

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Form containing inventor information for Inventor 1 (Jason Stowers), Inventor 2 (Alan Telecky), Inventor 3 (Andrew Grenville), and Inventor 4 (Douglas Keszler). Each entry includes fields for Given Name, Middle Name, Family Name, City, State, and Country, along with a Remove button.

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the Add button.

Form fields for Title of Invention (PHOTOPATTERNABLE INORGANIC HARDMASK) and Attorney Docket Number (5063.02US01).

Correspondence Address section with a radio button selection for address type (Customer Number or Firm/Individual Name) and the corresponding Customer Number (62274).

Government agency section with radio button selection for whether the invention was made by a U.S. Government agency, and a field for NSF grant numbers (DGE-0549503 and IIP-0912921).

Entity Status

Applicant claims small entity status under 37 CFR 1.27

- ☒ Yes, applicant qualifies for small entity status under 37 CFR 1.27
- ☐ No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Peter S. Dardi/			Date (YYYY-MM-DD)	2010-06-01
First Name	Peter	Last Name	Dardi, Ph.D.	Registration Number (If appropriate)	39650

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PHOTOPATTERNABLE INORGANIC HARDMASK

GOVERNMENT RIGHTS

Development of the inventions described herein was at least partially funded with government support through U.S. National Science Foundation grants DGE-0549503 and IIP-0912921, and the U.S. government has certain rights in the inventions.

Versatile inorganic materials for processing into devices can comprise polyatomic oxide ions, such as metal suboxide cations and/or polyatomic anions. These inorganic materials can be processed using aqueous solutions. These materials can be effectively formed into dielectric materials as described in published U.S. patent application 2005/0242330 to Herman et al., entitled "Dielectric Material," incorporated herein by reference. With appropriate selection of the metal elements in the composition, semiconductor films can be formed. The semiconducting inorganic oxide compositions are described further in published U.S. patent application 2010/0044698 to Herman et al., entitled "Semiconductor Film Composition," incorporated herein by reference. Through the use of a peroxide ligand, aqueous precursor solutions can be stabilized sufficiently to provide an effective photo-patternable composition that can be deposited and patterned. The photo-patternable compositions can be used as a resist or for the direct patterning of a material for incorporation into a structure having patterned integrated devices. The general use of these materials as a resist is described in published PCT application WO 2009/120169 to Keszler et al., entitled "Solution Processed Thin Films and Laminates, Devices Comprising Such Thin Films and Laminates, and Methods for the Use and Manufacture," incorporated herein by reference.

The following slides provide documentation of further improvements in the solution based photo-patternable compositions. Note that LWR is an abbreviation for line width roughness. A presentation abstract provides further summary.

Presentation Abstract

We present here a directly photopatternable inorganic hardmask for 193 nm lithography. This resist is based on the solution-deposited dielectric HfSOx [1], which has previously been reported to be a high-performance, high-sensitivity electron beam resist [2]. HfSOx resists exhibit a number of desirable

characteristics for use in electron beam lithography such as high resolution and low LER (Figure 1). HafSOx resists have the added advantages of exceptional etch resistance, (demonstrated by an etch selectivity over Si > 160 under a RIE process using SF₆ plasma), and high sensitivity, where doses as low as 8 $\mu\text{C}/\text{cm}^2$ (30 keV) have been realized.

5 In light of these promising electron-beam results, we have extended our investigation of HafSOx resists as hardmasks directly patterned by 193-nm lithography. By tuning its composition, we have achieved a remarkably high index of 2.0 at 193 nm, thereby providing additional process latitude relative to conventional photoresists. The result is a high contrast, negative tone resist that operates in an optimal thickness range of 20 to 40 nm. Initial 193-nm exposures using interference lithography have yielded 60-
10 nm lines and spaces (Figure 2). The platform's demonstrated resolution with e-beam exposure strongly suggests its extendibility to 32 nm.

The HafSOx platform is also differentiated from other inorganic resists on the basis of its amorphous nature and chemical inertness, allowing it to function directly as a hard mask with high-fidelity pattern transfer. We have further demonstrated the ability to build multilayer films by simply
15 depositing subsequent coats on annealed HafSOx base layers without forming interfaces between coats. This capability enables the use of HafSOx resists in double patterning techniques such as litho-freeze, litho-etch processes, where a second resist layer is deposited on a developed resist underlayer.

[1] J.T. Anderson, C.L. Munsee, C.M. Hung, T.M. Phung, G.S. Herman, D.C. Johnson, J.F. Wager and D.A. Keszler, Adv. Funct. Mater., 17 (2007) 2117-2124, incorporated herein by reference.

20 [2] J. Stowers and D.A. Keszler, Microelectronic Engineering, 86 (2009) 730-733, incorporated herein by reference.

[3] Tom Wallow, et al SPIE 69211F (2008), incorporated herein by reference.

The references incorporated by reference herein are incorporated in their entirety to the extend the material incorporated by reference is not in contradiction to the explicit disclosure herein, which shall
25 completely control interpretation of the present disclosure over any inconsistent incorporated material.

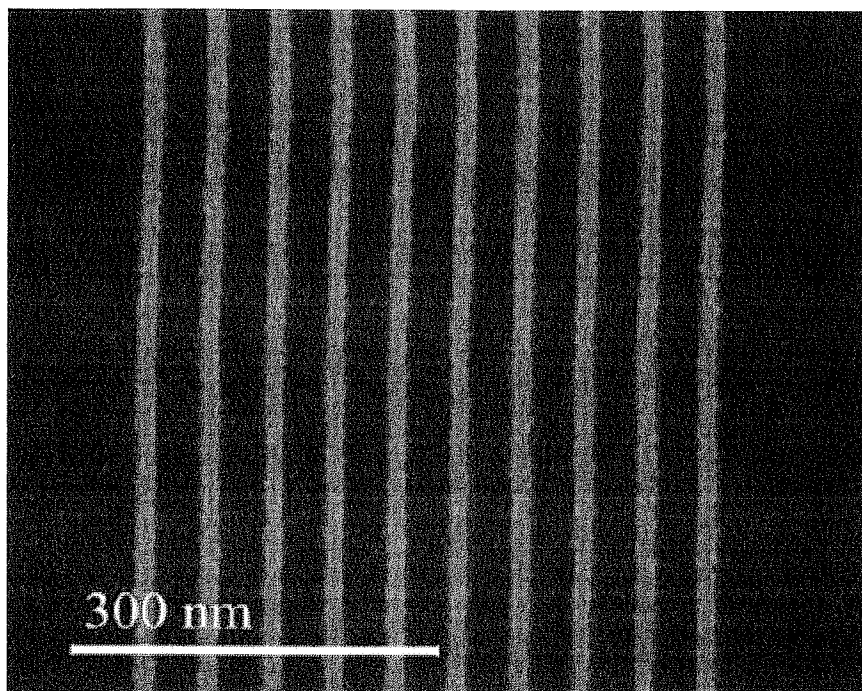


Figure 1: SEM image of 15 nm lines on a 50 nm pitch by electron beam lithography, LWR = 3.4 nm

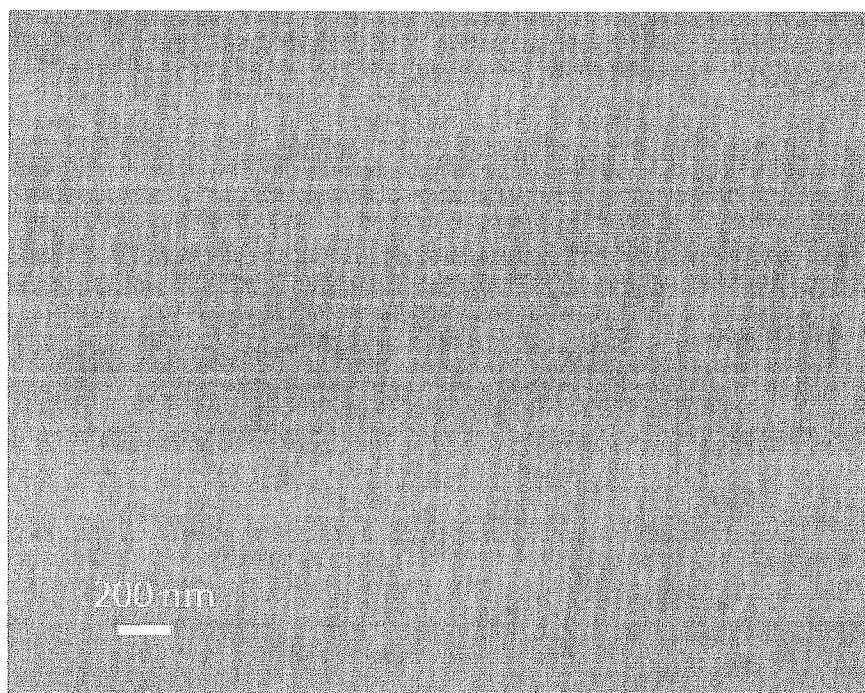


Figure 2: SEM image of 60 nm half-pitch features at a dose of 21 mJ/cm².

What is claimed is:

1. The compositions described herein.

5

2. The structures described herein.

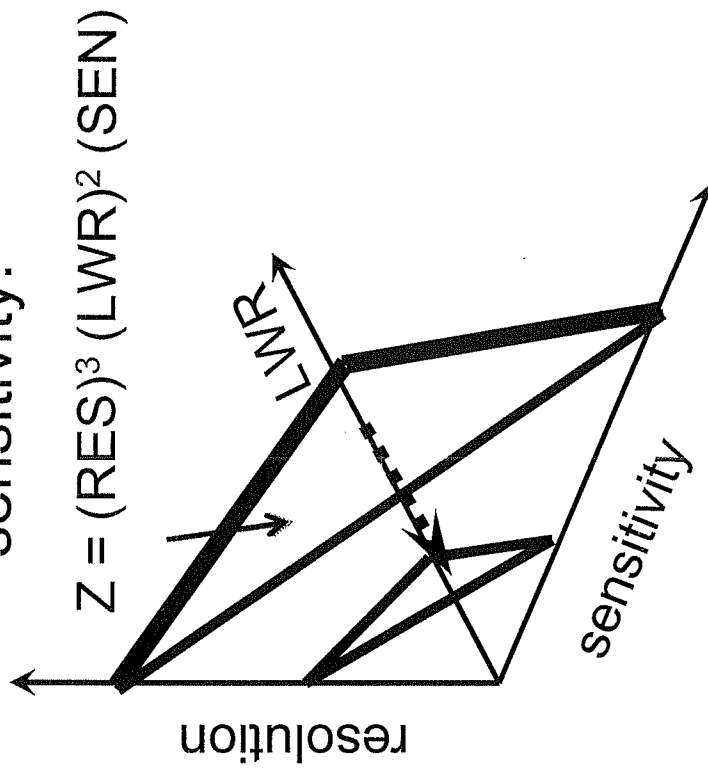
3. The methods described herein.

Motivation

Challenge:

RLS limitations of
conventional chemically
amplified resists

Tradeoff between
resolution, LWR and
sensitivity.



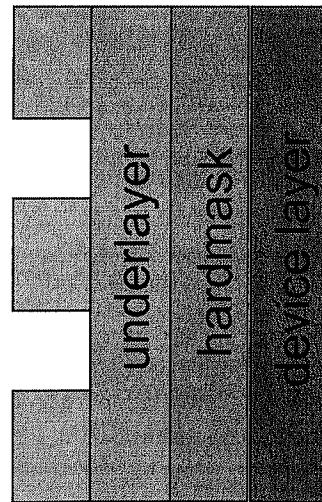
Motivation

Challenge:

Integration cost and complexity due to hardmask and double patterning schemes

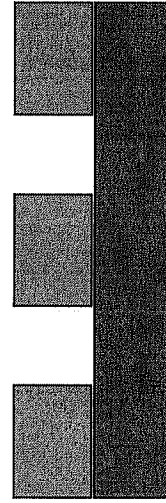
Photopatternable inorganic hardmask:

- high etch selectivity
- directly applicable to double patterning



Conventional Stack

VS.



Photopatternable Hardmask Stack

Objective

High
performance
resist

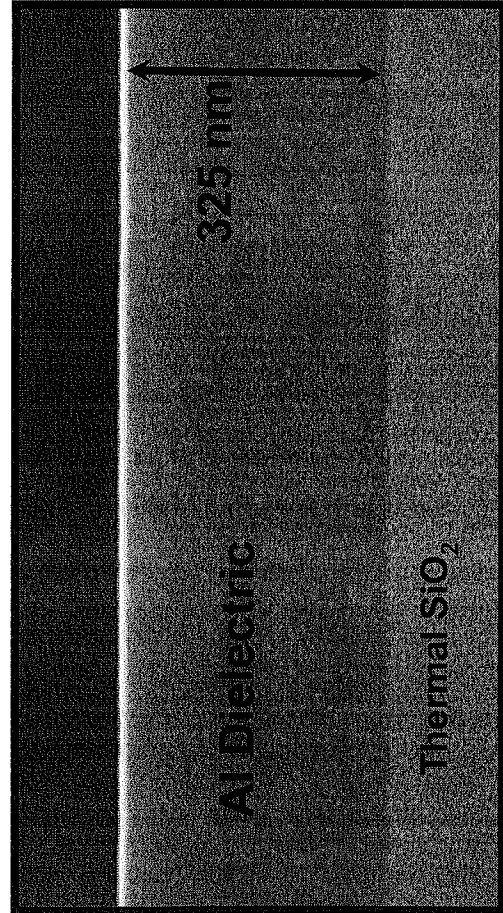
+

Patternable
hardmask

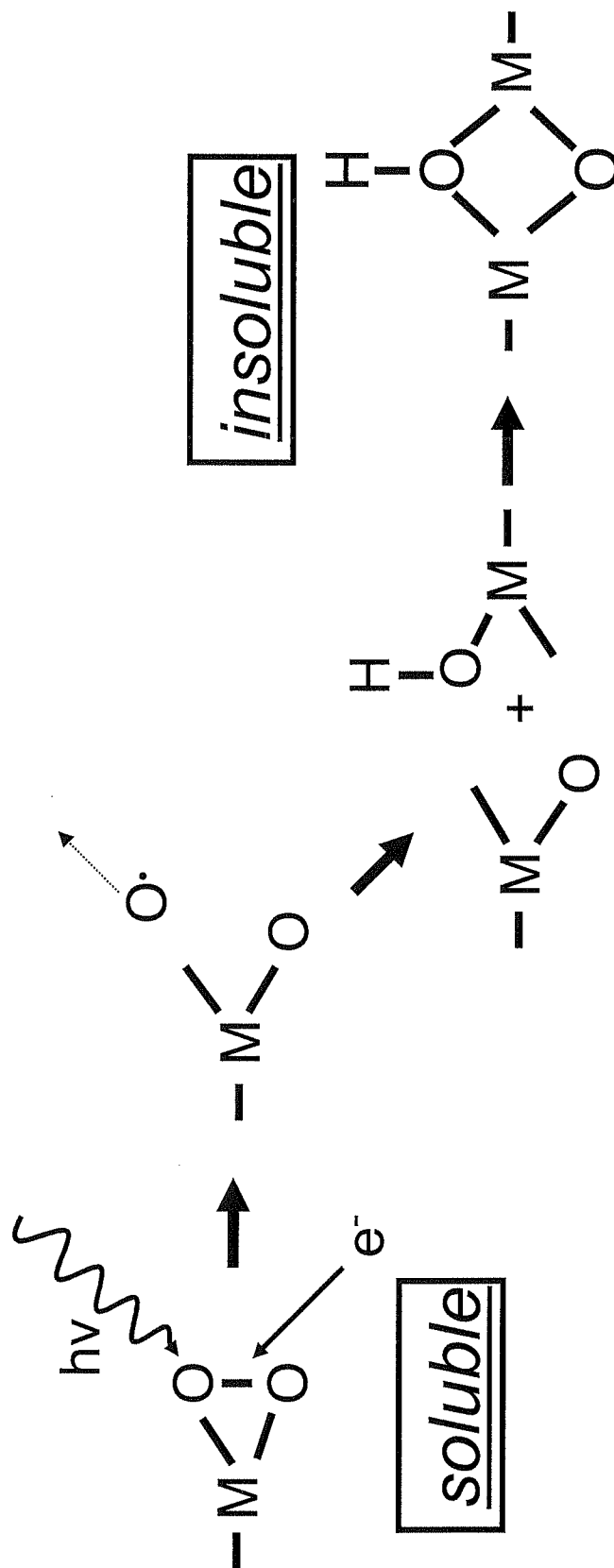
High Quality Inorganic Films From Solution

Vacuum quality metal
oxide thin films
deposited using solution
processing

- Performance: fully dense films and atomically smooth surfaces
- Environmentally benign aqueous solutions
- Highly scaleable formulation process
- Directly patternable

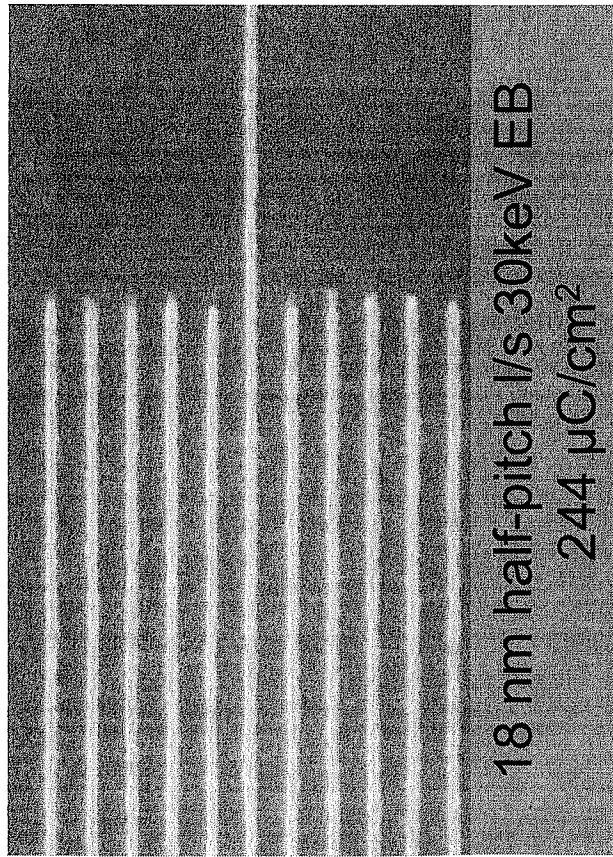
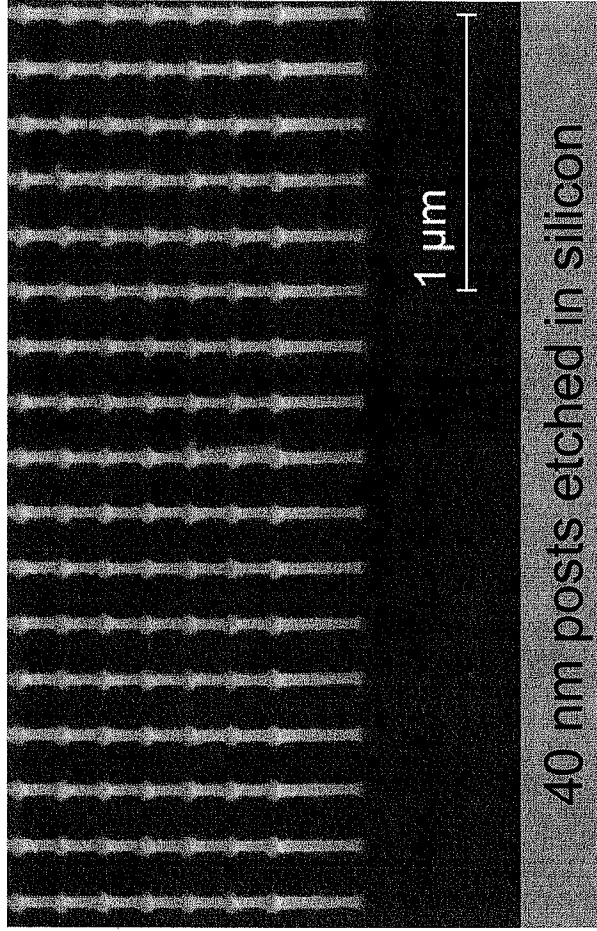


Negative Tone Exposure Mechanism



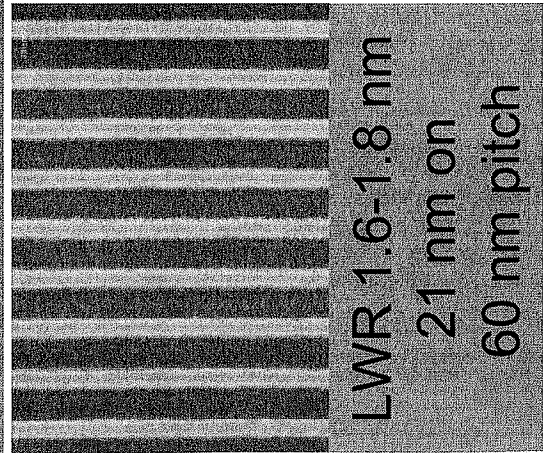
Sensitive to UV, EUV and electron beam exposure!

Patternable Hardmask

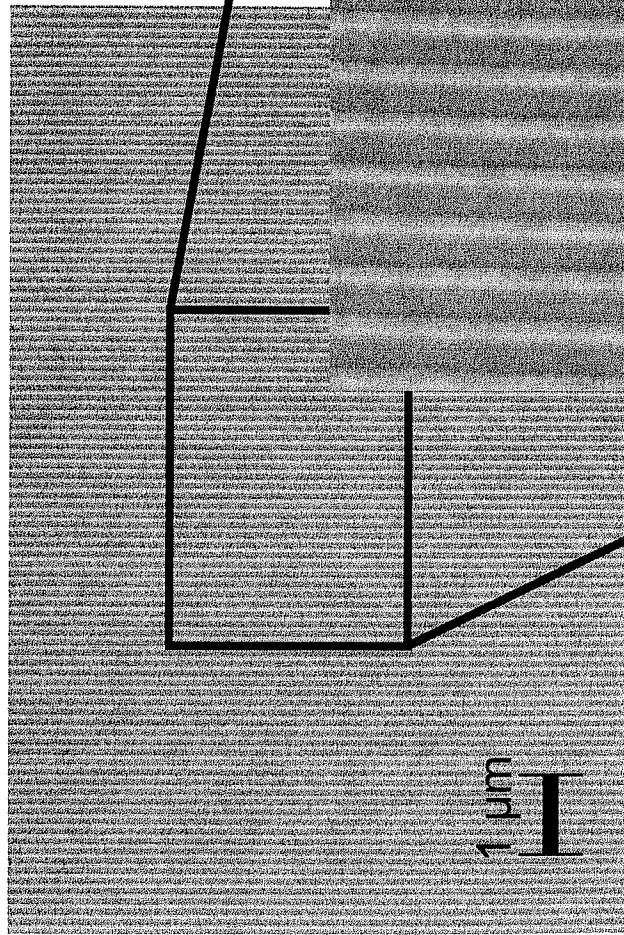


Resist Features:

- high resolution, low LWR
- Fast negative tone, non-CAR platform
- high etch selectivity allows very thin layer₆



Extension to 193 nm Lithography

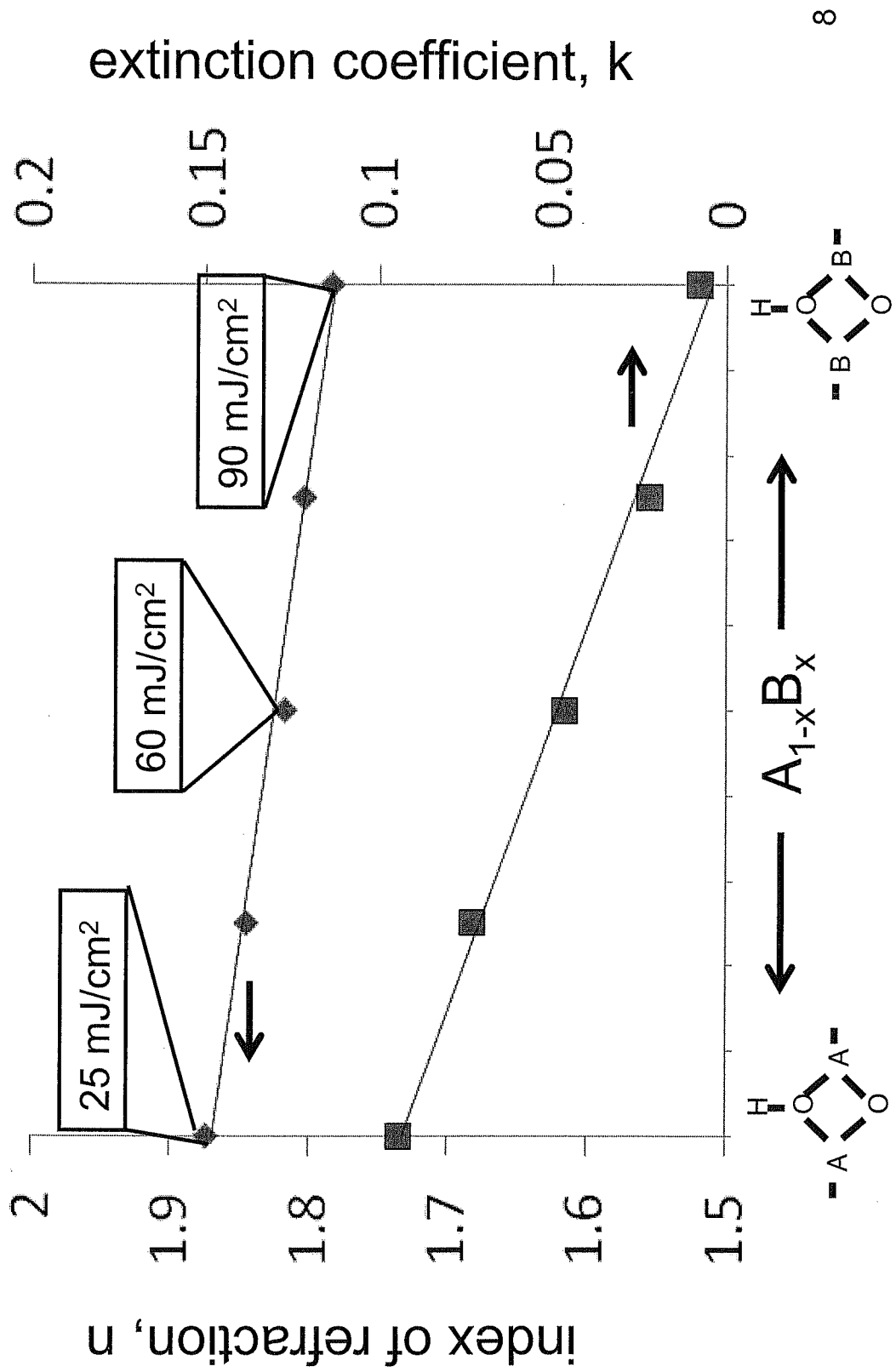


Dose: 20 mJ/cm²
CD 40 nm, 60 nm half-pitch
by dry interference imaging

Compositional variability → tunable optical properties

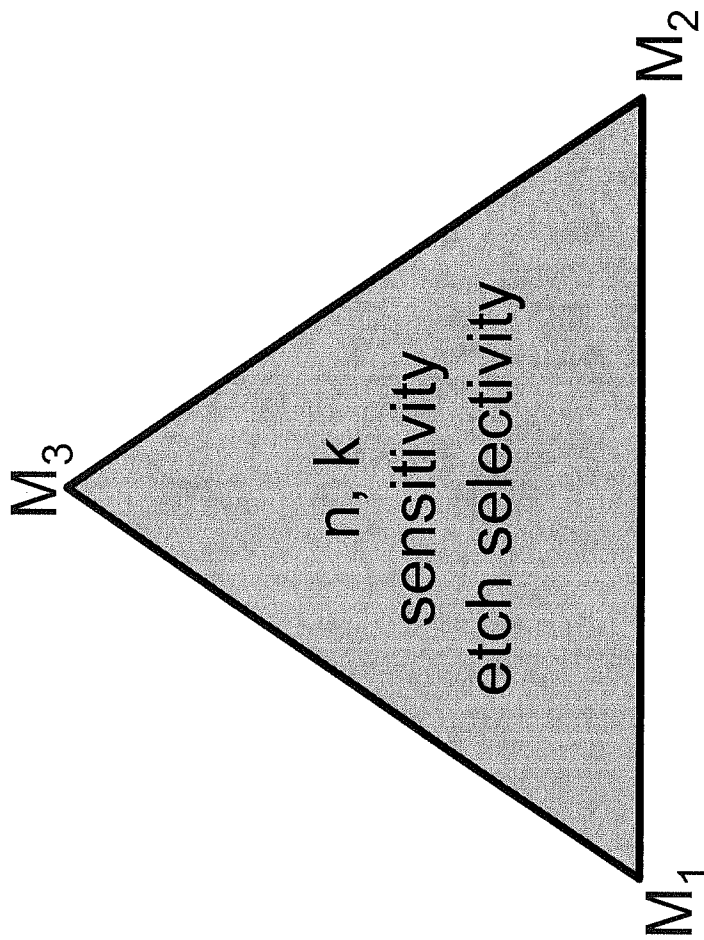
Tunable Composition

Allows design space for application to 193 nm lithography:



Tunable Composition

Inorganic resist platform



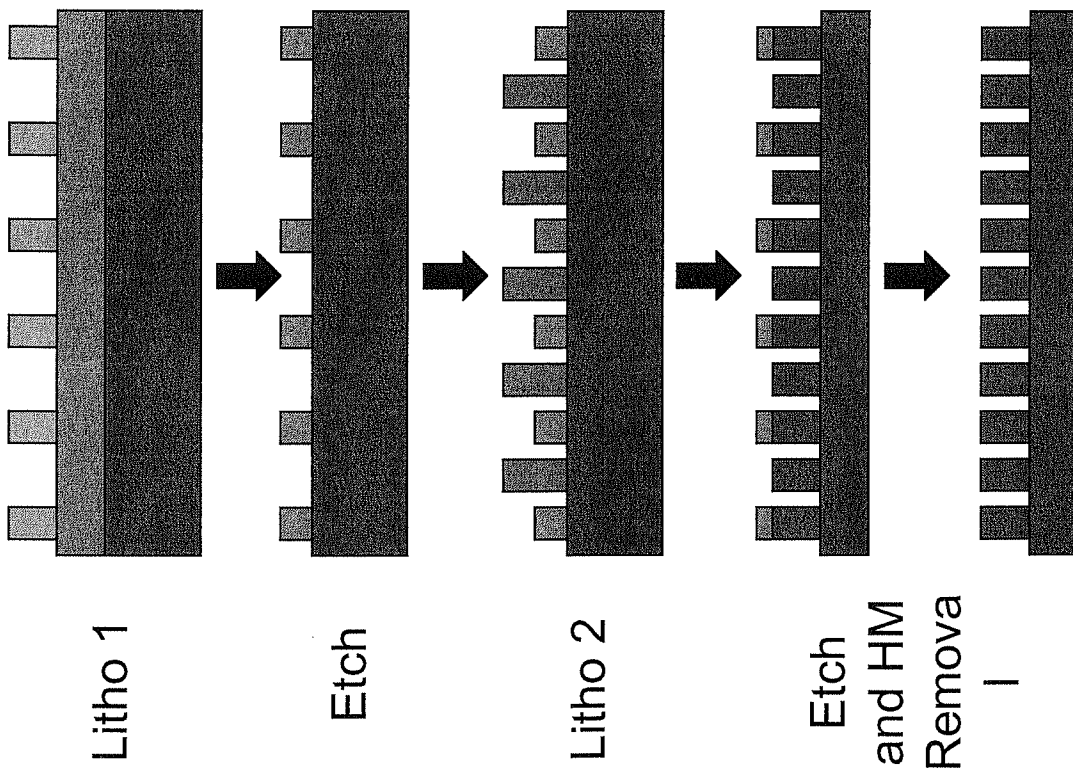
Chemistry is directly amenable to a wide variety of compositions



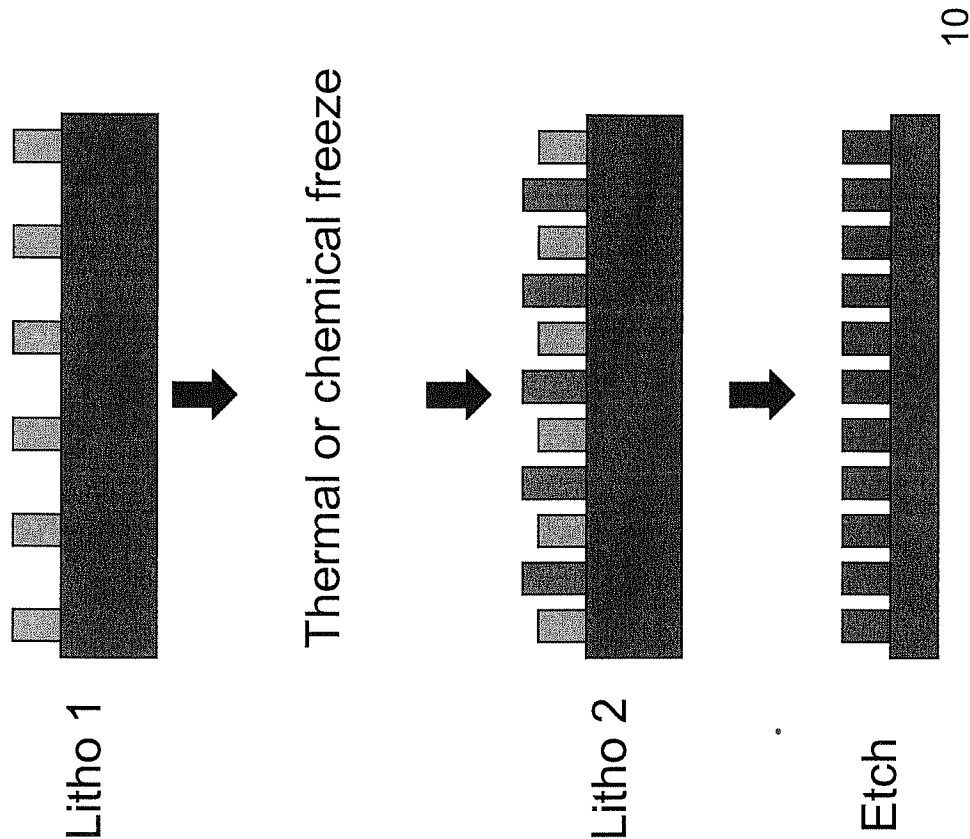
Allows for fine tuning of optical and etch properties!

Double Patterning

Litho-etch Litho-etch (LELE)

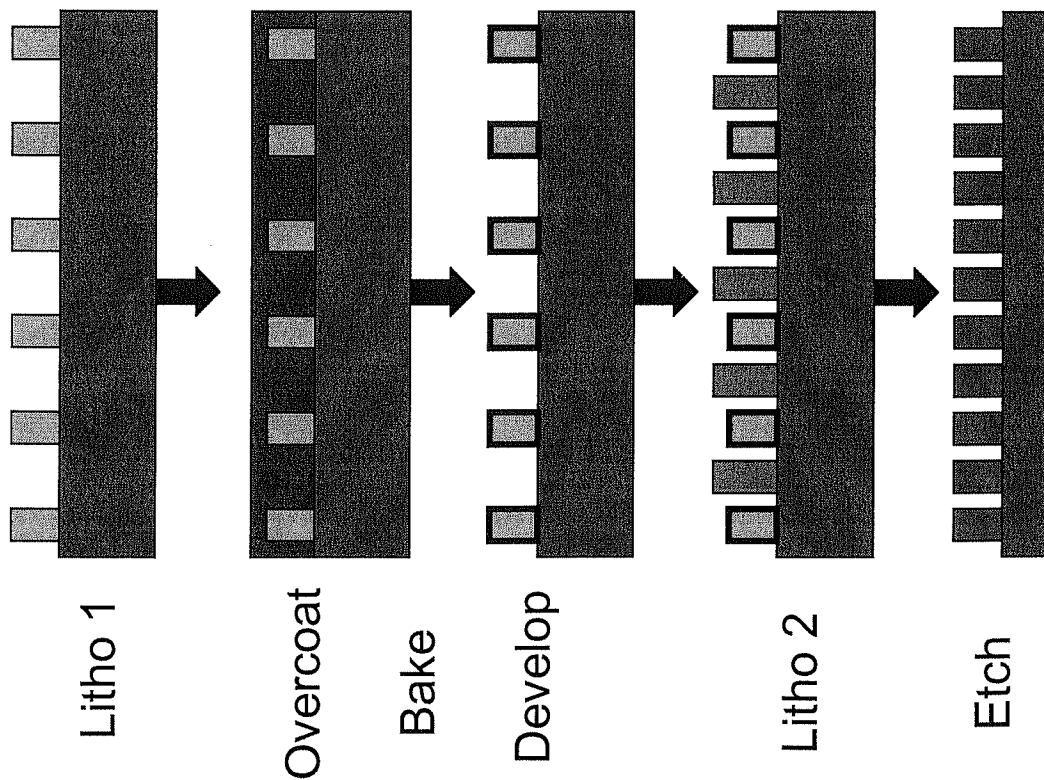


Litho-freeze Litho-etch (LFLE)

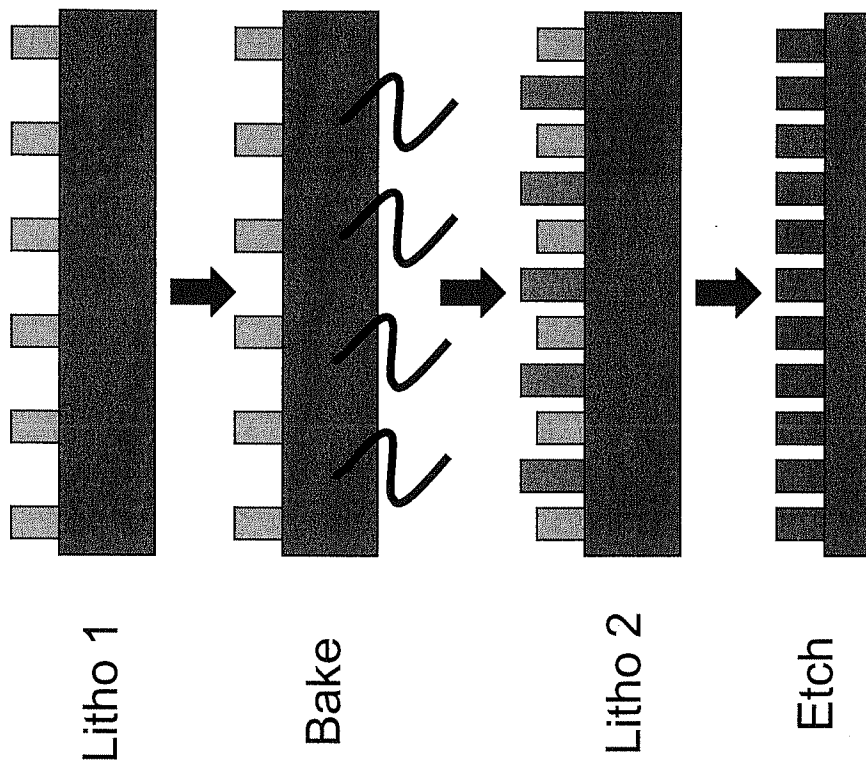


Double Patterning – LFLE

Chemical Freeze Process

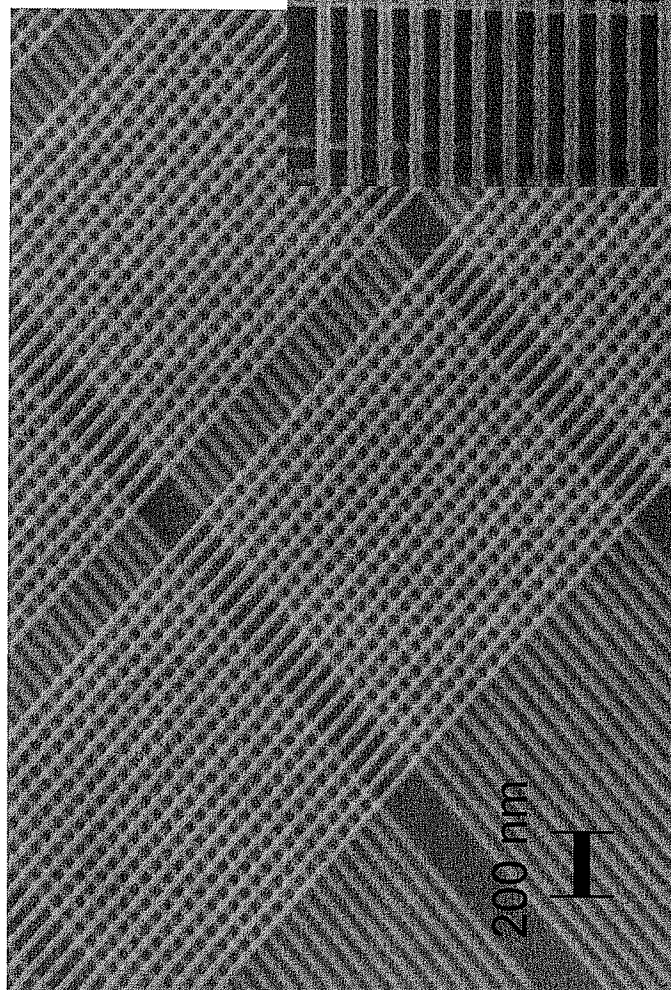


Thermal Freeze Process

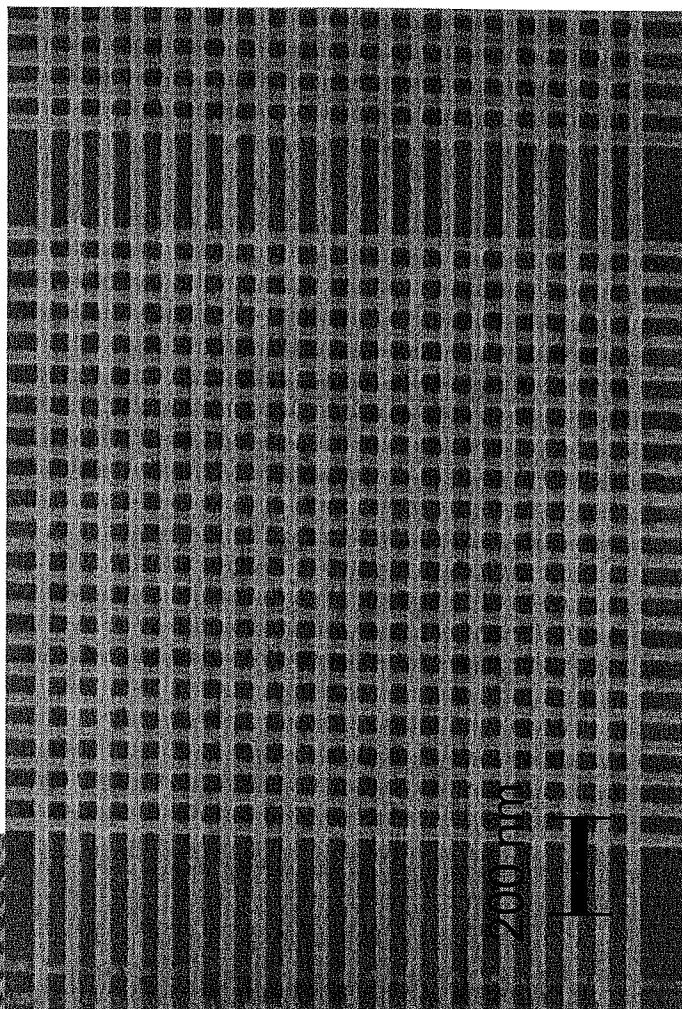


Thermal freezing = more efficient process
Lower Cost

LFLE – Electron Beam



LFLE using 30 kV e- beam
30 nm HP, 500 $\mu\text{C}/\text{cm}^2$



Well resolved and uniform contact holes

12

Conclusion

Inorganic photopatternable hardmask demonstrated:

- high etch selectivity (thin to mitigate pattern collapse)
- high sensitivity
- scalable aqueous solution deposition

Tunable composition:

- multiple wavelengths (e-beam, 193 nm, EUV...)
- range of optical properties

Double patterning / LFLE process demonstrated