

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

W.R. Grace & CO.-CONN

Petitioner

v.

Cochise Technology, LLC

Patent Owner

Patent No. 11,224,864

Original Issue Date: January 18, 2022

Title: CO TO CO₂ COMBUSTION PROMOTER

Inter Partes Review No. Unassigned

DECLARATION OF EVERETT CARPENTER

I, Everett Carpenter, declare as follows:

I. Introduction

1. I have been retained on behalf of G.W. Aru, LLC et al. (“G.W. Aru” or “Patent Owner”) as an independent expert consultant to provide this declaration concerning the technical subject matter relevant to the *inter partes* review (“IPR”) petition of U.S. Patent No. 11,224,864 (“the ‘864 patent”) filed W.R. Grace & Co.-Conn (“Petitioner”).
2. I receive no compensation for this work other than my standard hourly compensation fee for the time I spend on this matter. My compensation is not related in any way to the outcome of this proceeding, and I have no other interest in this proceeding.
3. In this declaration, I offer my expert opinion regarding the technical subject matter of claims 1-22 (“the challenged claims”) of the ‘864 patent and certain alleged prior art. The substance and bases of my opinions appear below.

II. Background and Qualifications

4. My qualifications for forming the opinions set forth in this report are summarized here and explained in more detail in my curriculum vitae, which is attached as Appendix A and incorporated herein. Appendix A also includes a list of my publications.

5. I am currently an active, tenured, full professor in the Department of Chemistry at Virginia Commonwealth University. I am also an Affiliate Professor of Chemical and Life Science Engineering and the Co-Director of the Nanoscience and Nanotechnology Program at Virginia Commonwealth University.
6. I received a Ph.D. degree in Chemistry from the University of New Orleans in 1999. I received a Bachelor's Degree in Chemistry from the Appalachian State University in 1996. I also received a Master's in Business Administration degree from Virginia Commonwealth University in 2019.
7. Starting in 1999, I worked at the Naval Research Laboratory for 5 years. For the first two years, I was a National Research Council Research Fellow in the Materials Physics Branch. For the last three years I was a Staff Scientist in the Materials and Sensors Branch.
8. I joined academia in 2000. My first position was at Catholic University of America where I worked as an adjunct professor for four years. In 2001 I began a concurrent position as a research professor at George Washington University, a role I held until 2008.
9. From 2004 to the present, I have served in multiple roles at Virginia Commonwealth University. From 2004 to 2008 I was an assistant

professor in the Department of Chemistry. From 2008 to 2013 I was an associate professor in the Department of Chemistry. From 2013 to the present I have been a full, tenured professor in the Department of Chemistry. From 2008 to present, I have been an affiliate professor in the Chemical and Life Science Engineering program. From 2009 to 2016 I was the Director of the Nanomaterials Core Characterization Facility. From 2009 to present, I have served as the Co-Director of the Nanoscience and Nanotechnology Program.

10. From 2008, I have also held private roles. From 2008-2009 I was the Chief Executive Officer of Anvil The Materials Forge, Inc. From 2012-2015 I was the Chief Technology Officer of Nanofoundry, LLC. From 2018 to present I have served as the President and Founder of Evertechnologies, LLC. And from 2023 to present, I have served as the Chief Operating Officer and Founder of ThermaGEL Innovations, Inc.
11. I am named as a co-inventor on more than 20 U.S. patents and have co-authored more than 190 publications. My publications have been well recognized by the technical community and I have been recently identified as one of the top 5% of cited Materials Scientists worldwide and in the top 2% of researchers cited worldwide.

12. I have received several awards for my technical contributions. They include: The US Navy's Special Contribution Award (2000-2007); The Alan Berman Research Paper Award (2005); multiple cover features in Dalton Technologies (2006, 2007); National Academy of Inventors at VCU (2018), Senior Member of the National Academy of Inventors at VCU (2020), and Fellow of the International Association of Advanced Materials (2023). I have served on the Scientific Editorial Review Board for Reviews in Nanoscience and Nanotechnology (2009) and the Advisory Board of inChemistry magazine (2009).
13. My general expertise is in the field of materials science, including nanomaterials and catalysts including core shell nanoparticles, as well as production/manufacturing technologies for such materials.
14. I have been working in the field of nanoparticles and nanomaterials for more than 20 years. I have conducted and directed research in this field, have conducted and directed development in this field and have published numerous papers, patents and books on the topic of nanoparticles and their production. My research and development activities have related to the synthesis, design, characterization, and applications of nanomaterials. Specific nanomaterial-related research

topics, on which I have personally worked and published, include the following:

- The design and synthesis of nanoparticles with core-shell structures;
 - The design and development of metal catalysts, including bimetallic catalysts and silica-supported metal catalysts.
15. I have made pioneering contributions to the following technical fields: magnetic nanomaterials, metallic catalysis, core-shell nanoparticles, and alloy production methods.

III. MATERIALS CONSIDERED

16. In forming the opinions set forth in this declaration, I have considered and relied upon my education, knowledge of the relevant field, and my experience. I have also reviewed and considered the '864 patent (WRG-1001) and at least the following additional materials.
- Petition for *Inter Partes* Review of the '864 Patent ("Petition")
 - Declaration of Michael P. Harold, Ph.D. ("Harold Declaration," WRG-1003)
 - U.S. Patent Application 2007/0197379 to Miura ("Miura") (WRG-1004)
 - U.S. Patent No. 6,509,290 to Vaughn, et al. ("Vaughn 290") (WRG-1005)
 - U.S. Patent No. 6,358,881 to Peters, et al. ("Peters") (WRG-1006)

- U.S. Patent Application 2005/0054516 to Vaughn, et al. (“Vaughn 516”) (WRG-1007)
- U.S. Patent No. 7,053,024 to Baker, et al. (“Baker”) (WRG-1008)
- Great Britain Patent No. 2,310,384 to Lin, et al. (“Lin”) (WRG-1009)
- U.S. Patent No. 7,230,035 to Espinoza (“Espinoza”) (WRG-1011)
- Sadeghbeigi, R. (2020). *Fluid catalytic cracking handbook: An expert guide to the practical operation, design, and optimization of FCC units*. Butterworth-Heinemann. (EX2002)
- Demmel, E. Effective Use of CO Promoter in Fluid Catalytic Cracking Operation. Intercat Corporation. (EX2003)
- Tang, Y. L., Mo, X., Allahverdi, Y., & Izakya D. (2012) High Resolution Electron Microscopy Study of Nano Structure in CO Emission Control Additives. Microscopy and Microanalysis, July 29-August 2, 2012, Phoenix, AZ. (EX2004)
- Luo, L., Rainer, D., & Gonzalez, J. A. (2007). Laboratory deactivation testing for the stability of FCC CO combustion promoters. Applied Catalysis B: Environmental, 72(3-4), 212-217. (EX2005)
- Muroi, T. (2012). Role of precious metal catalysts. Noble Metals, 301-334. (EX2006)
- Pinna, F. (1998). Supported metal catalysts preparation. Catalysis Today, 41(1-3), 129-137. (EX2007)
- Mojet, B. L., Miller, J. T., Ramaker, D. E., & Koningsberger, D. C. (1999). A new model describing the metal–support interaction in noble metal catalysts. Journal of catalysis, 186(2), 373-386. (EX2008)

- Argyle, M. D., & Bartholomew, C. H. (2015). Heterogeneous catalyst deactivation and regeneration: a review. *Catalysts*, 5(1), 145-269. (EX2009)
 - Defendant W.R. Grace & Co.-Conn's Answer to Plaintiff's Complaint (EX2010)
 - Tian, G., Xia, D., & Zhan, F. (2004). The oxidation of tetralin and its effect on the stability of fluidized catalytic cracked diesel. *Energy & fuels*, 18(1), 49-53. (EX2017)
 - Ruckenstein, E., & Chu, Y. F. (1979). *Redispersion of platinum crystallites supported on alumina—role of wetting*. *Journal of Catalysis*, 59(1), 109-122. (EX2018)
 - Van Santen, R. A. (2017). Chapter 3: *Physical Chemistry, Elementary Kinetics. Modern heterogeneous catalysis: an introduction*. John Wiley & Sons. (EX2019)
17. This declaration consists of my complete opinions on the topics I was asked to discuss. I reserve the right to supplement my opinions in the event the Petition is instituted. I also reserve the right to express additional opinions should additional and/or presently unknown information about this matter become known by me at a later date.

IV. UNDERSTANDING OF THE LAW

18. Although I took a patent review course, I am not replying on that knowledge. I am opining as a technical expert and I am not offering any legal opinions.

19. In rendering my analysis, I have been informed by counsel regarding various legal standards for determining patentability. I have applied those standards as told to me by counsel in forming my technical opinions expressed in this report.

A. Level of Skill in the Art

20. I understand that the claims and specification of a patent are addressed to and intended to be read by others of skill in the art to which the patent pertains, or to which the patent is most nearly connected, at the time of the filing of the patent application.
21. I understand that a person of ordinary skill in the art (“POSITA”) is a hypothetical person who is presumed to be aware of all of the pertinent art. The person of ordinary skill is not an automaton and may be able to fit together the teachings of multiple prior art references employing ordinary creativity and the common sense that familiar items may have obvious uses beyond their primary purposes.
22. I understand that multiple factors should be used to decide the skill of the POSITA, including: the types of problems encountered in the art, prior art solutions to those problems, the rapidity with which innovations are made, the sophistication of the technology, and the education level of active workers in the field.

B. Claim Construction and Scope

23. I understand that the patent claims describe the invention made by the inventor and describe what the patent owner owns and what the owner may prevent others from using. I understand that an independent claim sets forth all the requirements that must be met to be covered by that claim. I further understand that a dependent claim does not itself recite all of the requirements of the claim but refers to another claim and incorporates all of the requirements of the claim to which it refers.
24. I understand that claim terms are given their plain and ordinary meaning in light of the patent specification as understood by a POSITA at the time of the invention.
25. I understand that the single most useful source of the meaning of a claim term is the claims themselves.
26. I understand that a primary source for guidance in the understanding of claim terms is the intrinsic evidence. Intrinsic evidence consists of the patent specification and prosecution history.
27. I understand that a secondary source for guidance in the understanding of claim terms is extrinsic evidence. Extrinsic evidence includes dictionaries, publications, patents, and textbooks.

C. Anticipation

28. I understand that anticipation analysis is a two-step process. The first step is to determine the meaning and scope of the asserted claims. Each claim must be viewed as a whole, and it is improper to ignore any element of the claim. For a claim to be anticipated under: (1) each and every claim element must be identically disclosed, either explicitly or inherently, in a single prior art reference; (2) the claim elements disclosed in the single prior art reference must be arranged in the same way as in the claim; and (3) the identical invention must be disclosed in the single prior art reference, in as complete detail as set forth in the claim. Where even one element is not disclosed in a reference, the anticipation contention fails. Moreover, to serve as an anticipatory reference, the reference itself must be enabled, i.e., it must provide enough information so that a person of ordinary skill in the art can practice the subject matter of the reference without undue experimentation.
29. I further understand that where a prior art reference fails to explicitly disclose a claim element, the prior art reference inherently discloses the claim element only if the prior art reference must necessarily include the undisclosed claim element. Inherency may not be established by

probabilities or possibilities. The fact that an element may result from a given set of circumstances is not sufficient to prove inherency.

D. Obviousness

30. I understand that under an obviousness analysis, the scope and content of the prior art are to be determined; differences between the prior art and the claims at issue are to be ascertained; and the level of ordinary skill in the pertinent art resolved. A claim is invalid for obviousness if differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a POSITA to which said subject matter pertains. Secondary considerations such as commercial success, long felt but unsolved needs, skepticism in the industry, failure of others, and the like, may be used to give light to the circumstances surrounding the origin of the subject matter sought to be patented.
31. I understand that a prior art reference is proper to use in an obviousness determination if the prior art reference is analogous art to the claimed invention. I understand that a prior art reference is analogous art if at least one of the following two considerations is met. First, a prior art reference is analogous art if it is from the same field of endeavor as the claimed invention, even if the prior art reference addresses a different

problem and/or arrives at a different solution. Second, a prior art reference is analogous art if the prior art reference is reasonably pertinent to the problem faced by the inventor, even if it is not in the same field of endeavor as the claimed invention.

32. I understand that even if all aspects of the claimed invention were individually known in the art, that is not sufficient to establish a prima facie case of obviousness without some objective reason to combine the teachings of the references as arranged in the claim under consideration. On this point, I understand that mere statements to the effect that a combination was obvious is not sufficient in the absence of articulated reasoning with rational underpinning to support the conclusion of obviousness. I understand that a mere combination of references disclosing individual elements itself does not satisfy the burden of proving invalidity by preponderance of the evidence.
33. I understand that it is important to identify a reason that would have prompted a POSITA to combine the elements in the way the claimed new invention does. I further understand that a POSITA must have had a reasonable expectation of success in combining the elements of different references. This is so because inventions in most, if not all, instances rely upon building blocks long since uncovered, and claimed

discoveries almost of necessity will be combinations of what, in some sense, is already known. Because of this, it is not appropriate to use the challenged patent as a roadmap to find its prior art components.

34. I understand benefits that would motivate a combination must be weighed against the detriments caused by the same combination.
35. I understand that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I further understand that when the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be nonobvious.
36. I understand that obviousness inquiries involve looking at interrelated teachings of multiple patents; the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art, all in order to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue. I further understand that to prove obviousness, this analysis must be made explicit.

37. I understand that a change in the prior art is not an obvious design choice if it would exacerbate problems desired to be solved by the patents-in-suit.
38. I understand that a prior art reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the Asserted Patents.
39. I further understand that an inference of nonobviousness is especially strong where the prior art's teachings undermine the very reason being proffered as to why a person of ordinary skill would have combined the known elements.
40. If a proposed modification to a reference would render the prior art invention being modified unsatisfactory for its intended purpose, or if the prior art teaches away from the proposed modification, then there is no suggestion or motivation to make the proposed modification.
41. If a proposed modification or combination of prior art references would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims prima facie obvious.

42. In establishing obviousness, one must avoid the temptation to read into the prior art the teachings of the invention at issue and guard against slipping into the use of hindsight. The prior art itself, and not the applicant's achievement, must establish the obviousness of the combination. That is, a claim cannot serve as a motivation to combine prior art references.

E. Dependent Claims

43. I understand that a dependent claim incorporates each and every limitation of the claim from which it depends. Thus, my understanding is that if a prior art reference fails to anticipate an independent claim, then that prior art reference also necessarily fails to anticipate all dependent claims that depend from the independent claim. Similarly, my understanding is that if a prior art reference or combination of prior art references fails to render obvious an independent claim, then that prior art reference or combination of prior art references also necessarily fails to render obvious all dependent claims that depend from the independent claim.

F. Practicing a Claim

44. I understand that an analysis of whether a product infringes or practices a patent claim requires two steps. The first step is to determine the

proper meaning and scope of the claims, as discussed above. The second step is to compare the claims, properly construed, to the product.

45. I understand that literal infringement of a patent claim requires each limitation recited in the asserted claim to appear in the product.
46. I understand that, if a product does not contain or include all elements of a claim of a patent, then there may still be infringement under the doctrine of equivalents. I understand that a claim requirement is present under the doctrine of equivalents if the difference between the claim requirement and a corresponding aspect of the accused product or method is insubstantial to one of ordinary skill in the art. In making this determination, I understand that I am to consider whether the corresponding aspect or step performs substantially the same function in substantially the same way to achieve substantially the same result as the requirement in the claim. Under the doctrine of equivalents, those of ordinary skill in the art do not have to know of the equivalent when the patent application was filed or when the patent issued. Thus, the inventor need not have foreseen, and the patent need not describe all potential equivalents to the invention covered by the claims. Also, changes in technique or improvements made possible by technology

developed after the patent application is filed may still be equivalent for the purposes of the doctrine of equivalents.

V. LEVEL OF SKILL IN THE ART

47. I understand that the level of ordinary skill in the relevant art at the time of the invention is relevant to inquiries such as the meaning of claim terms, the meaning of disclosures found in the prior art, and the reasons one of ordinary skill in the art may have for combining references.
48. I have reviewed the definition of the level of ordinary skill in the art proposed by Petitioner. The Petition states that a person having ordinary skill in the art (“POSITA”) with respect to the ‘864 patent would have been an advanced degree in a relevant field, such as chemistry, chemically engineering, or material science, with experience working with supported metal catalysts, and had at least 2-3 years of experience with oxidation catalysts and their application, and work experience could compensate for less formal education and vice versa. Petition, 5.
49. For purposes of this declaration, I have been asked to apply this level of skill in the art in my analysis. I note that “oxidation catalyst” is a broader term that includes CO to CO₂ combustion promoters, the latter of which is the focus of the ‘864 patent, as well as numerous other types of catalysts.

50. Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, participated in organizations, and worked closely with many such persons over the course of my career.

VI. BACKGROUND AND STATE OF THE ART PRIOR TO THE FILING OF THE '864 PATENT

51. The '864 patent is directed to CO to CO₂ combustion promoters. WRG-1001, 1:20-26. CO to CO₂ combustion promoters are used in fluid catalytic cracking (FCC) units. FCC technology is used in petroleum refineries to “break” or “crack” the large hydrocarbon molecules of crude oil into smaller molecules into petrochemical products such as gasoline, diesel, and kerosene. EX2002, 1.

52. The cracking is performed in the riser/reactor portion of a FCC unit. *Id.*, 15-16. The large hydrocarbon crude oil is fed into the bottom of the riser, where it contacts fluidizable catalyst particles at high temperatures. *Id.*, 16. The catalysts cause the large hydrocarbon molecules to be broken down (“cracked”) into smaller hydrocarbon molecules (thus the “Fluid Catalytic Cracking” name). *Id.*, 1.

Catalysts are not themselves reactants and are not consumed during the first cracking reaction they catalyze. *See Id.*, 109. Rather, the catalysts are able to catalyze multiple instances of cracking. *Id.*

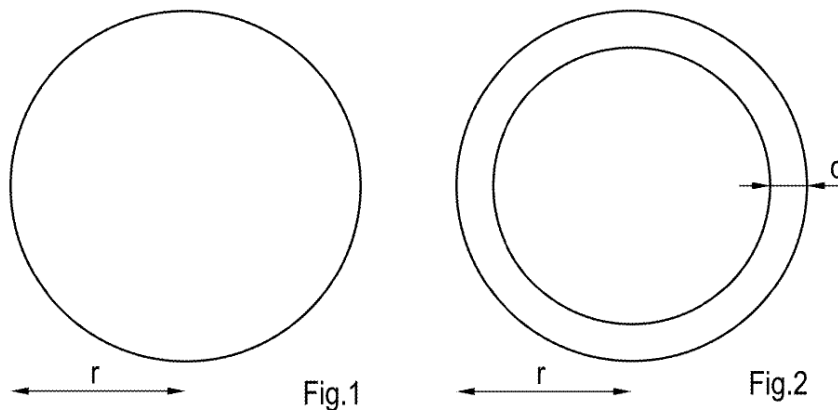
53. Cracking involves a number of reactions and reaction products. *Id.*, 14. For example, cracking also produces solid carbon products collectively referred to coke. *Id.*, 17. The coke settles in and on the catalyst particles. *Id.* Eventually, the buildup of coke in and on the catalyst particles interferes with the catalyst's ability to crack the hydrocarbons in the reactor. *Id.* This is sometimes referred to as "poisoning" the catalyst.
54. To remove the coke from the catalyst particles and permit continued reuse of the catalyst particles, the catalyst material is moved from the riser/reactor into a regenerator portion of the FCC unit. *Id.*, 14, 23. In the regenerator, the coked catalyst particles are exposed to air, often enriched with additional oxygen, and considerably hotter temperatures than those found in the riser/reactor (e.g., around 700 °C as compared to around 535 °C), which are able to burn the coke, thereby removing it from the catalyst particles. *Id.*, 23; WRG-1001, 3:6-10. The burning of the coke is very exothermic (it produces more heat) and produces carbon monoxide. EX2002, 23.
55. Once the coke is combusted, the hot regenerated catalyst is returned to the riser/reactor section by flowing through the regenerated catalyst

standpipe(s). *Id.*, 16. The flow rate of regenerated catalyst is controlled to meet the reaction temperature target. *Id.*

56. Meanwhile, the burning of the coke in the regenerator is producing carbon monoxide. *Id.*, 23-24. Carbon monoxide production is undesirable. In the first instance, the release of CO is bad for the environment. Secondly, the carbon monoxide is susceptible to combustion to produce carbon dioxide. *Id.* But if this occurs in an uncontrolled manner in the FCC unit it can cause undesired spikes in temperature and damage FCC equipment. WRG-1001, 1:46-52.
57. It is therefore important to ensure that a high degree of the carbon monoxide, preferably all of the CO, is combusted to form carbon dioxide (CO to CO₂ combustion). If properly controlled, the CO to CO₂ combustion will occur primarily in the “dense phase” of the fluid bed regenerator. EX2002, 17. The “dense phase” is a portion of the regenerator that has a high concentration of catalyst particles. *Id.*, 24. Accomplishing the CO to CO₂ combustion in the dense phase permits the catalyst particles to absorb the heat of the combustion. *Id.*, 23. Whereas, the carbon monoxide leaves the dense phase and moves into the “dilute phase” of the regenerator, or downstream aspects of the FCC unit and combusts in those areas, the CO to CO₂ combustion is

referred to as “afterburning” and as mentioned above can be damaging to both safety and efficiency of the FCC operations. WRG-1001, 1:46-52.

58. Accordingly, ways to efficiently and effectively promote CO to CO₂ combustion in the dense phase of the regenerator have long been of significant interest to the FCC industry. In the 1970s, it was found that noble metals, particularly platinum, would promote CO to CO₂ combustion. EX2002, 3; EX2003, 1. These noble metals, and the formulations of them that were used in FCC regenerators are collectively referred to as “CO to CO₂ combustion promoters.” EX2002, 117.
59. Initially, platinum was added directly to the regenerators. This turned out to be inefficient and soon the platinum was impregnated throughout supports. EX2003, 1. These supports (particles) were typically alumina, silica, or mixtures thereof. *Id.* The impression one might get from looking at patents, including Figures 1 and 2 of the ‘864 patent is that each particle is solid.



However, the POSITA knows that these figures are just schematics and do not show the pores that go throughout the particle. By analogy, the particle is more like Swiss cheese than Parmigiano Reggiano.

60. There were a number of reasons for using porous particles. The most significant was to maximize the total surface area for the reactants to interact with a GVIII noble metal such as platinum. EX2003, 1. By including pores the reactants had access to internal surface area as well as external surface area. *Id.* In these porous particles, the internal surface area of all the pore walls is about 1,000 times the external or outer surface of the particle itself. This also permitted what was believed to be the most effective use of the platinum. *Id.*
61. However, platinum and the other GVIII noble metals do not readily attach to particles of alumina, silica, or mixtures thereof.

62. In any chemical manufacture process that uses at least one liquid, a property of the materials known as wettability influences the resulting structure. Wettability refers to the attraction of a liquid phase to a solid surface. If a combination of a liquid and solid has a higher degree of wettability, the liquid will soak into the solid. If a combination of a liquid and solid has a lower degree of wettability, the liquid will tend to form beads or droplets on the solid surface and not to soak into the solid surface.
63. This is easily illustrated by the wettability of different clothing fabrics. A cotton t-shirt and water have a high degree of wettability. If, while wearing a cotton t-shirt, you are caught in a rainstorm, the wet will quickly soak the cotton t-shirt. The water and cotton fabric have a high degree of attraction and the water will soak through the t-shirt.
64. However, a vinyl raincoat and water have a very low degree of wettability. Therefore, if you are wearing a raincoat when the rainstorm catches you, the water will form beads and stay on the surface of the raincoat.
65. Turning back to the materials relevant to the instant claims, silica and/or alumina particles and aqueous solutions of noble metals have a low degree of wettability. See, EX2018. Therefore, when such particles are

contacted with a solution of noble metals, the solution will form beads across the surfaces of the particles – both the outer surface and any interior surfaces such as the walls of pores. When the particles are dried, the solution evaporates leaving a residue of noble metal on all the surfaces, internal and external throughout the particle. The particles become ***impregnated*** with the solution of noble metals. This inherent property is at work in “wet impregnation” or “incipient wetness” manufacturing processes. In any such process, the solution of noble metals will be found on any silica and/or alumina surface it encounters and will impregnate porous particles as it forms beads along the pore walls.

66. When the impregnated particles are then dried, the noble metals are left behind when the solvent evaporates. This part of the process is easily visualized by the layperson in the spots left behind on a glass bowl or even raincoats. Minerals and other compounds dissolved in the dishwater or rainwater are spread across the available surfaces while dissolved in the water. When the solid item dries and the water evaporates, the minerals or other compounds are left behind. In the case of a glass bowl, the spots will be visible on the interior and the exterior surfaces of the bowl.

67. In a porous particle, the spots will be similarly left behind on all available surfaces, including all of the pore walls that extend into and through the porous particle. In the case of porous silica and/or alumina particles subjected to wet impregnation or incipient wetness processes with an aqueous solution of noble metals, the noble metals will be left behind on the various surfaces of the particles. Depending on the precise concentrations and chemistry, the noble metals may clump together in smaller or larger groups of atoms. So the noble metals may form small “clumps” or “droplets,” on surfaces of a porous particle but these will be spread uniformly throughout the porous particle on all the available surfaces and the concentration of the noble metals will be uniform along any cross-section of the porous particle.
68. As explained by one of the leading manufacturers of FCC catalysts and additives, INTERCAT, Inc., owned by Johnson Matthey:
- It was once believed that the platinum needed to be impregnated directly on the surface of the entire FCC catalyst inventory. However, Upson² clearly demonstrated in commercial trials that the platinum was just as effective when added as a concentrate in the form of platinum dispersed on a solid support. This method of adding the platinum catalyst to an

FCC unit is now universally accepted by the industry. EX2003,
1.

69. This article further explains:

The “ideal” CO promoter is one with the following physical and chemical properties. The support must be a highly attrition-resistant material, have a high particle density, and have a minimum amount of particles smaller than 40 microns. These properties are, of course, necessary to minimize first cycle losses of the promoter and give high retention in the unity inventory. The support should also have a moderately high surface area and a high pore volume to provide ready access of the reactants to the platinum catalyst. *The platinum must be uniformly dispersed on the support for maximum effectiveness*; this is accomplished by INTERCAT’s proprietary manufacturing techniques. *Id.* (emphasis added).

70. Petitioner has a similar view about the prevalence of uniform distribution of GVIII noble metal. It is my understanding that the Petitioner in this matter has stated that “Grace admits that in conventional CO to CO₂ combustion promoters the intended design is

for noble metal to be distributed homogenously through the support particles.” EX2011, ¶ 40.

71. Consequently, just before the filing of the priority application leading to the ‘864 patent, April 24, 2018, the field as a whole believed that it was necessary to maximize the exposed surface area of the noble metals.
72. It is important to note that “surface” is not necessarily analogous with “outer boundary.” Because each pore of a porous particle has a significant surface area forming the wall of the pore, a porous particle has an exceptionally large total surface area as compared to a solid particle. The total surface of a porous particle extends into and throughout the particle and is not found only on the outer surface of the particle. In such a porous particle, the pore wall surfaces can have about 1,000 times the area as the exterior or outside surface of the particle. Such particles manufactured by the standard method of impregnating the particle with a solution containing the noble metal, a salt, or a complex thereof and drying as discussed above were believed to achieve a high level of noble metal surface area homogeneously throughout the particle. Therefore, it was believed that the CO to CO₂ combustion promoter particles having noble

metals adsorbed throughout the pores would achieve maximum efficiency in converting CO to CO₂. EX2003, 1.

73. It is also generally accepted in the art that a major source of deactivation of CO to CO₂ combustion promoters in FCC operations is a process known as sintering. Sintering is caused by the high temperatures and moisture levels the CO to CO₂ combustion promoters encounter in the FCC units, and it causes small clusters of noble metal atoms to grow into much larger clusters of noble metal material. A study from Interact-Johnson Matthey analyzed traditional CO to CO₂ combustion promoters before and after 4 weeks in an FCC unit. The study found that prior to use, the platinum in the analyzed CO to CO₂ combustion promoters was present as “small clusters” or “monoatomic” platinum. But after 4 weeks of use “the Pt nano particles have an average size of 13 nm which indicates a significant sintering.” EX2004, ¶ 2. The study then concluded “increased Pt particle size means decreased metal surface area and effective sites of Pt, which certainly will cause the degradation” of the CO to CO₂ combustion promoters. *Id.*

A. Overview of the '864 Patent

74. The '864 patent teaches that a disadvantage of the CO to CO₂ combustion promoters is the relatively large amounts of noble metals needed to achieve the desired CO combustion in the FCC process WRG-1001, 2:14-20.
75. The conventional approach to addressing the high cost of noble metal was to just produce CO to CO₂ combustion promoters with varying total amounts of platinum or palladium in the product. Typically, manufacturers of CO to CO₂ promoters were selling 3 types of such combustion promoters – one with high levels of noble metal, one with medium levels of noble metal, and a final one with low levels of noble metals.
76. In stark contrast to this approach, the '864 patent teaches that instead of a uniform distribution you have an outer region, described as an eggshell, where that outer region contains the majority of the noble metal. WRG-1001, 2:24-63. As explained in more detail:
- The eggshell or outer shell suitably has a depth from the outer surface toward the interior of the particle of between 1 to 10 microns. In this eggshell, which includes the outer surface of particle, suitably more than 60 wt%, suitably more than 80 wt%

and even more suitably more than 90 wt% of the noble metal is present of the total of noble metal present in the particle. *Id.*, 4:25-31.

77. The POSITA would be aware that the art was aware of four ways of describing the location of metals on a porous support – 1) egg yolk – where the metal is concentration in the center, 2) egg white – where the metal is concentrated in the region between the center region and the outer region, 3) eggshell – where the metal is concentrated in the outer region, and 4) uniform distribution – where the metal is distributed uniformly throughout the particle. WRG-1009, 16.
78. As discussed above, it is difficult to direct the distribution of the noble metal to be in a specific region because of the wettability. The ‘864 patent accomplishes this by first introducing a medium into the pores to essentially block the pores from the solution of the GVIII metal and salt. The examples of the ‘864 patent show the use of water to fill 90% of the pore volume. Then, the examples use the customary impregnation procedure – but instead of a uniform distribution the majority of the noble metal was in the outer region – forming an eggshell of noble metal.

79. Consequently, the CO to CO₂ combustion promoters of the ‘864 patent depart from this conventional wisdom about distribution of the noble metals. Rather than maximizing the surface area of the noble metals by uniformly dispersing the noble metals throughout the entire promoter particle, the CO to CO₂ combustion promoters of the ‘864 patent have GVIII metals present in the particles in an eggshell distribution, such that a higher concentration of GVIII metal is present in the outer region of the particle as compared to the concentration of GVIII metal in the center of the particle. WRG-1001, 2:19-33.
80. Under the conventional wisdom of the art, such noble metal eggshell CO to CO₂ combustion promoters would be expected to provide less CO to CO₂ combustion for the same amount of CO to CO₂ combustion promoter because of the loss of total noble metal surface area for reaction. Previous studies had examined different amounts of noble metals in CO to CO₂ combustion promoter and found that “as expected CO reduction capability increased with the Pt level” of the CO to CO₂ combustion promoter. EX2005, Section 3.1. But surprisingly, the CO to CO₂ combustion promoters of the ‘864 patent provide as much, if not more, CO to CO₂ combustion than the same amount of a prior art CO to CO₂ combustion with uniform noble metal

distribution, even though they use less noble metal. WRG-1001, 2:64-3:2. This means that a CO to CO₂ combustion promoter of the '864 patent can use less total noble metal and achieve the same degree of CO to CO₂ combustion. *Id.* The CO to CO₂ combustion promoters therefore provide striking savings in materials use, which translates into significant cost savings.

81. In addition to their high efficiency and cost savings, the CO to CO₂ combustion promoters of the '864 patent also display the surprising ability to produce less NO_x formation for the same amount of CO to CO₂ combustion, as compared to prior art CO to CO₂ combustion promoters. WRG-1001, 3:14-37. NO_x formation results in damaging emissions from FCC units and reducing NO_x formation is a significant safety and environmental goal.
82. I also note that traditional methods of manufacturing CO to CO₂ combustion promoters (and other catalysts or promoters) necessarily result in uniform distribution of materials in porous particles, due to wettability, as discussed in detail above.

B. Dr. Harold Misrepresents the State of the Art of CO to CO₂ Combustion Promoters

83. Dr. Harold misrepresents the general state of the art of CO to CO₂ combustion promoters and he misrepresents the art at the time of the '864 patent.
84. CO to CO₂ combustion promoters are not “generally referred to as oxidation catalysts.” WRG-1003, ¶ 20. The term “oxidation catalyst” is much more general, referring to a wide range of catalysts of varying sizes, chemical compositions, that individually have a wide range of uses and hence are each used in particular temperatures and pressures.
85. In other words, while all CO to CO₂ combustion promoters catalyze an oxidation reaction and thus fall within the class of oxidation catalysts, not all oxidation catalysts, not even the majority, are CO to CO₂ combustion promoters.
86. “CO to CO₂ combustion promoters,” the subject of the '864 patent, refers to particles that promote the combustion of carbon monoxide (CO) in fluid catalytic cracking (FCC) processes.
87. CO to CO₂ promoters have a very specific application. When referring to a CO to CO₂ combustion promoter, a POSITA would understand that the process in which the particles are being used is an FCC process.

88. An “oxidation catalyst,” however, is any type of catalyst that performs any oxidation reaction. There are hundreds if not thousands of oxidation reactions that make use of catalysts that have nothing to do with the petroleum industry, let alone FCC processes. For example, palladium is used to catalyze the formation of acetic acid from ethylene gas, in the production of hydrogen peroxide, phenol, aniline, 1,5-butanediol(1,5-GB), MIBK, oxalic acid, de-methyl carbonate, gamma-butyrolactone, methylmethacrylate, toluene di-isocyanate, and cyclohexane. EX2006, 305-313.
89. I also note that Dr. Harold alleges that “[a]s of 2018, there were two commonly-known structures of catalytic particles – uniform distribution and eggshell distribution.” WRG-1003, ¶23. This is not true.
90. First, as discussed above, there were, by April 24, 2018, at least four structures of spheroidal supported catalytic particles known. These structures are, for example, described in the Lin reference. WRG-1009, 16.
91. It also appears that Dr. Harold attempts to conflate the existence of eggshell distribution catalysts with these distributions being used in combustion promoters. Dr. Harold alleges eggshell distributions were

desirable for the reasons laid out in the '864 patent. However, at the time of the '864 patent, it was not appreciated that noble metal distributed in an eggshell would be a suitable distribution of a CO to CO₂ combustion promoter. Dr. Harold significantly ignores the accepted wisdom of using a uniform distribution.

92. More specifically, at the time of invention, it was believed that noble metal supported catalysts needed to have noble metal highly dispersed throughout the entirety of the support to achieve optimal performance. EX2007, 129 (“To this purpose, the active phase - in our case the metal - must be in a sufficiently high dispersed form which results in a large specific surface area and consequently in a maximum specific activity.”) It was believed at the time of invention that with supported precious metal catalysts in particular, “the active metal phase should be highly dispersed in order to obtain high activity.” *Id.*, 131.
93. As discussed above, it was generally accepted in the art that the activity of a noble metal in catalyzing CO to CO₂ combustion was directly linked to the surface area of the noble metal because the noble metal reacted with CO only where a noble metal surface was present. EX2003, 1. Therefore, it was universally sought to disperse the noble

metal across all surfaces of the support particle (e.g., to achieve a uniform concentration throughout a porous particle). *Id.*

94. Although Miura does not describe a CO to CO₂ combustion promoter, this concept is reiterated in Miura. Miura teaches that for their three-way catalysts, increasing the amount of noble metal on the particle and increasing the surface area of noble metal contacted with the exhaust gas can improve performance. WRG-1004, [0071].

C. Catalysts are Reaction and Process-Specific

95. A POSITA would not have been motivated to use catalysts described for purposes other than CO to CO₂ combustion promotion in FCC operations as CO to CO₂ combustion promoters.
96. Catalysts are highly unique to the processes they are intended to catalyze. Referring just to noble metal supported catalysts, a multitude of parameters impact catalytic activity, including the catalyst particle size, the composition of the support material, the porosity of the support material, the type of noble metal being supported, the size of the noble metal particles on the support, and the amount of noble metal on the support, the distribution of the noble metal on the support, the reactants and the reaction to be catalyzed, the physical form of the reaction vessel, the temperature the reaction will occur at, and the pressure the

reaction will occur at. Each of these parameters can impact the performance of the catalyst and unless all parameters are the same, a POSITA would not expect that a catalyst from a first system could be successfully used in a second system.

97. As an example, it well known in the art that different systems that carry out the same type of chemical reaction on the same starting material require different catalyst compositions. EX2006; EX2008, 373. This is illustrated by Pd/Al₂O₃ catalysts used in the hydropurification of ethylene and propylene. EX2006, 306. Palladium supported catalysts selectively hydrogenate acetylene to either ethylene or propylene. *Id.* The reaction catalyzed, that is, the product obtained from the acetylene, depends on the amount of palladium loaded onto the alumina support. *Id.*, 307. If the catalyst is 0.01%-0.02%Pd/Al₂O₃, the acetylene will be selectively hydrogenated to ethylene. *Id.*, 307. If the catalyst is 0.1%-0.2%Pd/Al₂O₃, the acetylene will be selectively hydrogenated to propylene. *Id.* Thus, varying even the *amount* of metal loaded on the support can completely alter the outcome of the reaction.
98. Further, different catalysts are needed to catalyze the identical reactions depending on the types of reactors that are used to carry out the process. Processes that use fixed bed reactors require different sized catalyst

particles than processes that use fluid bed reactors. In fluid bed reactors, relatively smaller-sized catalyst particles are used because the catalyst is fluidized with reactants. WRG-1011, 7:51-67.

99. In fixed bed reactors, reactants move through the reactor and contact catalyst which is fixed in place. *Id.* Larger-sized catalyst particles or compositions are used to prevent the catalyst from fluidizing. *Id.* The catalyst size can impact the flow and pressure in the fixed bed. So once again, catalysts influence reaction conditions and catalyst design is specific to the reaction conditions.
100. Further, a catalyst capable of catalyzing a reaction in a system having reactants under certain temperatures and pressures may not be suitable for catalyzing the same reaction under different temperatures and pressures. The materials from which a catalyst is made or the way noble metal is distributed in the catalyst may work for low temperature reaction systems but the same catalyst may degrade and be unusable in high temperature systems. “Since most sintering processes are irreversible or are reversed only with great difficulty, it is important to choose reaction conditions and catalyst properties that avoid such problems.” EX2009, 216.

101. A multitude of other factors may also render a catalyst unsuitable for use in a given system. For example, a catalyst may be suitable for a reaction in one system, but the catalyst may not be suitable for the same type of reaction in a second system because reactants in the second system may poison the catalyst and deactivate it. *Id.*, 147. Similarly, other chemicals in a system may interact with the catalyst in the second system and foul it, deactivating it in that way. *Id.*
102. A further concern, particularly with catalysts provided in or on porous particles, are diffusion limits. Reactant chemicals must be able to reach a catalyst and therefore the diffusion limit – how far the reactants can move into the pores will affect catalyst design. But diffusion limits are highly dependent on temperature. EX2019, Section 3.5. So a catalyst suitable for a high temperature use can be ineffective for a lower temperature use and vice versa.
103. For these reasons, a POSITA would not assume that a catalyst showing certain chemical activity for a given reaction under very specific reaction conditions would have catalytic activity for a different reaction under different reaction conditions unless the catalyst had been evaluated for that additional system.

104. Stated another way, the composition, size, and shape of a catalyst is dependent on not only what reaction it is carrying out, but the conditions under which that reaction is to be carried out. Catalyst design is exquisitely specific to the application and developments in catalyst design are never ***assumed*** to be universally applicable.

VII. OPINIONS

105. My opinions on the specific prior art references, their disclosures, what a POSITA would have found obvious at the time of invention, and the bases for these opinions are presented below.

106. In particular, Miura fails to make the '864 claims obvious for at least the following reasons, each of which is discussed in detail below:

- a. Miura does not teach a noble metal eggshell. The only eggshell Miura describes is a ceria eggshell. Miura's manufacturing methods would have necessarily created uniform distribution of noble metals in their metal oxide support.
- b. Miura's catalysts are not CO to CO₂ promoters and a POSITA would not have looked to Miura's auto catalysts in order to develop or modify a CO to CO₂ combustion promoter.

A. Miura Does Not Teach an Eggshell Catalyst

107. Miura does not teach using an eggshell distribution of a noble metal.

Rather, as explained below, when discussing noble metals, Miura teaches a uniform distribution and in all examples uses the same amount of the precious metal.

108. Specifically, Miura teaches:

...the present invention provides a process for producing a metal oxide particle comprising multiple species of metal oxides and capable of satisfactorily exerting the properties of respective metal oxides. WRG-1004, [0011].

109. Miura goes on to teach:

Further the present invention provides an exhaust gas purifying catalyst, which can exert a heat resistance improving effect due to ZrO_2 , and an effect of preventing sintering of a noble metal supported on CeO_2 at the same time, by supporting the noble metal on a particulate support comprising a core relatively rich in ZrO_2 and a surface layer relative rich in CeO_2 . *Id.*, [0012].

110. To the extent that Miura teaches a different outer region, it is one relatively rich in ceria (CeO_2). This is confirmed by the Example section of Miura where all the examples of the invention taught have

such a ceria surface region as opposed to the comparative examples.
See also Table 1 of WRG-1004.

111. It is further explained that this metal oxide particle has high heat resistance and the ceria can prevent sintering. *Id.*, [0005].
112. Both Dr. Harold and Petitioner point to Figure 2. Dr. Harold states that Figure 2 depicts a zirconia core, a ceria-rich surface area, and a noble metal, platinum, forming the particulate support of the surface. WRG-1003, ¶77.
113. This ignores the fact that Figure 2 is a schematic that does not show the pores going throughout the metal oxide particle. This also ignores that the specification and examples teach adding platinum by the traditional approach of impregnating the metal oxide particle with a solution containing a salt and/or a complex salt of noble metal and drying and then firing it. WRG-1004, [0101], [0104], [0107], [0110], [0112], [0115], [0118], [0120], [0131], [0134], [0137], [0140]. The result of such methods would be uniform distribution of the noble metal.
114. Furthermore, a POSITA would immediately appreciate that Figure 2 is a schematic that illustrates, with considerable creative license and oversimplification, a point the specification is making and is not an accurate depiction of the reality Miura's particles. For example, Miura

is clear in their Examples that the difference between their “Pt particle” and “particulate support” diameters is on the order of 1,000-fold. *Id.*, [0098], [0128]. In contrast, the difference between the individual cross-hatched circles and the total particle diameters in Figure 2 of Miura are approximately 9-fold. Clearly, Miura’s Figure 2 is a schematic, a graphic representation that is oversimplifying many aspects of reality for illustrative purposes. This is analogous to subway maps, which abandon any attempt to accurately portray distances or precise rail paths in order to provide riders with an easy to read map that emphasizes the order of stops. Accordingly, a POSITA would turn to the specification to understand the physical reality of Miura’s auto catalysts.

115. Specifically, Miura teaches that noble metal can be loaded on the support “by any known method, for example, by a method of impregnating metal oxide particles with a solution containing a salt and/or a complex salt of noble metal.” *Id.*, [0049]. Miura then provides the specific explanation that the noble metal can be supported by dispersing the metal oxide particles in noble metal solution followed by drying and firing. *Id.*, [0072]. This method of impregnation is known in the art as “wet impregnation.”

116. Wet impregnation is a well-known and widely used technique in the art that is used to uniformly distribute catalytically active material, like noble metal on porous support particles, like the metal oxide supports taught by Miura. EX2007, 130, 132. In wet impregnation, porous support particles are contacted in an excess of active metal solution. *Id.* The active metal solution is allowed to fill the pores of the porous support. *Id.* The active metal solution disperses uniformly throughout the entirety of the support. *Id.* The support filled with active metal solution is then dried and fired such that only the active metal remains and is highly dispersed throughout the support. *Id.*, 132, 134.
117. Miura describes using the wet impregnation technique generally and Miura teaches wet impregnation to load noble metals onto the metal oxide particles in its working examples 7-10. WRG-1004, [0098]-[0110].
118. Dr. Harold states in his declaration that eggshell distributions reduce the amount of noble metal loaded on a particle as compared to uniform distributions and Dr. Harold states this may motivate a POSITA to use an eggshell distribution. WRG-1003, ¶ 23. Miura, however, teaches that it is desirable to **increase** the amount of noble metal on its supported particles. WRG-1004, [0071]. Miura teaches particles that “make[] it

possible to **increase** the amount of noble metal which can be supported.” *Id.* This further makes clear not only that Miura does not teach an eggshell distribution, but that an eggshell distribution would not be desirable for Miura’s purposes. *Id.*

B. Miura’s Catalysts are Not CO to CO₂ Combustion Promoters

119. The catalyst taught by Miura is not used in an FCC process. The catalyst taught by Miura is a three-way exhaust gas purifying catalyst, a catalyst that is used in a catalytic converter – a fixed bed reactor to purify auto exhaust gas. WRG-1004, [0002]. Miura does not teach a CO to CO₂ combustion promoter, as the term is understood and used in the art.
120. The goal of Miura is to make metal oxide particles that have a diameter of 50 nm or less. WRG-1003, [0015]. That is 0.05 microns. This is extremely small. This is the size of the pores of CO to CO₂ combustion promoters. The POSITA would have no reason to change the size of the metal oxide particle itself, because if one wanted a larger size catalyst, then the particles would be physically combined as Miura did. As shown in the Examples many of these small metal oxide particles are shaped into a 1 mm square pellet before subsequently being used as an auto catalyst. WRG-1004, [0101], [0104], [0107], [0110], [0112], [0115], [0118], [0131], [0134], [0137], [0140]. These pellets are further

fixed into a honeycomb pattern. To make a suitable FCC particle, these metal oxide particles would be need to be shaped into an appropriately-sized FCC catalyst particle. Given the roughly 1,000-fold difference in magnitude between Miura's 50 nm particles and the microsphere-sized particles of the '864 patent, this would require billions of metal oxide particles per actual FCC particle. The noble metal would thus be dispersed throughout the resulting FCC particle, the exact opposite of the eggshell concentration described in the '864 patent.

121. Additionally, no reduction in the amount of platinum is taught by Miura. Thus, the POSITA simply would not find Miura relevant to the type of catalyst of the '864 patent.
122. A POSITA would not be motivated to use Miura's particles in an FCC process as CO to CO₂ combustion promoters for many reasons. For one, there is no disclosure in Miura that its automotive catalysts would be usable to as CO to CO₂ combustion promoters. As I discussed above, catalysts are very sensitive to the conditions in which they are used and a POSITA would not assume, just because *one* of the three reactions Miura's catalyst catalyzes is CO oxidation, that the Miura catalyst would necessarily work as CO to CO₂ combustion promoter.

123. Further, a POSITA would recognize that Miura's three-way catalytic properties may be detrimental to an FCC process. Miura's ability to catalyze reactions other than the oxidation of CO may result in the catalysis of undesirable reactions in an FCC unit. For example, the Miura teaches that when its catalyst is used in a fixed bed reactor at temperatures of exhaust gas purification applications, its catalyst is able to oxidize hydrocarbons. WRG-1003, [0002]. A POSITA would know that the oxidation of hydrocarbons is not desirable in FCC processes because these reactions chemically destabilize the products of the catalytic cracking process. EX2017. A POSITA would not therefore use Miura's catalyst as CO to CO₂ combustion promoter because it may be detrimental to the overall FCC process. *Id.* There was no reduction in the amount of platinum used by Miura.
124. A POSITA would not assume that the Miura catalysts would promote the combustion of CO to CO₂ when used in an FCC process because the reaction conditions at and systems in which Miura's catalysts catalyze exhaust gas purification of reactions are different than those in FCC processes. Miura's catalysts purify exhaust gas in catalytic converter, a type of fixed bed reactor, where Miura's small catalyst particles are used to make large catalyst pellets or to coat monolithic

supports that remain fixed in place. WRG-1004, [0002], [0050]. Miura's reactors (catalytic converters) reach temperatures of no higher than about 300°C. *Id.*, [0124].

125. In contrast, FCC processes use fluidized catalysts in fluid bed reactors, and CO to CO₂ combustion promoters are fluidized in FCC processes. Further, the units in which CO to CO₂ combustion promoters are used reach temperatures of more than 700°C. Miura does not disclose that its catalysts would catalyze the oxidation of CO to CO₂ at higher temperatures nor does Miura disclose that its catalyst would be able to withstand the high temperatures at which CO to CO₂ combustion promoters must operate.
126. Further, Miura's particles have a diameter of no more than 10 µm, preferably 50 nm. WRG-1004, [0015]. A POSITA would recognize that these particles are too small for use in an FCC process. For example, Baker teaches that when using a catalyst in a fluid bed reactor, there shouldn't be an excess of very small catalyst particles, referred to as "fines," in fluid bed systems because those particles can plug gas recycle lines and be difficult to remove. WRG-1008, 4:4-8. Baker teaches that no more than 30% by weight of the particles in a fluid bed catalyst particle distribution should have a diameter of less than 20 µm.

Id., 3:20-25. *100% of Miura's particles have a diameter of less than 10 μ m.* A POSITA would therefore not believe Miura's metal oxide particles would be useful for a fluid bed system and therefore not be useful in an FCC system. Conversely, Miura's 1 mm pellets, formed from a multitude of metal oxide particles, would have noble metal distributed throughout the pellet (as described above) and do not provide the eggshell distribution of the '864 patent, and thus there is no way of arriving at the CO to CO₂ combustion promoter by being combined with the teachings of Baker.

127. Dr. Harold also recognizes that very small particles should not be used in fluid bed systems. He states that small catalyst particles can “bypass the cyclones used for separation in FCC processes and a proportion can enter the atmosphere, which has health and environmental implications.” WRG-1003, ¶ 52. A POSITA would recognize that Miura's less than 10 μ m particles would cause the system blockages cautioned by Baker, they would not be captured by the FCC's cyclones and therefore they would not be recycled back to the FCC process as intended, and they may be released into the atmosphere and be an environmental hazard.

128. Accordingly, not only is Miura's catalyst not a CO to CO₂ combustion promoter, a POSITA would not have been motivated to use Miura's catalyst particles in an FCC system as a CO to CO₂ combustion promoter.

C. Baker Does Not Teach A CO to CO₂ Combustion Promoter

129. Baker is also directed to an entirely different type of catalyst, namely one for use in the production of vinyl acetate monomer. WRG-1008, 1:15-17, 2:59-62. Such a catalyst has its own constraints on size, chemical composition, etc. Baker teaches that the active metal catalyst, or its precursor, is distributed predominantly in a layer below the surface of the particle. *Id.*, 3:32-34. This would typically be referred to in the art as an egg white distribution. WRG-1009, 1.

130. Baker also indicates that their vinyl acetate production catalysts may be used in fixed or fluid bed processes. WRG-1008, 2:59-62. Notably, Baker is clear that different reaction conditions require different catalyst design, clearly teaching that fixed and fluid bed processes require different-sized vinyl acetate monomer catalyst particles and that the disclosed catalyst must be sized depending on the type of bed, that is, fixed or fluid, being employed. *Id.*, 7:55-66. Further, a POSITA would not be motivated to scale a shell-type catalyst for a fluid bed

application based on the teachings of Baker. Baker teaches that “palladium and gold being at/near the surface are susceptible to loss through attrition” for fluid bed reactors. *Id.* 1:36-37. Baker illustrates the loss of palladium and gold when prepared as a shell type catalyst in Table 2, which demonstrates over 50% of both are lost during the attrition test. *Id.* 10:12-28.

D. Lin Does Not Teach a Specific CO to CO₂ Combustion Promoter

131. Lin teaches a method of making eggshell catalysts, but teaches away from such catalyst forms for fluid bed operations, noting that the preferred catalyst form for use in fluidized beds is the egg yolk. WRG-1009, 4. Lin merely states that eggshell catalysts have been used for CO oxidation, but Lin does not teach what these catalysts are made of, their geometry, or the systems in which they are used. *Id.*, 2. The only specific catalysts that Lin teaches are used to catalyze the selective hydrogenation of isoprene to isopentane in a fixed bed reactor. *Id.*, 5-9. Hydrogenation reactions and oxidation reactions are two distinct types of chemical reaction.

132. A POSITA would not believe that a catalyst for the selective hydrogenation of isoprene to isopentane in a fixed bed reactor would

be usable in an FCC process or that it would work as a CO to CO₂ combustion promoter.

E. Espinoza Does Not Teach A CO to CO₂ Combustion Promoter

133. Espinoza is concerned with the production of syngas. WRG-1011, 1:24-30. Syngas production is the steam reforming or partial oxidation of small-chain hydrocarbons into carbon monoxide and hydrogen. *Id.*, 1:24-30. That is, Espinoza is producing the precise compound that a CO to CO₂ combustion promoter is destroying.
134. A POSITA would not believe that a catalyst for the production carbon monoxide would be usable in an FCC process or that it would work as a CO to CO₂ combustion promoter.
135. Moreover, Espinoza focuses on adding an impenetrable non-porous layer. So it is fundamentally different from the CO to CO₂ combustion promoter of the '864 patent.

VIII. ADDITIONAL REMARKS

136. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.
137. I 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.

A handwritten signature in black ink, appearing to read "Everett Capen". The signature is written in a cursive, flowing style with a large, stylized "R" at the end.

Dated: September 21, 2023

By:

APPENDIX A

Everett E. Carpenter

Professor of Chemistry
Affiliate Professor of Chemical and Life Science Engineering
Nanoscience and Nanotechnology Program Co-Director

Virginia Commonwealth University
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<https://chemistry.vcu.edu/people/faculty/carpenter.html>

Personal Statement:

I am an accomplished senior faculty and serial entrepreneur with more than 25 years of success across the chemical manufacturing, education, and alternative energy industries. As an internationally recognized expert in nanomaterials, I am an asset to anyone seeking to expand their research portfolio, evaluate potential innovations, and proceed with marketing and business planning. I am experienced in patent or trademark preparation, research security, and marketing. I have broad areas of expertise include international and global marketing, strategic business development, entrepreneurship, team leadership, public speaking, and project planning.

EDUCATION AND TRAINING

Business Development Academy – Certified Patent Valuation Analyst	2022
The Business Development Academy's world-renowned training approaches patent valuation from analytical, legal, financial and practical perspectives – helping to develop the knowledge and critical thinking abilities to negotiate and structure more accretive licensing arrangements.	
Omniprep Patent Bar Review	2020
The Patent Bar Exam is the exam for those who want to be admitted to the Federal Patent Bar. Another name for the Patent Bar Exam is the Patent Agent's Exam or Patent Agent Exam.	
National Outdoor Leadership School – Wilderness First Responder Training	2018
Virginia Commonwealth University	2016-2019
Master's in Business Administration – MBA Management and Entrepreneurship Master's Degree in Business Administration with focus on marketing and global expansion. I have worked with several fortune 500 companies to help develop a global expansion plans into Europe and Asia, new product development and strategic planning for corporate turnaround, and market entry planning. I am a serial entrepreneur transitioning my research from the university into a start-up company I founded three times. I have negotiated several joint-development agreements and have interacted with several venture capital groups.	
National Science Foundation – Advanced Project Research Agency - Energy	2012
Inaugural entrepreneurial evaluation class of ARPAe-Innovation Corps. The National Science Foundation (NSF) I-Corps program prepares scientists and engineers to extend their focus beyond the university laboratory, and accelerates the economic and societal benefits of NSF-funded, basic-research projects that are ready to move toward commercialization. Part of a three-man team to evaluate the commercial potential of a Rare-earth free permanent magnet. Included study of business plan development.	

National Research Council Research Fellow – Naval Research Laboratory	1999-2000
Materials Physics Branch – Advisors Jeff Byers / Vincent Harris, Part of my fellowship responsibilities was the development of the first of its kind chemical synthesis laboratory within the Branch. My research focused on the development of core- shell nanoparticles for tailored electronic and magnetic properties for power electronic applications.	
University of New Orleans	1999
Ph. D. Chemistry Advisor Charles O'Connor Dissertation title “Synthesis of Magnetic Nanoparticles Using Reverse Micelles” While in New Orleans I supervised the undergraduates working in my laboratory. I was an integral part of the synthesis efforts of the successful Advanced Materials Research Institute.	
Appalachian State University	1992-1996
M.S.* Chemistry (Conc.: Polymer Chemistry) Advisor William Glenn Thesis title “Catalytic Degradation of Poly(ethylene terephthalate)” B.S. Chemistry (Conc.: Environmental Chemistry) Advisor Thomas Rhyne	
Ashworth Community College – Private Investigator License DCJS-RE-0148913	2015
Caldwell Community College and Technical Institute	1992
A.S. Mathematics * Last graduate student in the program, transferred before theses was defended	

POSITIONS

ThermaGEL Innovations, Inc. – Chief Operating Officer/Founder	2023- Current
Everttechnologies, LLC – President/Founder	2018-Current
Virginia Commonwealth University	
<u>Full Professor - Department of Chemistry</u>	2013-Current
In addition to my departmental committee and teaching responsibilities, I have served on numerous other committees including faculty search committees, department tenure committees, tenure and promotion committees within the College of Engineering, including the successful search for a new dean in the College of Engineering and the graduate research dean of engineering. I have also been involved in search committees to fill the position of technology manager. As a researcher, I oversee an active research effort, which at one point included 42 people from 6 different institutions and over \$3M in funding annually.	
Affiliate Professor - Chemical and Life Science Engineering	2008-Current
Associate Professor - Department of Chemistry	2008-2013
Assistant Professor – Department of Chemistry	2004-2008
Virginia Commonwealth University	
<u>Nanoscience and Nanotechnology Program Co-Director</u>	2009-Current
As program director I was responsible for the development of the doctoral program. This program was the first of its kind in the Commonwealth and one of only 7 within the United States. I developed the program from inception all the way through final approval from the State Council of Higher Education. I remained the director supervising the most successful interdisciplinary program at VCU with currently 12 affiliate faculty, 19 graduate students and 9 PhD graduates. After our fifth year review by SCHEV in 2014, we passed all enrollment, graduation, and research metrics. It was noted by the Dean's office that this was due to my leadership.	
Virginia Commonwealth University	
<u>Director of Nanomaterials Core Characterization Facility</u>	2009-2016

In 2009, to help support the Nanoscience and Nanotechnology program, the university developed the Nanomaterials Core Characterization Facility. Due to my work with the program and my success with a NSF-Major research instrumentation proposal, I was chosen to lead this first of its kind facility.

From the initial establishment of the facility, I supervised the procurement of over

\$10M in instrumentation to support research across all departments at VCU with currently over 200 researchers. As part of the facility, I was responsible for supervision of the internal users as well as two dedicated technicians and one graduate assistant. Part of my responsibilities included user billing, overseeing facility operations, preparing scientific reports for external users, preparing annual reports detailing out the ~\$200K annual budget, and recruitment of new external users.

Nanofoundry, LLC – Chief Technology Officer	2012-2015
Anvil The Materials Forge, Inc – Chief executive officer	2008-2009
George Washington University – Research professor	2001-2008
Catholic University of American – Adjunct Professor	2000-2004
Naval Research Laboratory – Washington DC	2000-2004

Staff Scientist – Materials and Sensors Branch

As a staff scientist at NRL, I was responsible for the supervision of fellows within our section. I also acted as the Branch Chemical Hygiene Officer. I developed and maintained safety protocols in the various laboratories within the branch. My research became integral part of larger DARPA and ONR programs with over \$1M in research budgets.

AWARDS, HONORS, and ACTIVITIES

2023	Inducted as Fellow of the International Association of Advanced Materials
2023	Identified by Research.com as one of the top 5% of cited Material Scientists worldwide
2022	Identified as one of the top 2% of researchers cited worldwide by Elsevier
2020	Elected Senior member of the National Academy of Inventors @ VCU
2018	Inducted in the National Academy of Inventors @ VCU
2017	Program Member International Conference on Magnetism
2016	Science News “Small and Powerful: pushing the boundaries of nano-magnets” DOE news brief Presentation of the Hello Tomorrow Conference by invention only
2015	Program Committee International Conference on Fine Particle Magnetism
2014	Runner up Environmental Research Presentation CleanEquity Monaco
2013	Principle Investigator for Inaugural ARPA-e Innovation Corps Program
2013-2011	Nominated for Distinguished Service Award College of Humanities
2009	Nominated for Royal Society of Engineers Visiting Fellowship American Chemical Society Community Interaction panelist, Advisory Board member of inChemistry magazine Scientific editorial review board for Reviews in Nanoscience and Nanotechnology Session Chair Magnetism and Magnetic Materials 54th Conference
2007	Research featured on the cover of Dalton Transactions
2006	Research Featured on the cover of Dalton Transactions
2005	Alan Berman Research Paper Award in recognition of outstanding research paper Research Featured in AzoNews article “Highly Magnetized Nanoparticles Based on Metallic Iron Could One Day be Used in a Non-Invasive Therapy for Cancer
2000-2007	Awarded the US Navy’s special contribution Award

FUNDING

AGENCY/DURATION	TOTAL (AMOUNT)	ROLE
VCU- Commercialization Fund July 2022- July 2023	Co-PI Development of phase change materials incorporated in Textiles (PI: Renee Lamb) \$10000	Co-PI
VCU- Breakthrough Grant July 2022-July 2024	Additive Manufacturing of Anisotropic Alnico Permanent Magnets (PI: Radhika Barau) \$199572	Co-PI
VCU- Accelerate Grant July 2022 – July 2024	Seeking Sustainability in a High-Risk Environment: Cultural Niche Construction on El Hierro, Canary Islands, Spain (PI: Stevenson) \$150,000	Co-Investigator
VCU- ISEE Jan 2023 – Dec 2023	Enabling a Circular Economy: Sustainable Manufacturing of Biodegradable Bonded Magnets (PI: Radhika Barau) \$60,000	Co-PI
NSF-IUCRC July 2023-July 2024	Fabrication of Pd-Graphene Oxide tethered catalysts unfunded (PI:Gupton) \$70000	Co-PI
VCU / Presidential QUEST Research Grant	Commercialization of a “LCMO based magnetic refrigeration” (\$20,010) <i>Results of this project will be the demonstration of a working prototype a magnetic refrigeration</i>	PI
National Science Foundation- Major Research Instrumentation 09/2017-08/2020	MRI: Acquisition of a Physical Properties Measurement System With 9 Tesla Magnetometer (Dynacool) for Research and Teaching at VCU PI H Rhadimani, Co-PIs, S. Khanna, S. Bandyopadhyay, and J Atulashima (\$281,610 with an additional 55 cost sharing) <i>The was just the eight MRI grant that VCU has ever received.</i>	CO-PI
National Science Foundation- USC/VCU IUCRC CeRCaS 06/2017 – 06/2018	Continuous production of supported metal catalysts on silica (\$20,000 selected and funded by industrial partner BASF, UOP, and Afton)	PI
National Science Foundation- USC/VCU IUCRC CeRCaS 06/2017-06/2018	In Situ XRD study of bimetallic catalysts (\$38,458 selected and funded by industrial partner BASF and Exxon)	PI
National Science Foundation- USC/VCU IUCRC CeRCaS 06/2015-06/2017	Continuous system of catalytic nanoparticles (\$69,300 selected and funded by industrial partner BASF)	PI
BASF - Joint Development Award 2013	Non equity investment for the development of Carbide based permanent magnets (\$300,000 through small business Nanofoundry)	PI
Rogers Corporation – Product Development 2013	Non equity investment for the development of novel core-shell electronics (\$75,000 through small business Nanofoundry)	PI
Lockheed Martin – Product Development 2013	Non equity investment for the development of novel magnetic wire structures and methods to manufacture them (\$75,000 through small business Nanofoundry)	PI
National Science Foundation – Small	Production of Cobalt Carbide Permanent Magnets (\$750,000 through small business Nanofoundry)	VCU-PI

Business Innovation Research Phase 2 06/2013-06/2015		
National Science Foundation – Small Business Innovation Research Phase 1 09/2013-03/2014	Production of Cobalt Carbide Permanent Magnets (\$150,000 through small business Nanofoundry)	VCU – PI
DOE – Advanced Research Projects Agency - Energy 01/2012 – 9/2013	Discovery and Design of Novel Permanent Magnets using non-strategic elements with secure supply chains (total project contract \$2,911,374 as published by ARP Ae) <i>Only wet chemical approach funded out of 500 pre-proposal and one of only 13 total funded. Project included researchers from 7 different institutions and over 45 researchers.</i>	PI
National Science Foundation- Major Research Instrumentation 07/2009-06/2012	“MRI: Acquisition of Confocal Raman Microscope for research and education at VCU”; PI Bertino, Co-PIs, M. Peace, MS. Bandyopadhyay, and K. Wynne (\$185,000 with \$45,000 cost sharing)	CO-PI
Bill and Melina Gates Foundation 06/2013 – 06/2014	Targeting Oviductal glycoprotein with magnetic nanoparticles: a novel method for non-surgical female sterilization? (\$55,000) PI: Jeffrey Jensen, OSHU	PI
DOE – Advanced Research Projects Agency - energy 01/2010-12/2013	High Energy Permanent Magnets for Energy Applications, (Chemistry budget 300,000; Project total \$4500000) PI: George Hadjipanayis, UDel	CO-PI
National Science Foundation- Major Research Instrumentation 07/2009-06/2012	“MRI: Acquisition of TEM for research and education at VCU”; PI Bertino, Co-PIs, M. El-Shall, S. Bandyopadhyay, and K. Wynne \$ 459,000.00 (with an additional \$201,000 matching)	CO-PI
National Science Foundation- Major Research Instrumentation 07/2008-06/2011	“MRI: Acquisition of X-ray photoelectron spectrometer (XPS) for research and education at VCU”; Co-PI’s, M. El-Shall, M. Collinson, M. Bertino, and K. Wynne \$ 590,522.00 (with an additional \$329,478 matching) <i>First funded NSF MRI grant funded from the College of Humanities and Science. I have been involved with all three successful applications from the college.</i>	PI
Office of Naval Research 01/2007 – 12/2008	“Novel acute rescue strategies using nonpulmonary oxygenation”; PI Kevin Ward, Emergency Medicine Co-Investigator’s, Huvard and McHugh Chemical Engineering, (Chemistry budget \$212,340; Project total \$1583378) <i>Became co-director of the materials component of the VCU reengineering shock center in the school of medicine.</i>	CO-PI
VCU-Community Engagement Grant 06/2007-06/2008	“Ecological monitoring in Charles County”; PI Anne Wright, Biology (budget \$5398; Project total \$23000)	CO-PI
Thomas and Kate Miller Jeffress Memorial Trust 06/2006 – 05/2007	“Ferrite development for image enhanced magnetodynamic therapy” (budget \$20,000)	PI
American Cancer Society – IRG	“Enhanced ferrites for magnetodynamic therapy” (Annual budget \$13,193)	PI

08/2005-08/2006		
DARPA - BIOMAGIC 07/2003 – 07/2004	“Core-shell magnetic nanoparticles for biological applications” (\$90K)	PI
DARPA - METAMAGNETS 01/2000 – 12/2003	“Metamaterials: Core shell nanoparticles for high frequency applications” (1,172,000 total) PI: Vincent Harris, NRL	CO-PI

PATENTS DISCLOSED, PUBLISHED, AND AWARDED

INVENTORS, TITLE	ASSIGNEE/STATUS
Carpenter, EE. et al.; Mixed Metal Supported Catalyst	Aqueous Global Solutions - pending
Carpenter, EE. et al; Active cooling textiles	VCU – Disclosed
Carpenter, E.E.; LCMO for magnetic refrigeration	Filed, NDA and MTA with Sumida Corp.
Carpenter, E.E. et al.; Production of stable hydrophobic colloids	Nanofoundry
Carpenter, E.E. et al.; Method for large scale production of MnFe alloys	Nanofoundry
Carpenter, E.E. et al.; Method for large scale production of FeN alloys	Nanofoundry
Carpenter, E.E. et al.; Method for generating and tuning curie temperature of ambient magnetocaloric materials	Nanofoundry
Carpenter, E.E.; Non-rare earth magnetic nanoparticles	VCU- Licensed WO2013103762 A1
J. Richardson, D. Stuart, E. E. Carpenter Method and apparatus for improving heat transfer in industrial water systems with ferrofluids	Patent Files - US20120199320 A1
Carpenter, E.E. Solvothermal Synthesis of Nanoparticles, Virginia Commonwealth University 2013	VCU - Licensed
Carpenter, E.E. Intermetallic nanoparticles for permanent magnets, Virginia Commonwealth University 2013	VCU - Licensed
Carpenter, E.E. Production of Cobalt Carbide nanoparticles, Virginia Commonwealth University 2013	VCU - Licensed
Carpenter, E.E. Design of electrical devices using magnetic nanoparticles, Virginia Commonwealth University 2013	VCU - Licensed
Ward, K. W.; Huvard, G.; Carpenter, E. E. Portable oxygen generator, Virginia Commonwealth University, 2007	VCU – Licensed WO2009006586 A3
Ward, K. W.; Carpenter, E. E. Novel means to provide nonpulmonary oxygenation and improve tissue oxygenation, Virginia Commonwealth University, 2006.	VCU - Licensed
Carpenter, E.E.; Harris, V. G. Method for making magnetic fluorescent core- shell nanoparticles, 2007.	NRL – Patent filed 20070111020
Carpenter, E.E.; Harris, V. G. Fluorescent-magnetic nanoparticles with core- shell structure, 2004.	NRL – Patent Issued 7,235,228
Kurihara, L.K.; Carpenter, E.E. Low temperature diol processing of fine metallic particles and coatings, 2002.	NRL – Patent issued 7,033,416
Carpenter, E.E.; Harris, V. G. Nanoparticle manganese zinc ferrite synthesized using reverse micelles, 2002.	NRL – Patent filed 20030190471
Carpenter, E.E.; Harris, V. G. Magnetic nanoparticles having passivated metallic cores, 2001.	NRL – Patent filed 20030190475
Carpenter, E.E.; O'Connor, C. J.; Khumbar, A. Synthesis of core-shell nanoparticles via micro-emulsions, 1999.	UNO – Patent issued 6,773,823

PUBLICATIONS

BOOKS, BOOK CHAPTERS, OR REVIEWS

Smith, S. E., Tsui, M., Williams, B., & Carpenter, E. E. (2022). Chemical Processing and Magnetic Properties of Ferrite Nanoparticles. *Modern Ferrites*, Volume 1: Basic Principles, Processing and Properties, 1.

Morrison, S. A.; Harris, V. G.; Carpenter, E. E. Chemistry and Physics of Doped Mixed Metal Ferrites Nanoparticles, In *Doped Nanomaterials and Nanodevices*; Chen, W., Ed.; American Scientific Press: 2011; Vol. 3, 87-96.

LaLena, J. N.; Cleary, D. A.; Carpenter, E. E.; Dean, N. F. *Inorganic Materials Synthesis and Fabrication*. John Wiley and Sons: New York, NY, 2008.

Willard, M. A.; Kurihara, L. K.; Carpenter, E. E.; Calvin, S.; Harris, V. G., Chemically prepared magnetic nanoparticles. In *Encyclopedia of Nanoscience and Nanotechnology*; Nalwa, H.S., Ed 2004, 2, 815-848

Willard, M. A.; Kurihara, L. K.; Carpenter, E. E.; Calvin, S.; Harris, V. G., Chemically prepared magnetic nanoparticles. *International Materials Reviews* 2004, 49, (3-4), 125-170.

ARTICLES OR ABSTRACTS (h-INDEX 48, I10-INDEX 104, OVER 8027 CITATIONS)

1. Williams, B.; El-Gendy, A. A.; Carpenter, E. E., Exchange bias and enhanced anisotropy from exchange coupled Fe₃C/CoO nanoaggregates. *Journal of Magnetism and Magnetic Materials* **2017**, 444, 332-337.
 2. Tsui, M. H.; Dryer, D. T.; El-Gendy, A. A.; Carpenter, E. E., Enhanced near room temperature magnetocaloric effect in La_{0.6}Ca_{0.4}MnO₃ for magnetic refrigeration application. *RSC Advances* **2017**, 7(74), 46589-46593.
 3. Smith, S. E.; Huba, Z. J.; Almalki, F.; Regalbuto, J.; Monnier, J.; Carpenter, E. E., Continuous-flow synthesis of Cu—M (M= Ni, Co) core—shell nanocomposites. *Journal of Flow Chemistry* **2017**, 7 (1), 18-22.
 4. Clifford, D. M.; Castano, C. E.; Tsui, M. H.; Rojas, J. V.; Carpenter, E. E., Tailoring the magnetic properties of Fe_xCo_(1-x) nanopowders prepared by a polyol process. *Dalton Transactions* **2017**, 46(31), 10364-10373.
 5. Carpenter, E. E.; Huba, Z. J.; Carroll, K. J.; Farghaly, A.; Khanna, S. N.; Qian, M.; Bertino, M., Non-rare earth magnetic nanoparticles. US Patent 9,773,594: 2017.
 6. Williams, B.; Clifford, D.; El-Gendy, A. A.; Carpenter, E. E., Solvothermal synthesis of Fe₇C₃ and Fe₃C nanostructures with phase and morphology control. *Journal of Applied Physics* **2016**, 120 (3), 033904.
 7. Smith, S. E.; Siamaki, A. R.; Gupton, B. F.; Carpenter, E. E., CuPd nanoparticles as a catalyst in carbon—carbon cross-coupling reactions by a facile oleylamine synthesis. *RSC Advances* **2016**, 6(94), 91541-91545.
 8. Carpenter, E.; El-Gendy, A. A.; Khanna, S., High anisotropy nanoparticles. US Patent App. 14/227,283: 2016.
 9. Abdeen, M.; Sabry, S.; Ghozlan, H.; El-Gendy, A. A.; Carpenter, E. E., Microbial-physical synthesis of Fe and Fe₃O₄ magnetic nanoparticles using *Aspergillus niger* YESM1 and supercritical condition of ethanol. *Journal of Nanomaterials* **2016**, 2016.
 10. El-Gendy, A. A.; Bertino, M.; Clifford, D.; Qian, M.; Khanna, S. N.; Carpenter, E. E., Experimental evidence for the formation of CoFe₂C phase with colossal magnetocrystalline-anisotropy. *Applied Physics Letters* **2015**, 106(21), 213109.
 11. Clifford, D. M.; Castano, C. E.; Lu, A. J.; Carpenter, E. E., Synthesis of FeCo alloy magnetically aligned linear chains by the polyol process: structural and magnetic characterization. *Journal of Materials Chemistry C* **2015**, 3(42), 11029-11035.
 12. Huba, Z. J.; Carpenter, E. E., A versatile synthetic approach for the synthesis of CoO, Co_xC, and Co based nanocomposites: tuning kinetics and crystal phase with different polyhydric alcohols. *CrystEngComm* **2014**, 16(34), 8000-8007.
 13. Huba, Z. J.; Carpenter, E. E., Monitoring the formation of carbide crystal phases during the thermal decomposition of 3d transition metal dicarboxylate complexes. *Dalton Transactions* **2014**, 43 (32), 12236-12242.
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14. Gilliland III, S. E.; Carpenter, E. E.; Shultz, M. D., Modified Seed Growth of Iron Oxide Nanoparticles in Benzyl Alcohol—Optimization for Heating and Broad Stability in Biomedical Applications. *Nanobiomedicine* **2014**, *1*, 9.
15. El-Gendy, A. A.; Qian, M.; Huba, Z. J.; Khanna, S. N.; Carpenter, E. E., Enhanced magnetic anisotropy in cobalt-carbide nanoparticles. *Applied Physics Letters* **2014**, *104* (2), 023111.
16. Clifford, D. M.; El-Gendy, A. A.; Lu, A. J.; Pestov, D.; Carpenter, E. E., Room Temperature Synthesis of Highly Magnetic Cobalt Nanoparticles by Continuous Flow in a Microfluidic Reactor. *Journal of Flow Chemistry* **2014**, *4* (3), 148-152.
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18. Yoon, H.; Xu, A.; Sterbinsky, G.; Arena, D.; Huba, Z.; Carpenter, E.; Meng, S.; Carroll, K. In *In-situ Mechanistic Study of Cobalt Carbide Nanoparticles by Quick-XAFS*, APS Meeting Abstracts, 2013; p 38008.
19. Sterbinsky, G.; Carroll, K.; Yoon, H.; Meng, S.; Huba, Z.; Carpenter, E.; Arena, D. In *Magnetic and electronic structure of high-coercivity cobalt-carbide nanoparticles for permanent magnet applications*, APS Meeting Abstracts, 2013.
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22. Franzel, L.; Phumisithikul, K.; Bertino, M.; Carpenter, E., Synthesis of multiphasic inhomogeneous Mo/MoC nanoparticles by pulsed laser ablation. *Journal of nanoparticle research* **2013**, *15* (11), 2032.
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30. Huba, Z. J.; Carpenter, E. E., Size and phase control of cobalt-carbide nanoparticles using OH⁻ and Cl⁻ anions in a polyol process. *Journal of Applied Physics* **2012**, *111* (7), 07B529.
31. Franzel, L.; Bertino, M.; Huba, Z.; Carpenter, E., Synthesis of magnetic nanoparticles by pulsed laser ablation. *Applied Surface Science* **2012**, *261*, 332-336.
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33. Carroll, K. J.; Huba, Z. J.; Spurgeon, S. R.; Qian, M.; Khanna, S. N.; Hudgins, D. M.; Taheri, M. L.; Carpenter, E. E., Magnetic properties of Co₂C and Co₃C nanoparticles and their assemblies. *Applied Physics Letters* **2012**, *101* (1), 012409.

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 180. Clifford, Dustin M; Castano, Carlos E; Tsui, Melissa HM; Rojas, Jessika V; Carpenter, Everett E; Tailoring the magnetic properties of Fe x Co (1- x) nanopowders prepared by a polyol process *Dalton Transactions* **46** 31 10364-10373 2017
 181. Williams, Brent; El-Gendy, Ahmed A; Carpenter, Everett E; Exchange bias and enhanced anisotropy from exchange coupled Fe₃C/CoO nanoaggregates *Journal of Magnetism and Magnetic Materials* **444** 332-337 2017
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182. Tsui, Melissa HM; Dryer, Devon T; El-Gendy, Ahmed A; Carpenter, Everett E; Enhanced near room temperature magnetocaloric effect in $\text{La}_{0.6}\text{Ca}_{0.4}\text{MnO}_3$ for magnetic refrigeration application RSC Advances 7 74 46589-46593 2017
 183. Abdeen, Mai; Sabry, Soraya; Ghazlan, Hanan; El-Gendy, Ahmed A; Carpenter, Everett E; Microbial-Physical Synthesis of Fe and $[\text{Fe}(\text{sub. 3})][\text{O}(\text{sub. 4})]$ Magnetic Nanoparticles Using *Aspergillus niger* YESM1 and Supercritical Condition of Ethanol Journal of Nanomaterials 2017 2017
 184. Tsui, Melissa HM; Dryer, Devon T; El-Gendy, Ahmed A; Carpenter, Everett E; Enhanced near room temperature magnetocaloric effect in $\text{La}_{0.6}\text{Ca}_{0.4}\text{MnO}_3$ for magnetic refrigeration application RSC advances 2017
 185. Hunt, CSM; Barua, R; Carpenter, EE; Influence of A-Site cation size-disorder on the magnetocaloric response of $\text{La}_{0.6}\text{Ca}_{1-x}\text{Sr}_x\text{MnO}_3$ nanoparticles AIP Advances 10 1 15228 2020
 186. Trinh, Thi Kim Hoang; Qiu, Weihua; Thornton, Meg; Carpenter, Everett E; Guo, Youzhong; A property fine-tuned sulfobetaine cholesterol derivative for membrane protein structural biology Biochimica et Biophysica Acta (BBA)-General Subjects 1865 7 129908 2021
 187. Sharma, Vaibhav; Balderson, Lilly; Heo, Rachel; Bishop, Omar; Hunt, Caitlin SM; Carpenter, Everett E; Hadimani, Ravi L; Zhao, Hong; Barua, Radhika; Room-temperature polymer-assisted additive manufacturing of microchanneled magnetocaloric structures Journal of Alloys and Compounds 920 165891 2022
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PRESENTATIONS → invited presentation (contributed presentations not listed)

- “Magnetocaloric Manganese Oxides for solid state cooling”, Advanced Materials Congress, 2023
- “Rational Synthesis of Magnetocaloric Manganese Oxides”, International Advanced Materials Research, 2023
- “Research Advances in Materials Science”, Livingstone Securities, 2022
- “LCMO Based Magnetic Refrigeration”, Appalachian State University, Boone, NC 2018
- “Rare-earth Free permanent magnets”, Power Electronic Industry Consortium, Washington, DC 2016
- “Flow synthesis of cobalt Carbide”, International conference on fine particle magnetism, Gaithersburg, MD 2016
- “Polyol Synthesis of Cobalt Carbide”, University of Basque Country, Bilbao – 2015
- “Alternative rare-earth Free Permanent Magnets” – Energy, Materials, and Nanotechnology, San Sebastian - 2015
- “Nanoparticles for catalytic Applications”, University of South Carolina, Columbia, SC May 2014
- “Enhancing Magnetic Properties of cobalt carbides”, International Rare earth permanent magnet, Annapolis, MD 2014
- “Cobalt Carbides by Polyol Process”, International Polyol Conference, Paris July 2014
- “Cobalt Carbides for permanent magnets”, Paris Diderot University, Paris, June 2013
- “Rare earth Magnetism”, Science Pub Richmond Jan 2013
- “Magnetodynamic treatment for permanent conception” –Oregon Science and Health University Jan 2013
- “Discovery and Design of Novel Permanent Magnets”, Magnetism and Magnetic Materials, Chicago 2013
- “Rare earth free permanent magnets”, International Conference on Magnetism, Orlando 2013
- “Rare-earth free permanent Magnets”, DOE Vehicles Briefing – Washington DC, 2013
- “Rare-earth Free Permanent Magnets” Spring ACS Meeting, New Orleans 2013
- “Low carbon steel alternatives for permanent magnets”, MRS Spring Meeting San Francisco – 2013
- “Rare-earth free permanent magnets”, ARPae Energy Summit Washington DC - 2013
- “Novel Permanent Magnets”, UVa NeXT speaker, February 2012

- “Drug Delivery Platforms”, November 2011, BIT 2nd Annual World Conference of Nanomedicine Shenzhen, China
- “Novel Permanent magnets”, International Materials Research Society, August 2011
- “Nanomaterials: What is the big deal about being small?”, Roanoke College, May 2011
- “Targeted Drug Delivery using Magnetic Nanoparticles” UMBC, April 2011
- “Novel Permanent Magnets”, VCU – Dept of Physics, April 2011
- “Magnetic Nanoparticles for Biomedical Applications” Rockefeller University, April 2011
- “Biomedical Application of Magnetic Nanoparticles” George Washington University, April 2010
- “Biomedical Application of Magnetic Nanoparticles” Howard University, April 2010
- “Biomedical Application of Magnetic Nanoparticles” University of New Orleans, March 2010
- “Biomedical Application of Magnetic Nanoparticles” Western Carolina University, February 2010
- “Nanotechnology; what is the big deal about being small?” VCU-COB October 19, 2009
- “B-2 Bombers to Breast Cancer; role of materials chemistry” Randolph Macon College- October 2009
- “Biomedical Application of Magnetic Nanoparticles”, VCU – CLSE, Nov 1, 2009
- “STS – Nanotechnology and Sustainability”, Green Day STS series VCU Oct 2nd, 2009
- “Nanoparticles; What is the big deal about small?” VCU-COB Executive MBA program, March 28, 2009
- “B-2 Bombers to Breast Cancer; role of materials chemistry” University of North Carolina- Wilmington, NC, January 2009
- “Biomedical Application of Magnetic Nanoparticles” Appalachian State University, Boone, NC November 2008
- “B-2 Bombers to Breast Cancer; role of materials chemistry” Roanoke College, Salem, VA September 2008 “Biological Application of Magnetic Nanoparticles; impact of size and crystal structure” William and Mary, Williamsburg, Sept, 2008
- “Synthesis of magnetic nanoparticles for biomedical applications” Particles 2008, Orlando, FL May 2008.
- “Emerging Technologies – Nanoparticles”, VCU COB-MS department, March 17, 2008
- “Design of magnetic nanoparticle for biomedical applications” India Institute of Physics, Joint US/Indo
- workshop of biological application of nanoparticles Bhubaneswar, India, February 20, 2008
- “The Chemistry and Physics of Doped Magnetic Nanoparticles” National Chemical Laboratory, Pune, India, February 18, 2008
- “Nanoparticles; What are they and how are they used?”, VCU-COB, Executive Masters Program in information technology. VCU COB-IS department January 19, 2008
- “Nanoscience at Virginia Commonwealth University”, NanoDay General Assembly, Richmond VA October, 2007
- Shultz, M. D., Carpenter, E. E. , “Magnetic Polymer Nanocomposites” Trends in Nanotechnology, San Sebastian, Spain September 3-7, 2007
- “Gold-Iron nanocomposites”, University of Basque Country, Department of Physical Chemistry, Bilbao, Spain, September 5, 2007
- Regional Meeting of the American Chemical Society, Collegeville, PA, Chemical Synthesis of Magnetic Nanoparticles. May 16-18 (2007),
- Morrison, S.A., Radwan, F., Shultz, M.D., Carpenter, E. E. , “Iron Nanoparticles as Magnetic Carriers” PARTICLES 2006, Orlando, FL
- “Nanoparticles; What are they and how are they used?”, VCU-Department of Chemistry, NANORATS Junior High School Robotics Team September 2006
- “Nanoparticles; What are they and how are they used?”, VCU-Department of Chemistry, NANODOTS Elementary School Robotics Team October 2006
- “Nanoparticles; What are they and how are they used?”, VCU-COB, Executive Masters Program in information technology 2006.

- “From B-2 bombers to breast cancer”, George Mason University, Fairfax, VA September 2006
- “From B-2 Bombers to Breast Cancer, atomic engineering of magnetic nanoparticles”, VCU – Department of Chemical Engineering, April 7th 2006
- “Synthesis of Magnetic Clusters”, NIST – Gaithersburg, January 18th, 2006
- “Nanoparticles: Synthesis and applications in biosensors”, Division of Consolidated Laboratory
- Services, CDC level 1 meeting, Richmond, VA April 19th, 2006.
- “From B-2 Bombers to Breast Cancer, the Role of Materials Chemistry”, UNC- Chapel Hill, March 7th, 2005

COURSES TAUGHT

CHEM 306 – Industrial Chemistry
 CHEM 591 – Introduction to Powder X-ray Diffraction – Certified X-ray technician training
 CHEM 320 – Inorganic Chemistry
 CHEM 406 – Inorganic Chemistry II
 CHEM 620 – Advanced Inorganic Chemistry
 CHEM 102 – General Chemistry II
 CHEM 691 – Materials Characterization
 CHEM 691 – Magnetochemistry
 CHEM 691 – X-ray absorption spectroscopy
 NANO 571 – Nanoscale Chemistry

MENTORING

• Post-doctoral associates

Ahmed El-Gendy - 2012-2015 Assistant Professor in Physics at University of Texas – El Paso
 Asma al-Turki - 2011-2013 King Saud University
 Shannon Morrison – 2004 -2006 Lead Scientists Southern Clay Products

• Graduate students

Dr. Christopher Olhaver – Chemistry 2023
 Dr. Margaret Thornton – Chemistry 2022
 Dr. Catlin Hunt – Chemistry 2021
 Dr. Melissa Tsui – Chemistry 2018
 Dr. Sarah Smith – Chemistry 2017
 Dr. Brent Williams – Nanoscience 2017
 Dr. Dustin Clifford – Nanoscience 2016
 Dr. Turki al-Mugitaab – Nanoscience 2016
 Dr. Stanley Gilliland – Nanoscience 2015
 Dr. April Hines – Chemistry 2015
 Dr. Zachary Huba – Chemistry 2015
 Dr. Daniel Hudgins – Chemistry 2014
 Dr. Kyler Carrol – Chemistry 2013
 Dr. C. Ryan Warren – Chemistry 2012
 Mr. Dale Stuart – Chemistry Masters 2012
 Dr. Farah Radwan – Chemistry 2011
 Dr. Sweta Naik – Chemistry 2011
 Ms. Meghann Broderick – Chemistry Masters 2010
 Dr. Jose Ramon Marin – Chemistry 2009 University of Basque Country
 Dr. Michael Shultz – Chemistry 2008
 Mr. Imran Zaldi – Chemistry Masters 2008
 Ms. Melissa Michaels – Chemistry Masters 2007

ASSOCIATIONS

American Chemical Society, American Physical Society, Magnetic Section of the Institute for Electricians and Electronic Engineers, American Association for the Advancement of Science, Materials Research Society, Virginia Academy of Science, American Institute for Chemical Engineers, Materials Research Society, American Association of University Professors, Virginia Association of Scholars
