, and N were all found to be stronger effects than any cross term interactions. For the ILD a-SiN_x:H etch rate, the predicted maximum etch rate is centered at 100% H and broadly decreases as one moves toward the Si-N tie-line with a minimum predicted at predominantly silicon-rich conditions [see Fig. 6(b)]. This visually indicates that, within the film-forming regions of the Si-N-H system, hydrogen content and silicon content are the dominating factors for determining the a-SiN_x:H ILD etch rate.

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3. a-SiC_x:H

Figure 7 presents the ES and ILD etch rates for the a-SiC_x:H films investigated in this study as a function of both hydrogen content and C/Si ratio, x. As shown in Fig. 7(a), the a-SiC_x:H ES and ILD etch rates were both quite low at 2–3 Å/s for <45% H. However, the ES etch rate showed a huge variance (~2–55 Å/s) for films with hydrogen content of 45%–55%, while the ILD etch rate remained relatively unchanged as hydrogen content increased further. The ES etch rates can be better understood by looking at their dependence on C/Si ratio. As Fig. 7(b) shows, the increase in ES etch rate for films with >45% hydrogen content corresponds directly with a shift in the C/Si ratio away from the stoichiometric value of 1.0 to higher values. In fact, the a-SiC_x:H etch rate is observed to increase almost linearly with x from 1 to 4.5. With increasing carbon content, carbon becomes increasingly incorporated as terminal CH_3 groups instead of in a network-forming capacity where C is predominantly bound to C and Si atoms and hydrogen predominantly incorporated as monohydrides (C–H and Si–H).[85,86] In the latter case, three or four Si–C or C–C bonds must be broken in order for a Si or C atom to be removed from the material. However, for the terminal CH_3 species, only a single Si–C or C–C bond must be broken in order for a carbon atom to be removed from the material.

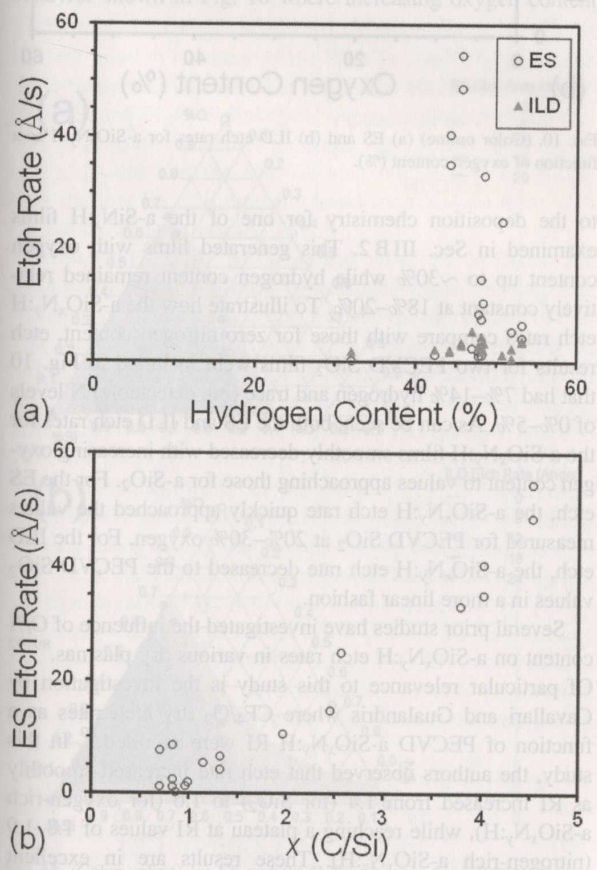


FIG. 7. (Color online) (a) ES and ILD etch rates for a-SiC_x:H as a function of hydrogen content (%), (b) a-SiC_x:H ES etch rates as a function of x (C/Si).

The amount of interconnected nanoporosity was also observed to increase substantially for SiC_x:H films with H > 45% and C/Si > 1,[59] coincident with environmental oxygen contamination increasing to as high as 15–18%. These factors likely also contribute to the enhanced ES etch rate for the highest carbon content a-SiC_x:H films due to deeper penetration into the surface of the films by the plasma-activated reactants generated in the CF_4/O_2 plasma. This is illustrated in Fig. 8 where the a-SiC_x:H ES etch rates are plotted as a function of mass density. Here, one can see a gradual increase in etch rate with decreasing mass density similar to that observed for a-C:H. One can also observe that the films with significant amounts of interconnected nanoporosity exhibit significantly higher etch rates relative to those with similar mass densities. This effect will be even more clearly shown later in the examination of the a-SiO_xC_y:H system.

For the ILD etch, the a-SiC_x:H etch rate essentially shows no dependence on hydrogen (or carbon) content, and the measured etch rates were quite low (<5 Å/s) for the composition space examined. This is consistent with the generally low to negligible etch rates observed for single-crystalline SiC in fluorinated plasmas[87] and the similarly low etch rates observed for a-SiC:H.[41] For highly polymerizing fluorinated plasmas (such as CHF_3), the low etch rates have been directly attributed to the growth of a relatively thick CF_x surface layer on a-SiC:H.[41,43,44]

To more clearly visualize the interplay between Si, C, and H content on the ES and ILD etch rates, a response surface analysis on the a-SiC_x:H system was also performed. The resulting ES and ILD etch rate ternary contour plots predicted from the RS model are shown in Fig. 9. As for the a-SiN_x:H system, the previously presented results for a-Si, a-Si:H, and a-C:H were included to allow the Si-C-H composition space to be more fully sampled and improve the coverage of the RS analysis. Similarly, the triangle of open circles in the hydrogen-rich portion of the Si-C-H composition demarcates the region where topological constraint theory[82,83] indicates continuously networked films are unlikely.

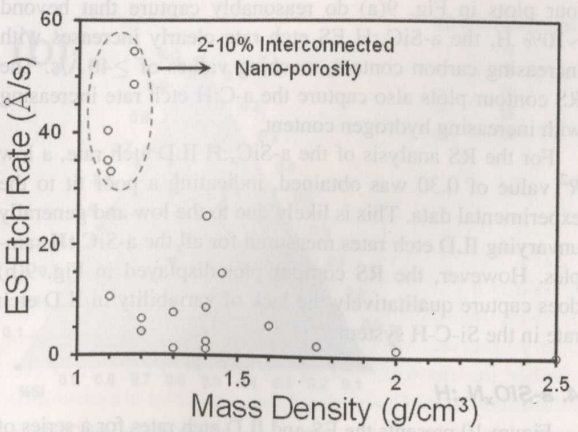


FIG. 8. (Color online) a-SiC_x:H ES etch rates as a function of mass density.

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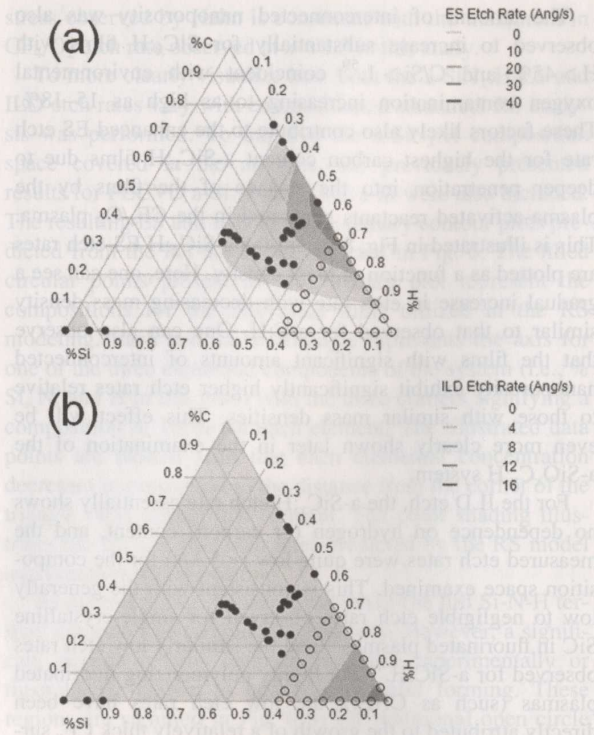


FIG. 9. (Color online) (a) ES and (b) ILD etch rates for a-SiC_x:H as a function of silicon, carbon, and hydrogen content (%). Filled circles represent experimental data points and open circles non-film-forming compositions.

For the RS analysis of the a-SiC_x:H ES etch rate, an R^2 value of 0.60 was obtained, indicating that only 60% of the observed variability in etch rate was captured by the RS model. This could be due to the incomplete coverage of the full Si-C-H composition space and/or the additional nonlinear effect resulting from the presence of nanoporosity which is not explicitly a function of elemental composition. We do note that the near zero etch rates predicted for the low hydrogen content composition space is consistent with the comparatively low CF_4/O_2 etch rates reported in the literature for single crystal SiC (Ref. 87) and diamond.[88] However, contour plots in Fig. 9(a) do reasonably capture that beyond ~20% H, the a-SiC_x:H ES etch rate clearly increases with increasing carbon content, reaching values of ≥40 Å/s. The RS contour plots also capture the a-C:H etch rate increasing with increasing hydrogen content.

For the RS analysis of the a-SiC_x:H ILD etch rate, a low R^2 value of 0.30 was obtained, indicating a poor fit to the experimental data. This is likely due to the low and generally unvarying ILD etch rates measured for all the a-SiC_x:H samples. However, the RS contour plot displayed in Fig. 9(b) does capture qualitatively the lack of variability in ILD etch rate in the Si-C-H system.

4. a-SiO_xN_y:H

Figure 10 presents the ES and ILD etch rates for a series of a-SiO_xN_y:H films produced by intentionally adding an oxidizer

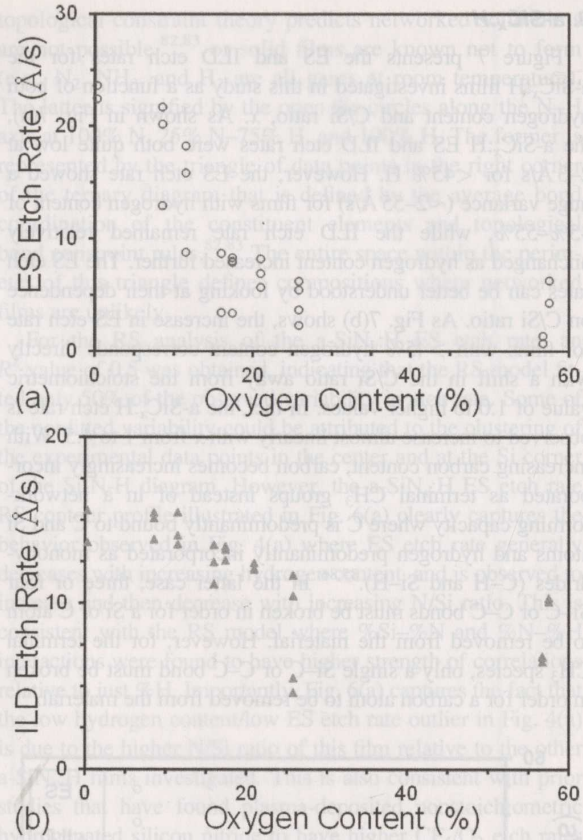


FIG. 10. (Color online) (a) ES and (b) ILD etch rates for a-SiO_xN_y:H as a function of oxygen content (%).

to the deposition chemistry for one of the a-SiN_x:H films examined in Sec. III B 2. This generated films with oxygen content up to ~30% while hydrogen content remained relatively constant at 18%–20%. To illustrate how the a-SiO_xN_y:H etch rates compare with those for zero nitrogen content, etch results for two PECVD SiO_2 films were included in Fig. 10 that had 7%–14% hydrogen and trace (but detectable) N levels of 0%–5%. As can be seen, both the ES and ILD etch rates for the a-SiO_xN_y:H films smoothly decreased with increasing oxygen content to values approaching those for a-SiO_2. For the ES etch, the a-SiO_xN_y:H etch rate quickly approached the values measured for PECVD SiO_2 at 20%–30% oxygen. For the ILD etch, the a-SiO_xN_y:H etch rate decreased to the PECVD SiO_2 values in a more linear fashion.

Several prior studies have investigated the influence of O/N content on a-SiO_xN_y:H etch rates in various dry plasmas.[89–92] Of particular relevance to this study is the investigation by Cavallari and Gualandris where CF_4/O_2 dry etch rates as a function of PECVD a-SiO_xN_y:H RI were reported.[89] In this study, the authors observed that etch rate increased smoothly as RI increased from 1.4 (for SiO_2) to 1.6 (for oxygen-rich a-SiO_xN_y:H), while reaching a plateau at RI values of 1.8–1.9 (nitrogen-rich a-SiO_xN_y:H). These results are in excellent agreement with those reported here for a-SiO_xN_y:H CF_4/O_2 etching where etch rate was also observed to increase with

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decreasing oxygen content and increasing RI (not shown). In contrast, Ueno *et al.* investigated CHF_3 reactive ion etching of PECVD a-SiO_xN_y:H and observed that the dry etch rate increased slightly as RI decreased from 2.1 to 1.6 and plateaued at a RI value of 1.44 (i.e., for SiO_2).[90] However, the counter trend observed by Ueno can be partly explained by the fact that the starting base a-SiN_x:H film was Si-rich with $x \cong 0.6$, whereas x for the starting a-SiN_x:H film in this study was closer to 1.0.

To help better understand how the exact elemental composition in the Si-O-N system can influence dry etch rates, we present in Fig. 11 ternary Si-O-N RS contour plots for ES and ILD etch rates based on the a-SiO_xN_y:H films investigated in this study. The plots are valid only for $H \leq 20\%$, and can more accurately be viewed as a slice through a Si-O-N-H pyramidal quaternary diagram at $H \sim 20\%$. However, we believe Fig. 11 should still be predictive of general trends for other hydrogen contents reasonably outside this narrow range of H. As for the previous ternary diagrams, the open circles represent known non-film-forming regions, which in this case essentially encompass the entire O–N axis and surrounding region (i.e., O_2, N_2, N_2O and similar species are all gases at room temperature). The R^2 for both the ES and ILD etch RS models were high at 0.8 and 0.9, respectively, and the predicted response surface contour plots reproduce well the behavior shown in Fig. 10 where increasing oxygen content for a-SiN_x:H film with $x=1$ leads to a decrease in both the ES and ILD etch rates. In addition, Fig. 11(b) shows that the addition of oxygen to a-SiN_x:H film with $x=0.6$ (i.e., >65% Si) can lead to a slight increase in ILD etch rate as observed in the Ueno study.[90]

5. a-SiC_xN_y:H

For the a-SiC_xN_y:H system, only a limited number of samples with compositions within the Si-C-N ternary system were obtained (see Table I), which exhibited high ES etch rates of ~50 Å/s and moderate ILD etch rates of ~5 Å/s. Despite the limited composition space for the SiC_xN_y:H samples, when included with samples from the previously presented Si-N-H and Si-C-H systems, a reasonable response surface analysis of the Si-C-N system was possible. As Secs. III B 1–III B 4 have shown that high hydrogen content and interconnected porosity can significantly influence both the ES and ILD etch rates, the merged a-Si:H, a-C:H, a-SiN_x:H and a-SiC_x:H datasets were intentionally limited to samples with hydrogen content <50% where interconnected porosity was observed to develop in a-C:H and a-SiC_x:H. The resulting Si-C-N ternary ES ($R^2=0.8$) and ILD ($R^2=0.9$) etch rate RS contour plots are both shown in Fig. 12. For the ES etch rate, a predicted maximum exists along the C-N tie-line at approximately 45% N. This maximum decreases with increasing Si content along a ridge that follows a tie-line to roughly 85% Si on the Si-N tie-

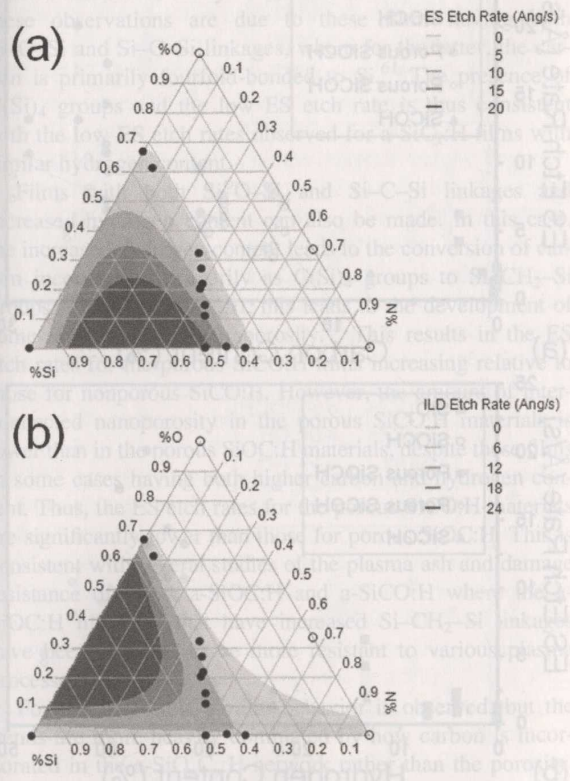


FIG. 11. (Color online) (a) ES and (b) ILD etch rates for a-SiO_xN_y:H as a function of silicon, oxygen and nitrogen content (%). Filled circles represent experimental data points and open circles non-film-forming compositions.

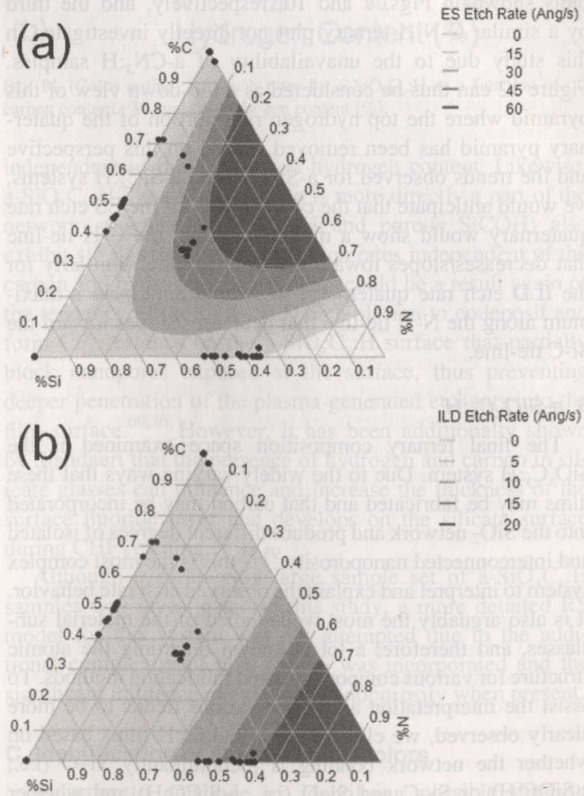


FIG. 12. (Color online) (a) ES and (b) ILD etch rates for a-SiC_xN_y:H as a function of silicon, nitrogen, and carbon content (%).

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line. Interestingly, the predicted maximum corresponds to an approximately stoichiometric C_3N_4 composition, and may represent a material class worthy of further investigation in this regard. This maximum is somewhat similar to the maximum observed along the C-H tie-line in the Si-C-H system and suggests that the addition of nitrogen to carbon could play a similar role in reducing network connectivity and developing nanoporosity.

In contrast, the ILD etch rates show a maximum that falls within the nitrogen-rich phase field and decreases with increasing Si and/or C content at a similar rate. In this regard, we do note that while constraint theory would predict that continuous networked films are possible in the nitrogen-rich composition space, pure (100%) nitrogen is a gas (i.e., N_2). As both the predicted maxima also fall outside the composition range sampled for this ternary system, we note that some caution should be taken in these extrapolated results despite the high R^2 for the RS model.

As mentioned previously, hydrogen has been shown to have a significant influence on both the ES and ILD etch rates in a-SiN_x:H and a-SiC_x:H. Thus, it can be anticipated that hydrogen content variations would also have a similar effect within the a-SiC_xN_y:H system. In this regard, we can envision a three dimensional quaternary plot with hydrogen represented by an apex extending out of the plane for the Si-C-N ternary plots shown in Fig. 12. Two of the faces of this pyramid are represented by the Si-N-H and Si-C-H ternary plots shown in Figs. 7 and 10, respectively, and the third by a similar C-N-H ternary plot not directly investigated in this study due to the unavailability of a-CN_x:H samples. Figure 12 can thus be considered as a top-down view of this pyramid where the top hydrogen rich portion of the quaternary pyramid has been removed. Based on this perspective and the trends observed for a-SiN_x:H and a-SiC_x:H systems, we would anticipate that the contour plot for the ES etch rate quaternary would show a maximum along the C-H tie-line that decreases/slopes toward the Si-N tie-line. Similarly for the ILD etch rate quaternary, we would anticipate a maximum along the N-H tie-line that decreases/slopes toward the Si-C tie-line.

6. a-SiO_xC_y:H

The final ternary composition space examined is the SiO_xC_y:H system. Due to the widely varying ways that these films may be fabricated and that carbon may be incorporated into the SiO_2 network and produce different degrees of isolated and interconnected nanoporosity,[93,94] this is the most complex system to interpret and explain the observed etch rate behavior. It is also arguably the most well-studied of the material subclasses, and therefore, a lot is known regarding the atomic structure for various compositions and fabrication methods. To assist the interpretation and allow various trends to be more clearly observed, we classify the a-SiO_xC_y:H films based on whether the network bonding is predominantly Si–O (i.e., a-SiOC:H) or Si–C and Si–O (i.e., a-SiCO:H) and whether the films contain significant levels of interconnected porosity (typically >12% porosity with pore diameter ≥1 nm). The former classification is based on transmission Fourier transform-infrared spectroscopy measurements and the latter based on both ellipsometric porosimetry and positronium annihilation lifetime spectroscopy measurements that have all been previously described in detail.[58]

Figure 13 presents the a-SiO_xC_y:H ES etch rates as a function of both carbon and hydrogen content. A general increase in etch rate with both increasing carbon and hydrogen content was observed. This trend is consistent with prior observations for other systems (i.e., a-C:H, a-SiO_x:H, and a-SiC_x:H) where increasing hydrogen/terminal CH_x content was observed to lead to an increased ES etch rate. For a-SiO_xC_y:H, the connection between carbon and hydrogen content both increasing in concert is similar to that for a-SiC_x:H where for PECVD a-SiO_xC_y:H hydrogen is in many cases also predominantly coincorporated with carbon as terminal CH_x groups.[93,94]

Focusing on Fig. 13(a) in more detail, one can observe more subtle differences in etch rate. Relative to pure PECVD SiO_2, the incorporation of even trace (1%–4%) amounts of carbon was observed to result in a two-to-threefold increase in the ES etch rate. However, for increasing levels of carbon, the ES rate was either further increased or reduced depending on the way in which the carbon was incorporated into the

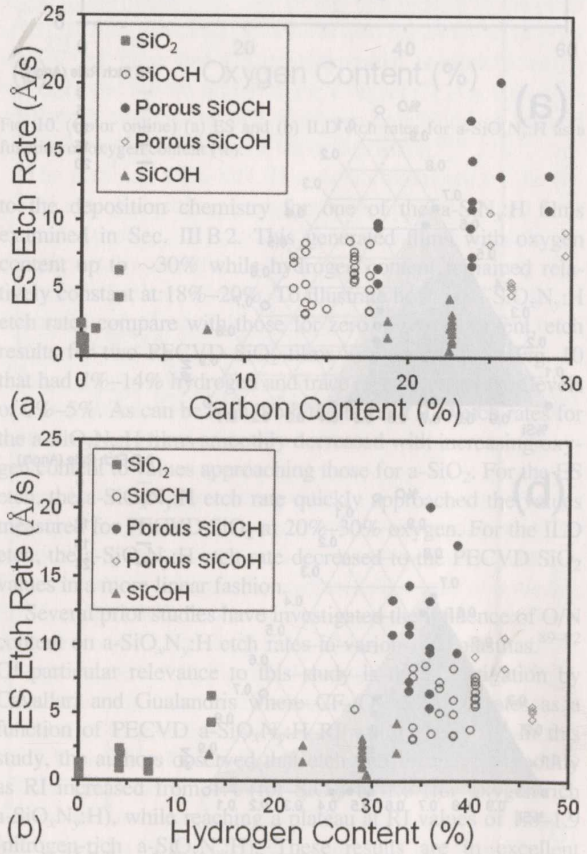


FIG. 13. (Color online) ES etch rates for a-SiO_xC_y:H as a function of (a) carbon content (%), and (b) hydrogen content (%).

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films. For the a-SiO_xC_y:H films with small amounts of carbon (12%–17%), the carbon was predominantly incorporated as terminal CH_x groups that lower the density of the material and increase both the size and amount of nanopores present in the material (see data points labeled SiOCH).[93,94] When the concentration of carbon incorporated as terminal CH_x groups increases beyond 18%, the nanopores present in these materials start to become interconnected, which results in a highly porous material.[58] As previously observed for both a-C:H and a-SiC_x:H, this leads to further increases in a-SiO_xC_y:H etch rate due to both the lower mass density and the ability of the plasma-generated etch precursors to penetrate more deeply into the surface of the a-SiO_xC_y:H film (see porous SiOCH data points). This latter point is more clearly observed in Fig. 13(b), in contrasting data points for SiOCH and porous SiOCH, where films with similar hydrogen content but higher levels of interconnected nanoporosity exhibit higher ES etch rates. A similar dependence of etch rate on porosity for low-*k* a-SiOC:H materials has also been observed and reported by others.[95–99]

However, carbon can also be incorporated directly in the network structure of a-SiO_xC_y:H as opposed to as terminal CH_x groups.[61,100] The a-SiO_xC_y:H thin films where carbon was incorporated in this fashion are signified in Fig. 13 as SiCOH and porous SiCOH. As shown in Fig. 13(a), the SiCOH films exhibit very low ES etch rates of 1–4 Å/s and, as illustrated in Fig. 13(b), also exhibit reduced hydrogen content relative to many of the SiOCH class films. Both of these observations are due to these films having both Si–O–Si and Si–C–Si linkages, where for the latter, the carbon is primarily fourfold-bonded to Si.[61] The presence of $C(Si)_4$ groups and the low ES etch rate is thus consistent with the low ES etch rates observed for a-SiC_x:H films with similar hydrogen content.

Films with both Si–O–Si and Si–C–Si linkages and increased hydrogen content can also be made. In this case, the increased hydrogen content leads to the conversion of carbon incorporated primarily as $C(Si)_4$ groups to Si–CH_2–Si groups.[100] As for a-SiC_x:H, this leads to the development of some interconnected nanoporosity.[58] This results in the ES etch rates for the porous SiCO:H films increasing relative to those for nonporous SiCO:H. However, the amount of interconnected nanoporosity in the porous SiCO:H materials is lower than in the porous SiOC:H materials, despite these films in some cases having both higher carbon and hydrogen content. Thus, the ES etch rates for the porous SiCO:H materials are significantly lower than those for porous SiOC:H. This is consistent with several studies of the plasma ash and damage resistance of low-*k* a-SiOC:H and a-SiCO:H where the a-SiOC:H materials that have increased Si–CH_2–Si linkages have been reported to be more resistant to various plasma processes.[101]

For the ILD etch, similar behavior is observed, but the trends are more heavily dominated by how carbon is incorporated in the a-SiO_xC_y:H network rather than the porosity. As shown in Fig. 14, the a-SiO_xC_y:H films wherein carbon is incorporated predominantly as terminal CH_x groups (i.e., SiOCH and porous SiOCH) all exhibit similar ILD etch rates

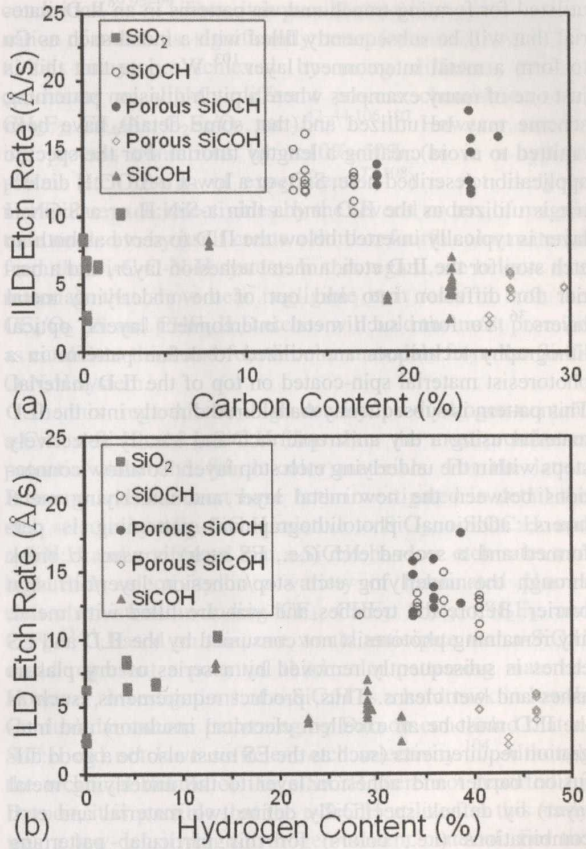


FIG. 14. (Color online) ILD etch rates for a-SiO_xC_y:H as a function of (a) carbon content (%), and (b) hydrogen content (%).

independent of the carbon and hydrogen content. Likewise, a-SiO_xC_y:H films where carbon is more directly a part of the network structure (i.e., SiCOH and porous SiCOH) also exhibit similar (but lower) ILD etch rates independent of the carbon and hydrogen content. This could be a result again of the tendency of the CHF_3 ILD etch plasma to codeposit and form CF_x residues on the a-SiO_xC_y:H surface that partially block nanopores exposed at the surface, thus preventing deeper penetration of the plasma-generated etchants into the film surface.[69,70] However, it has been additionally shown by Standaert that the presence of hydrogen and carbon in silicate glasses can influence and increase the thickness of the surface fluoride layer that develops on the silicate surface during CHF_3 etching.[102]

Although a sufficiently large sample set of a-SiO_xC_y:H samples was investigated in this study, a more detailed RS model for this system was not attempted due to the additional complexity of how carbon was incorporated and the significant influence of extended nanoporosity when present.

C. Identification of alternate etch colors

In order to conclude by identifying possible third or fourth color materials for pitch-division and multipattern processing, we consider a basic dual damascene scheme

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utilized for forming trench and via patterns in an ILD material that will be subsequently filled with a metal such as Cu to form a metal interconnect layer.[103] We note that this is just one of many examples where a pitch-division patterning scheme may be utilized and that some details have been omitted to avoid creating a lengthy tutorial. For the specific application described here, SiO_2 or a low-*k* a-SiOC:H dielectric is utilized as the ILD and a thin a-SiN:H or a-SiCN:H layer is typically inserted below the ILD to serve as both an etch stop for the ILD etch, a metal adhesion layer, and a barrier for diffusion into and out of the underlying metal layers.[36] To form such metal interconnect layers, optical lithography techniques are utilized to define patterns in a photoresist material spin-coated on top of the ILD material. This pattern is subsequently transferred directly into the ILD material using a dry anistropic etch and ideally selectively stops within the underlying etch stop layer. To allow connections between the new metal layer and underlying metal layers, additional photolithographical patterning is performed and a second etch (i.e., ES etch) is used to break through the underlying etch stop/adhesion layer/diffusion barrier. Before the trenches and vias are filled with metal, any remaining photoresist not consumed by the ILD and ES etches is subsequently removed by a series of dry plasma ashes and wet cleans. Thus, product requirements (such as the ILD must be an excellent electrical insulator) and integration requirements (such as the ES must also be a good diffusion barrier and adhesion layer to the underlying metal layer) by default specifically define two material and etch combinations (i.e., colors) for this particular patterning scheme (see Fig. 1 of Ref. 103 for more details regarding dual damascene patterning methods).

In more advanced dual damascene patterning schemes, a hardmask material may be added on top of the ILD to, among many additional considerations,[39] improve the pattern transfer fidelity of high aspect ratio features from the photoresist into the underlying ILD.[104] The hardmask in this case is ideally required to be selectively etched relative to the ILD, remain in place during the subsequent ILD and ES etches, and easily removed after completion of the ILD and ES etches. In this regard, such hardmasks represent a need for a third color material and etch combination. For more complex multipattern dual damascene schemes, additional backbone and spacer materials may be added on top of the hardmask that must in turn be selectively etched and removed relative to the underlying hardmask and exposed ILD and ES materials.[23] These backbone and spacer materials thus represent a need for a third or fourth color combination of materials and etches. In even more complex multipatterning schemes, dissimilar etch stop materials may be used to cover different metal lines that require unique etches to selectively breakthrough and etch one ES material in the presence of the others and the ILD material.[33] By default, the additional etch stop materials represent third and fourth color materials that require unique third and fourth color etches.

Consideration of the above dual damascene patterning schemes helps to define the material and etch criteria for potential third and fourth colors. Specifically, any third or fourth color material must have either a zero etch rate in both the ES and ILD etches or several orders of magnitude higher etch rate in these two etches relative to the ES and ILD materials utilized. This in turn requires the identification of a third and fourth color plasma etch that can etch the still-to-be-identified third and fourth color pattern materials but not etch the already defined ES and ILD materials. Although other etch chemistries were not investigated in this study, a number of other dry etch chemistries based on H_2, HCl, Cl_2, CCl_4, HBr, Br_2, BCl_3, NF_3, and SF_6 are available and commonly utilized in the semiconductor industry.[84,105] Thus, the goal of this study is to identify potential materials within the Si-C-O-N-H system that, in combination with these other etches, *may* facilitate third and fourth color patterning.

To help identify potential third and fourth color materials from the Si-C-O-N-H system in the context of the above dual damascene patterning schemes, we summarize in Fig. 15 the ES and ILD etch rates for the various materials examined normalized to the etch rate of a well-known ILD material: SiO_2. The results are again presented as a function of mass density both for clarity of presentation and to more easily facilitate discussion later regarding additional requirements for the various materials. As shown in Fig. 15(a), a wide range of etch

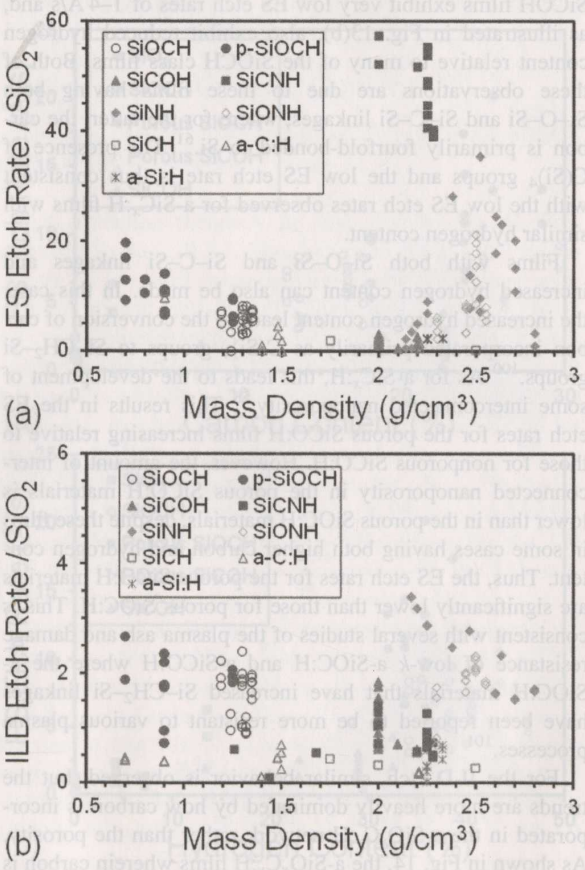


FIG. 15. (Color online) (a) ES etch rates and (b) ILD etch rates for various materials examined in this study relative to a-SiO_2.

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rates relative to SiO_2 was observed using the CF_4/O_2 ES etch. As perhaps expected based on the name of the etch, the a-SiN:H and a-SiCN:H materials most commonly used as the etch stop in dual damascene metal interconnect patterning exhibit significantly higher etch rates relative to SiO_2 with etch selectivities as high as ~60:1. This means that after trenches and vias have been properly defined in the ILD, the etch stop materials can be easily etched through to expose the underlying metal layer without significantly etching the ILD material further and inducing a loss in pattern fidelity or critical dimension (CD) control. However, some of this selectivity is lost if low-*k* a-SiOC:H or porous a-SiOC:H (p-SiOC:H) materials are used as the ILD instead of SiO_2 in order to reduce parasitic capacitive delays in the metal interconnect. As shown in Fig. 15(a), the a-SiOC:H and p-SiOC:H materials exhibit higher etch rates in the ES etch relative to SiO_2. Depending on the specific composition of the ILD and ES, the use of low-*k* ILDs can reduce the ES/ILD etch selectivity from as high as 60:1 to as low as 1:1.

From the perspective of identifying potential third and fourth color materials, none of the materials examined in the Si-C-O-N-H system exhibit several order of magnitude higher etch rates in the ES etch relative to SiO_2. SiCN:H exhibits the highest etch selectivity of up to 60:1, and based on response surface modeling of the Si-C-N ternary system, a-CN:(H) may demonstrate even higher etch selectivity than this. On the other hand, several materials exhibit sufficiently low to negligible ES etch rates to merit further consideration. Of these, the high-density/low-hydrogen-content forms of a-C:H, a-Si:H, a-SiC:H, and SiCO:H stand out as well as Si-rich a-SiN_x:H. To further cull this list, we next look at the ILD etch rates of the various examined materials in the CHF_3 ILD etch.

As shown in Fig. 15(b), all the materials exhibit comparable etch rates relative to SiO_2 with etch selectivities ranging from <0.1 to 5, with a-C:H, a-Si:H, a-SiC:H, and a-SiOC:H still exhibiting the lowest relative etch rates. The narrower range in etch selectivity can be attributed to the polymerizing nature of the CHF_3 chemistry that for blanket etch rate measurements can result in the formation of a significant fluorinated polymer surface layer in most cases. Once formed, physical ion bombardment and surface defluorination is required for etching to be sustained and this can reduce/mute the sensitivity between the etch chemistry and the material.[43,44] However, such polymer formation is beneficial in that the polymer buildup that occurs on the sidewalls of an etched feature helps to create the anisotropy needed to transfer high aspect ratio features into the desired material. For ILD etching, this polymer buildup also helps to slow the etch and overcome the low blanket etch selectivity observed between the various SiO_2 and a-SiOC:H ILD materials and a-SiN:H and a-SiCN:H ES materials shown in Fig. 15(b).[36,105]

At this point, we do note that the etch selectivities presented in Fig. 15 are relevant only to the specific process conditions utilized for the CF_4/O_2 and CHF_3 etches. Numerous studies have shown that widely varying etch rates and etch selectivities can be achieved by varying CF_4/O_2 ratios, pressure, power, bias, and numerous other process conditions.[89,95–99] Thus, it is possible that for a given combination of materials, significantly better (or worse) etch selectivities may be achieved by using different process conditions or slightly different process chemistries (i.e., CH_2F_2, CF_4/Ar, C_2F_6/O_2, etc.).[42–44,106,107] However, tweaking process conditions by ±10%–50% (as in a typical plasma etch design of experiments[72,108]) is not likely to manipulate etch selectivities by the several orders of magnitude needed to by itself create a third or fourth color material from the Si-C-O-N-H system. In this regard, we believe that materials that show near negligible etch rates in both the CF_4/O_2 ES and CHF_3 ILD etches will hold the most promise as candidate third and fourth color materials from the Si-C-O-N-H system.

In this regard, the high-density/low-hydrogen-content a-C:H, a-Si:H, and a-SiC:H films show the most promise as potential third and fourth color materials. For the latter, Posseme and Standaert have both investigated in detail the etch selectivity of a-SiC:H relative to SiO_2, a-SiOC:H, and a-SiN:H and confirmed that a-SiC:H has low etch rates and high etch selectivity in a variety of fluorinated plasma etch chemistries including CF_4, CHF_3, C_4F_8, CH_2F_2, and C_4F_6.[43,44] Based on this, one would anticipate that a-SiC:H could represent a potential third color patterning material. However, investigations of a-SiC:H as a hardmask in low-*k*/Cu dual damascene patterning by Darnon concluded that a-SiC:H did not have sufficient etch selectivity.[104] Although the technical details of the a-SiC:H were not reported by Darnon, it is possible that the a-SiC:H utilized in this study was a low-density/high-hydrogen-content material. For the a-SiC:H utilized by the same group in the Posseme study, a mass density of 2.0 g/cm^3 and hydrogen content of 50% was reported.[43] As this study has demonstrated, the etch resistance of a-SiC:H in both ES and ILD etches can be dramatically improved by reducing hydrogen content down to 25% to achieve mass densities of 2.5 g/cm^3 or greater. Therefore, reconsideration of higher density/lower hydrogen content a-SiC:H as a hardmask or other patterning material may be merited, but will require the identification of non-fluorine-based dry etch chemistries to enable selective dry patterning of a-SiC:H as well as wet chemical or other routes for a-SiC:H hardmask removal after the patterning process has been completed. The latter has been demonstrated for lower density forms of a-SiC:H,[109] but may be more challenging for higher density/lower hydrogen content forms of a-SiC:H.[110]

The challenges of etching high-density/low-hydrogen-content a-SiC:H may make a-C:H and a-Si:H more attractive as potential third/fourth color pattern materials from the Si-C-O-N-H system. Numerous methods for wet and dry etching of both materials are known,[111,112] and the use of various forms of both as hardmasks has already been reported.[113–116] The primary challenge with using a-C:H as a hardmask that limits its consideration as a possible third color pattern material concerns differentiation between a-C:H and photoresist. Specifically, the O_2 and H_2 based plasmas typically utilized to dry etch and pattern a-C:H can also aggressively attack photoresist.[117] These etches are also problematic when used

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for patterning low-k a-SiOC:H dielectrics due to their propensity to selectively remove carbon from low-k materials and create a host of performance and reliability issues.[118] Optical transparency can also be a major challenge for both a-C:H and a-Si:H.[114] However, this is a challenge for other commonly used hardmask materials such as TiN as well.[37]

Beyond blanket hardmask applications, use of a-C:H, a-Si:H, and a-SiC:H as backbone and/or spacer materials in multipatterning approaches may be limited by additional requirements beyond etch selectivities. As one example, spacer materials utilized in multipatterning processes must have high conformality and step coverage while having low deposition temperatures compatible with the melting point of the photoresist material that they may be deposited over.[119] For the CVD and PECVD methods most commonly utilized to deposit these materials, meeting both of these requirements can be a challenging task.[36] Atomic layer deposition (ALD) is one method that has shown the potential to meet these requirements for oxide materials, but viable ALD processes for a-C:H, a-Si:H, and a-SiC:H have so far yet to be demonstrated.[120]

Beyond the above discussion, we acknowledge that many additional factors come into consideration when selecting and optimizing materials and etches to support various patterning schemes. Factors such as line edge roughness, microtrenching, surface roughening, across wafer etch and CD uniformity, cost, defects and environmental-health-safety issues can further constrain and limit the selection process for identifying third and fourth color pattern assist materials and etches.[35,103] Such considerations are beyond the scope of this relatively simple attempt to screen a diverse array of materials based on two common ILD and ES etches. However, as noted previously, the presented study should allow a more rational selection of a reduced subset of materials to be selected for more detailed examinations of the material influence on pattern-dependent etch features.

In this regard, we do note that the carbon-nitrogen-hydrogen system (i.e., a-CN_x:H) is one composition space neglected in this study that has shown promise for developing tribological coatings for magnetic memory devices.[121] Although the response surface modeling of the Si-C-N system performed in this investigation does not suggest this composition space will yield potential third or fourth color materials, the development of such materials could bring additional flexibility and depth to the list of available pattern assist materials. Nevertheless, new materials outside the Si-C-O-N-H system will likely be required to achieve the ultimate goal of true four color patterning. As mentioned previously, TiN is one material outside the Si-C-O-N-H system that has found extensive use as a hardmask material in advanced patterning schemes,[37] but has limitations in terms of defects, optical transparency, and inducing mechanical instabilities in the patterning stack.[38,39] In a follow on article to this one,[56] we explore additional materials outside the Si-C-O-N-H system that offer the potential to be viable third and fourth colors, including high-k dielectric (Al_2O_3, AlN, HfO_2) and up-and-coming boron-containing low-k dielectric materials (a-B:H, a-BC:H, a-BN:H, and a-BP). As we will show in this second article,[56] these materials offer the potential to bring additional flexibility in the ultimate selection of materials and design of the pitch division pattern stacks.

IV. SUMMARY AND CONCLUSIONS

Two dry fluorinated plasma etches commonly utilized to selectively etch ILD (CHF_3) and ES (CF_4/O_2) materials in dual damascene patterning processes were utilized to survey the etch characteristics of a large array of materials from within the Si-C-O-N-H system to identify possible third and fourth color materials for use in advanced pitch division and multipatterning processes. The materials surveyed exhibited a wide range of relative etch rates in the CF_4/O_2 ES etch with common a-SiCN:H ES materials exhibiting etch selectivities as large as 60:1 and lower than 1:0.1 relative to SiO_2. In contrast, the observed range of etch rates for the CHF_3 ILD etch was reduced with typical ILD to ES etch selectivities ranging from 5:1 to 1:0.1 or less. The reduced range of etch rates observed for the CHF_3 ILD etch was attributed to the tendency of this chemistry to form fluorinated surface layers that required ion-bombardment-induced defluorination to drive further etching.

Both hydrogen and carbon incorporation were found to significantly influence the etch rates of the material classes investigated. Hydrogen was found to increase the dry etch rate of many of the materials by reducing both the atomic density and overall network connectivity. This was not the case, however, in some of the ILD etches due to the aforementioned formation of CF_x surface layers, or in the case of the SiN:H ES etch rates, where the correlation between etch rate and N/Si ratio was the dominant influence. The incorporation of carbon was found to increase or decrease the etch rate of materials depending on how the carbon was incorporated in the film. When carbon was incorporated directly into the network bonding of a material, the etch rates generally decreased or remained low. However, when carbon was incorporated primarily as terminal organic groups (typically CH_3), the etch rates increased following the trends for hydrogen. Further, incorporation of sufficiently large amounts of terminal organics resulted in the development of interconnected porosity and further increases in etch rate. By incorporating oxygen into SiN_x:H to yield SiO_xN_y:H films, both ES and ILD etch rates could be varied smoothly from SiN_x:H ranges to SiO_2 ranges.

Of all the materials examined, high-density/low-hydrogen-content a-C:H, a-Si:H, and a-SiC_x:H exhibited low to negligible etch rates in both the ILD CHF_3 and ES CF_4/O_2 etches and could represent potential third and fourth color patterning assist materials in combination with other still-to-be-determined etches. Beyond these materials, a-CN_x:H represents a composition space that has largely been ignored for patterning applications, but was predicted to exhibit very high (higher than a-$SiCN_x$:H) ES etch rates based on response surface modeling of the Si-C-N ternary system, and may warrant further investigation. It is likely that many more additional considerations beyond those examined in this study will need to be addressed to solidify the selection

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of the identified materials as potential third and fourth color materials. It is also likely that many more additional materials (and etches) will need to be identified to provide the flexibility of meeting not only the requirements of multipatterning processing, but the device and product integration requirements. In this regard, we hope that this relatively simple demonstration inspires future united combinatorial material composition and dry etch process chemistry studies. Additional efforts by the authors to perform a similar survey on materials outside the Si-C-N-O-H system including high-k (Al_2O_3, AlN, and HfO_2) and boron-containing low-k dielectrics (a-B:H, a-BC:H, a-BN:H, and a-BP) will be presented in a companion article to this one.[56]

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