UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LG ENERGY SOLUTION, LTD.,
Petitioner

v.

MOLECULAR REBAR DESIGN, LLC,
Patent Owner

Case IPR2024-01013
U.S. Patent 10,153,483

DECLARATION OF DEBORAH D.L. CHUNG, PH.D.

MRD EX. 2006
LGES v MRD
IPR2024-01013

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Exhibit No.	Description
MRD-2006	Declaration of Dr. Deborah D.L. Chung, Ph.D.
MRD-2007	WEBSTER'S NEW WORLD COLLEGE DICTIONARY (4th ed. 1999), various definitions
MRD-2008	U.S. Patent No. 8,703,009 ("Liu-009")
MRD-2009	Mengxuan Zhang et al., *Binder Assisted Dispersion of Agglomerated Carbon Nanotubes for Efficiently Establishing Conductive Networks in Cathodes of Li-Ion Batteries*, 8 ENERGY TECHNOLOGY 2000589 (2020).
MRD-2010	Varrla Eswaraiah et al., *Morphological, Thermal, Electrical and Electromechanical Properties of Polyvinylidene Fluoride (PVDF)-Functionalized Carbon Nanotube Composites (Preprint)*, AFRL-RX-WP-TP-2012-0277 INDIAN INSTITUTE OF TECHNOLOGY CHENNAI (2012).
MRD-2011	B. V. Bahaskara Rao et al., *Fabrication and Evaluation of Thin Layer PVDF Composites Using MWCNT Reinforcement: Mechanical, Electrical and Enhanced Electromagnetic Interference Shielding Properties,* 6 AIP ADVANCES 065107 (2016).
MRD-2012	Viraj Bhingardive et al., *Polyvinylidene Fluoride Based Lightweight and Corrosion Resistant Electromagnetic Shielding Materials*, 5 RSC ADV. 35909 (2015).
MRD-2013	Ming Wang et al., *The Influence of Polyvinylidene Fluoride (PVDF) Binder Properties on* $LiNi0_{.33}\ Co_{0.33}\ Mn_{0.33}\ O_2$ *(NMC) Electrodes Made by a Dry-Powder-Coating Process*, 166 JOURNAL OF THE ELECTROCHEMICAL SOCIETY A2151 (2019).
MRD-2014	Soumyaranjan Mishra et al., *Synthesis of PVDF/CNT and Their Functionalized Composites for Studying Their Electrical Properties to Analyze Their Applicability in Actuation & Sensing*, 509 COLLOIDS AND SURFACES A: PHYSICOCHEMICAL AND ENGINEERING ASPECTS 684 (2016).
MRD-2015	U.S. Patent No. 6,869,724

Exhibit No.	Description
MRD-2016	Lizhi Wen et al., *Effect of Conductive Material Morphology on Spherical Lithium Iron Phosphate*, 8 NANOMATERIALS 904 (2018).
MRD-2017	U.S. Patent Application Publication No. 2014/0319429 ("Nicolas-429")
MRD-2018	U.S. Patent Application Publication No. 2011/0256454 ("Nicolas-454")
MRD-2019	U.S. Patent Application Publication No. 2012/0058255 ("Gan")
MRD-2020	Wener Bauer et al., *Rheological Properties and Stability of NMP Based Cathode Slurries for Lithium Ion Batteries*, 40 CERAMICS INTERNATIONAL 4591 (2013).
MRD-2021	RESERVED
MRD-2022	RESERVED
MRD-2023	RESERVED
MRD-2024	Deposition Transcript of Dr. Yu Zhu in IPR2024-01013, dated March 14, 2025
MRD-2025	Deposition Transcript of Dr. Yu Zhu in IPR2024-01006, dated March 21, 2025
MRD-2026	Deposition Transcript of Dr. Yu Zhu in IPR2024-01011, dated March 21, 2025
MRD-2027	U.S. Patent No. 8,974,957
MRD-2028	U.S. Patent Application Publication No. 2024/0274804
MRD-2029 to MRD-2034	RESERVED
MRD-2035	U.S. Patent No. 10,273,403

Exhibit No.	Description
MRD-2036	U.S. Patent No. 10,374,254
MRD-2037	Aleksander Cholewinski et al., *Polymer Binders: Characterization and Development toward Aqueous Electrode Fabrication for Sustainability*, 13 POLYMERS 631 (2021).
MRD-2038	RESERVED
MRD-2039	U.S. Patent No. 8,557,351

I. INTRODUCTION

1. I have been retained as a technical expert by Molecular Rebar Design, LLC ("Molecular" or "Patent Owner") and asked to provide my objective and unbiased opinions concerning the patentability of U.S. Patent No. 10,153,483 ("the '483 Patent"). Specifically, I have been asked to provide my opinions on the patentability of the challenged claims of the '483 Patent in view of the grounds advanced in the pending Petitions for *Inter Partes* Review filed by LG Energy Solution Ltd. ("LG" or "Petitioner") against the '483 Patent (IPR2024-01013), the state of the art at the time of the claimed inventions, and the knowledge of a person of ordinary skill in the art at the time of the claimed inventions.

II. BACKGROUND AND QUALIFICATIONS

2. My Curriculum Vitae is attached hereto as Appendix A.

3. In forming the opinions expressed in this Declaration, I have considered and relied upon my education, background, and experience. In addition, I have reviewed and relied upon materials in preparation of this Declaration, as described herein.

4. I earned a Bachelor's (B.S.) Degree in Engineering and Applied Science in 1973 from the California Institute of Technology in Pasadena, California. I also earned a Master's (M.S.) Degree in Engineering Science in 1973 from the California Institute of Technology. I earned a Master's (S.M.) Degree in Materials

Science in 1975 from the Massachusetts Institute of Technology in Cambridge, Massachusetts. I also earned a Doctorate (Ph.D.) degree in Materials Science in 1977 from the Massachusetts Institute of Technology.

5. I am currently a SUNY Distinguished Professor of Mechanical and Aerospace Engineering at the University at Buffalo, The State University of New York, in Buffalo, New York. I am also the Founding Director of the Composite Materials Research Laboratory at the University at Buffalo, The State University of New York.

6. Prior to joining the University at Buffalo, I was a Teaching Assistant in the Department of Materials Science and Engineering at the Massachusetts Institute of Technology from 1973 to 1974. I was a Research Assistant in the Department of Materials Science and Engineering and the Department of Electrical Engineering and Computer Science at the Massachusetts Institute of Technology from 1974 to 1977. I was an Assistant Professor of Metallurgical Engineering and Materials Science and Electrical Engineering at Carnegie–Mellon University in Pittsburgh, Pennsylvania from 1977 to 1982. I was an Associate Professor of Metallurgical Engineering and Materials Science at Carnegie–Mellon University from 1982 to 1986. I was a Professor of Mechanical and Aerospace Engineering at University at Buffalo, The State University of New York (SUNY), from 1986 to 2024. In 2024, I became a SUNY Distinguished Professor at University at Buffalo, The State

University of New York. In addition, I became a Founding Director of the Composite Materials Research Laboratory at the University at Buffalo, The State University of New York, in 1989.

7. I am a Member (Fellow) of the American Academy of Arts and Sciences (elected in 2023). This Academy was founded by the Founding Fathers of the U.S.A. in 1780, with members including Washington, Kennedy and Einstein.

8. I hold an Honorary Doctorate Degree from University of Alicante, Alicante, Spain (2011).

9. I am Fellow of ASM International (1998), and Fellow of American Carbon Society (2001).

10. In 2004, I received the Pettinos Award from the American Carbon Society. This is an international award for outstanding achievement in research in the field of carbon materials. An award is given once every three years to one person (or one research group) in the world.

11. I received the UB President's Medal (2024) and the SUNY Chancellor's Award for Excellence in Scholarship and Creative Activities (2003). In addition, I was recognized as a SUNY Outstanding Inventor (2002).

12. In 2024, I received a Special Congressional Recognition from the U.S. Congress.

13. Through my professional work, and as reflected in my curriculum vitae (CV), I am an expert in the field of carbon materials and composite materials, including materials for electrical functions, materials for electrochemical functions, materials for mechanical functions, and materials for thermal functions. For example, I authored the following books on carbon materials and composite materials:

a. "Carbon Materials" published in 2019 by World Scientific Publishing Company;

b. "Functional Materials", 2nd Edition, published in 2021 by World Scientific Publishing Company;

c. "Carbon Composites: Composites with Carbon Fibers, Nanofibers and Nanotubes", 2nd Ed., published by Elsevier in 2017.

14. I am the author or co-author of over 600 peer-reviewed journal papers on varying topics related to the relationship among the processing (fabrication and modification), structure (internal structure in the microscopic level and macroscopic level) and properties (behavior) of materials, said materials including carbon materials, nanomaterials, composite materials, electrically conductive materials, polymeric materials, and ceramic materials, with their impact indicated by 49,747 citations, h factor = 115, according to Google Scholar (viewed on 3/31/2025).

15. Specific to the field of carbon and composite materials for electrical/electrochemical functions, I have authored or co-authored hundreds of peer-reviewed journal publications, all of which are listed in Appendix 1. Specifically, I have authored or co-authored:

a. 12 peer-reviewed archival journal publications on carbon materials for electrochemical functions, which include the functions related to electrodes, binders, electrically conductive additives, current collectors, electrical contacts, thermal management, and electromagnetic interference shielding,

b. 36 peer-reviewed archival journal publications on carbon nanomaterials, which include carbon nanotube, carbon nanofiber, carbon black, and graphite nanoplatelet,

c. 15 peer-reviewed archival journal publications on exfoliation of carbon materials, which include graphite and carbon fiber,

d. 17 peer-reviewed archival journal publications on intercalation, particularly the intercalation of graphite,

e. 6 peer-reviewed archival journal publications on binders, which include polymeric, ceramic and carbon materials,

f. 22 peer-reviewed archival journal publications on electrical contacts, which include those between carbon fiber composites, between metals, and between ceramic materials,

g. 33 peer-reviewed archival journal publications on electrical resistance, particularly the effect of mechanical and thermal stimuli on the electrical resistance of materials.

16. I also have considerable experience studying and working with carbon nanotubes. Specifically, I pioneered and provided international leadership in research on carbon nanofiber, which was originally known as carbon filament (prior to nanomaterials becoming "fashionable"). Carbon nanotube is a type of carbon nanofiber and was also originally known as carbon filament. Below are some of my peer-reviewed journal publications in this field. These publications pertain to the processing, structure, properties and applications of carbon nanotube and related materials.

- Xiaoping Shui, Christine A. Frysz, and D.D.L. Chung, "Solvent Cleansing of the Surface of Carbon Filaments and Its Benefit to the Electrochemical Behavior," Carbon 33(12), 1681-1698 (1995).
- Christine A. Frysz, Xiaoping Shui, and D.D.L. Chung, "Carbon Filaments and Carbon Black as a Conductive Additive to the Manganese

Dioxide Cathode of a Lithium Electrolytic Cell," J. Power Sources 58(1), 41-54 (1996).

- Christine A. Frysz, Xiaoping Shui, and D.D.L. Chung, "Use of Carbon Filaments in Place of Carbon Black as the Current Collector of a Lithium Cell with a Thionyl Chloride-Bromine Chloride Catholyte," J. Power Sources 58(1), 55-66 (1996).
- Xiaoping Shui and D.D.L. Chung, "High-Strength High-Surface-Area Porous Carbon Made From Submicron-Diameter Carbon Filaments," Carbon 34(6), 811-814 (1996); 34(9), 1162 (1996).
- Weiming Lu and D.D.L. Chung, "Mesoporous Activated Carbon Filaments," Carbon 35(3), 427-430 (1997).
- Christine A. Frysz and D.D.L. Chung, "Improving the Electrochemical Behavior of Carbon Black and Carbon Filaments by Oxidation," Carbon 35(8), 1111-1127 (1997).
- D.D.L. Chung, "Comparison of Submicron Diameter Carbon Filaments and Conventional Carbon Fibers as Fillers in Composite Materials", Carbon 39(8), 1119-1125 (2001).
- Weiming Lu and D.D.L. Chung, "Anodic Performance of Vapor-Deprived Carbon Filaments in Lithium-Ion Secondary Battery", Carbon 39(4), 493-496 (2001).

- Junhua Wu and D.D.L. Chung, “Improving Colloidal Graphite for Electromagnetic Interference Shielding by the Use of 0.1 μm Diameter Carbon Filaments”, Carbon 41(6), 1313-1315 (2003).
- Xuli Fu and D.D.L. Chung, "Submicron Carbon Filament Cement-Matrix Composites for Electromagnetic Interference Shielding," Cem. Concr. Res. 26(10), 1467-1472 (1996); 27(2), 314 (1997).
- Xiaoping Shui and D.D.L. Chung, "Submicron Nickel Filaments Made by Electroplating Carbon Filaments as a New Filler Material for Electromagnetic Interference Shielding," J. Electron.Mater.24(2), 107-113 (1995).
- Xiaoping Shui and D.D.L. Chung, "Piezoresistive Carbon Filament Polymer-Matrix Composite Strain Sensor," Smart Mater.Struct.5, 243-246 (1996).
- Steven W. Hudnut and D.D.L. Chung, "Use of Submicron Diameter Carbon Filaments for Reinforcement between Continuous Carbon Fiber Layers in a Polymer-Matrix Composite," Carbon 33(11), 1627-1631 (1995).
- Martin Segiet and D.D.L. Chung, “Discontinuous Surface-Treated Submicron-Diameter Carbon Filaments as an Interlaminar Filler in Carbon Fiber Polymer-Matrix Composites for Vibration Reduction”,

Composite Interfaces 7(4), 257-276 (2000).

- Xinghua Hong and D.D.L. Chung, “Carbon nanofiber mats for electromagnetic interference shielding”, Carbon 111, 529-527 (2017).
- Seungjin Han and D.D.L. Chung, "Strengthening and stiffening carbon fiber epoxy composites by halloysite nanotubes, carbon nanotubes and silicon carbide whiskers", Applied Clay Science, 83-84, 375-382 (2013).
- Yan Chen, David T. Shaw and D.D.L. Chung, "Hydrogen Storage in Aligned Carbon Nanotubes", Appl. Phys. Lett. 78(15), 2128-2130 (2001).
- Yunsheng Xu, Chia-Ken Leong and D.D.L. Chung, “Carbon Nanotube Dispersions as Thermal Pastes”, J. Electron. Mater. 36(9), 1181-1187 (2007).

17. I have no financial interest in Molecular Rebar or the ’483 Patent. I am being compensated for my time spent in connection with these proceedings at an hourly rate. I am also being reimbursed for reasonable expenses, such as travel expenses. My compensation is not contingent on my opinions, on the outcome of any matter, or on any of the technical positions I explain in this declaration.

III. LEGAL STANDARDS

18. I am not an attorney. For purposes of this Declaration, I have been informed about certain aspects of the law that are relevant to my opinions, as set forth below.

A. Patentability

19. I understand that for an invention claimed in a patent to be valid and patentable, it must be, among other things, new and not obvious in light of what was known and came before it. That which was known or came before the invention claimed is generally referred to as "prior art."

20. I understand that there are two ways in which prior art may render a patent claim unpatentable. First, the prior art can be shown to "anticipate" the claim. Second, the prior art can show that the claim was obvious to a person of ordinary skill in the field of the invention at the time the invention was made.

21. I understand that, for a patent claim to be "anticipated" by the prior art, each and every element or requirement of the claim must be found, expressly or inherently, in a single prior art reference. Further, I understand that anticipation requires that the single prior art reference must disclose the elements of the claim arranged or combined in the same way as in the claim.

22. It is my understanding that whether a claimed invention is obvious is a question of law, with underlying factual inquiries that are determined from the

perspective of a person of ordinary skill in the art at the time of the claimed invention.

23. It is my understanding that a claimed invention is obvious if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art (a "POSITA").

24. It is my understanding that obviousness requires consideration of the following underlying factual inquiries:

- determining the scope and content of the prior art
- ascertaining the differences between the claimed invention and the prior art;
- resolving the level of ordinary skill in the art; and
- evaluating objective evidence or "secondary considerations" of non-obviousness, such as experimental results, commercial success, long-felt but unresolved needs, failure of others, industry praise, and unexpected results.

25. It is my understanding that a reference must be analogous art to the claimed invention in order to be properly considered for use in an obviousness inquiry. It is my understanding that a reference is analogous art to the claimed invention if:

- The reference is from the same field of endeavor as the claimed invention (even if it addresses a different problem); or
- The 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).

26. It is my understanding that whether a reference is reasonably pertinent depends on how the problem faced by the inventor is reflected, either explicitly or implicitly, in the specification.

27. It is my understanding that the following are exemplary rationales that may support a conclusion of obviousness:

- Combining prior art elements according to known methods to yield predictable results;
- Simple substitution of one known element for another to obtain predictable results;
- Use of known techniques to improve a similar method or product in the same way;
- Applying a known technique to a known method or product ready for improvement to yield predictable results;
- Obvious to try – choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- Known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives

or other market forces if the variations are predictable to one of ordinary skill in the art; and

- Some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

28. In addition to the above, I understand that a person of ordinary skill in the art may resort to logic, judgment and common sense available to him or her at the time of the invention or prior to the invention to find a claim feature obvious, even if the prior art relied on does not explicitly state or teach that feature. I understand that when common sense is relied on to find a feature obvious, the reasoning for that conclusion must be articulated with sufficient clarity.

29. I also understand that a patent claim is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art. An obviousness determination requires finding both that a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success in doing so. I understand that it is important to be careful not to allow hindsight reconstruction of references to produce the claimed invention, without any explanation as to how or why the references would be combined to produce the claimed invention.

30. I understand that where claim element discloses a narrow range of a characteristic of a chemical compound, a prior art reference disclosing an overlapping, but much larger range, does not necessarily render the limitation obvious if the broader range encompasses versions of the compounds that would have distinct structures or behaviors different from than those in the claimed range. I understand that a POSITA would thus not be motivated to attempt to optimize the broader disclosed range because of those distinct differences in structure and behavior.

31. Regarding "objective evidence" or "secondary considerations," I understand that for such evidence to be relevant to the obviousness of a claim, there must be a causal relationship (called a "nexus") between the claim and the evidence. I also understand that such objective evidence may include: commercial success of products covered by the patent claims; long-felt need for the invention; failed attempts by others to solve the problem addressed by the invention; copying of the invention by others in the field; unexpected results achieved by the invention; praise of the invention; the taking of licenses under the patent by others; expressions of surprise by experts and those skilled in the art at the making or use of the invention; and that the patentee proceeded contrary to the accepted wisdom of the prior art.

32. I understand that a person of ordinary skill is also a person of ordinary creativity. I further understand that the obviousness analysis need not seek out

precise teachings directed to the specific subject matter of the challenged claim, but instead can take into account "ordinary innovation" that does no more than yield predictable results, which are inferences and creative steps that a person of ordinary skill in the art would be understood to employ.

33. I understand that sometimes it will be necessary to look to interrelated teachings of multiple patents and publications; the effects of demands known to the relevant field or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art. I understand that all these issues may be considered to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue.

B. Prior Art

34. I understand that for purposes of this proceeding, prior art includes patents and printed publications (e.g., journal articles) in or outside the United States before the effective filing date of the claimed invention. I also understand that prior art includes U.S. patents, published U.S. patent applications, and published international applications (pursuant to the Patent Cooperation Treaty) that themselves have an effective filing date before the effective filing date of the claimed invention, as long as they name another inventor.

C. Inherency

35. I understand that if a prior art reference does not expressly set forth a particular claim element, the prior art may still disclose that element if it is "inherent" in its disclosure. To establish inherency, it is my understanding that evidence must make clear that the missing descriptive matter is necessarily present in the thing described in the reference. It is my understanding that inherency may not be established by probabilities or possibilities. In other words, it is my understanding that the mere fact that a certain thing may result from a given set of circumstances is not sufficient to establish inherency.

36. I understand that under the principles of inherency, if a prior art device, in its normal and usual operation, would necessarily perform a claimed method, then the method will be considered to be anticipated by the prior art device. I also understand that when the prior art device is the same as a device described in the specification for carrying out the claimed method, it can be assumed that the device will inherently perform the claimed process.

D. Person of Ordinary Skill In The Art

37. I understand that "a person of ordinary skill in the art" or POSITA is a hypothetical person who is presumed to have known the relevant art at the time of the invention. Such a person would necessarily have the capability of understanding any scientific and engineering principles applicable to the pertinent art.

38. I understand that factors that may be considered in determining the level of ordinary skill in the art include, but are not limited to, the following:

a. the educational level of the inventor;

b. the type of problems encountered in the art;

c. prior art solutions to those problems;

d. the rapidity with which innovations are made;

e. the sophistication of the technology; and

f. the educational level of active workers in the field.

39. I understand that a person of ordinary skill in the art is not a real person, but rather is a hypothetical individual having the qualities reflected by the factors above. This hypothetical person has knowledge of all prior art in the relevant field as if it were arranged on a workshop wall and takes from each reference what it would teach to a person of ordinary skill in the art.

40. I understand that a person of ordinary skill in the art is a person of ordinary creativity, not an automaton. In many cases a person of ordinary skill will be able to fit the teachings of multiple prior art references together like pieces of a puzzle.

41. I understand that a person of ordinary skill in the art can collaborate with one or more other persons of ordinary skill in the art for one or more aspects

with which the other person may have superior expertise, experience, and/or knowledge.

E. Claim Construction

42. It is my understanding that claim construction, or the interpretation of the claims of a patent, is ultimately a question of law. I have been informed that claim terms are generally presumed to carry their ordinary and customary meaning. However, I understand that a patent applicant is his own lexicographer and is entitled to provide alternate definitions of words in common usage, but if the patent applicant uses a term that is in common usage without providing an alternate definition, then that term should generally be understood as having its common meaning.

43. I understand that a person of ordinary skill in the art is deemed to read a claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent specification and the "file history" of the patent developed during examination by the Patent Office.

44. I understand that the claims, the specification, and the file history are referred to as "intrinsic evidence," and are to be read as a person of ordinary skill in the art at the time of the invention would have done at the time of the alleged invention.

45. In addition to the intrinsic evidence, I understand that the court or tribunal may also consider other relevant evidence, which is called "extrinsic

evidence," concerning relevant scientific principles, the meaning of technical terms, and the state of the art. Such evidence includes the testimony of qualified expert witnesses. Although extrinsic evidence may be used to resolve ambiguities that may exist after reviewing the intrinsic evidence, I understand that extrinsic evidence cannot be used to contradict a claim construction that is clear from the intrinsic evidence.

46. I understand that some claims are independent, and that those independent claims are complete by themselves. Other claims refer to these independent claims, or other dependent claims, and are "dependent" on those claims. The dependent claims include all of the limitations of the claims on which they depend.

IV. BASES FOR OPINIONS

47. The opinions set forth in this Declaration are my own. In forming the opinions herein, I have considered the Petition for *Inter Partes Review* filed in the IPR proceedings referenced above and exhibits thereto, as well as the additional materials cited in this Declaration (including the exhibits to the Patent Owner's Response cited herein), and my education, training, and experience.

48. My analysis of the materials relating to this matter is ongoing and I will continue to review any new material that is provided to me. This Declaration represents certain opinions that I have formed to date and the bases for those

opinions. I reserve the right to revise, supplement, and/or amend my opinions based on new information presented to me and on my continuing analysis of the materials cited herein or later provided to me.

V. LEVEL OF ORDINARY SKILL IN THE ART

49. I understand that Petitioner's expert, Dr. Yu Zhu, provides his opinion that a POSITA would have at least a Master's degree in materials science, chemistry, chemical engineering, a field relevant to polymer science and engineering, or the equivalent, and at least three years of experience in nanomaterials, electrochemistry, batteries, or polymer related activities. LGES-1003 ¶11.

50. My education and experience exceed that of a POSITA as described above and qualify me to testify as to the knowledge of a POSITA under any reasonable definition. *Supra* Section II ("Background and Qualifications").

51. With these understandings, my testimony herein relates to the knowledge and understanding of a POSITA as of June 23, 2011. I understand this is the alleged "Critical Date" date applied by Petitioner, and I have been asked to use this date for the purposes of my testimony. I have formed no opinion on whether this date is the appropriate date, nor have I been asked to do so. Moreover, even assuming the Critical Date were to be June 21, 2012, my opinions in this Declaration would not change with respect to the understanding of a POSITA at the time of the invention.

VI. CLAIM CONSTRUCTION

52. I understand that Petitioner has not expressly proposed any terms for construction. Consequently, for purposes of this declaration, I apply the plain and ordinary meaning of the disputed terms as they would be understood by a POSITA.

VII. ASSERTED GROUNDS

53. I understand that in IPR2024-01013, Petitioner has asserted two grounds of unpatentability.

54. In Ground 1A, I understand that Petitioner has asserted that Claims 1-4 and 7-18 are obvious over the combination of Ohata and Kavan, further in view of Gong. Specifically, Petitioner contends that it would have been obvious to modify the process described in Ohata based on Kavan, by oxidizing the CNTs of Ohata at the levels taught by Kavan and using an active material that is $LiMnPO_4$ or $LiFePO_4$ as taught by Kavan. Petitioner further contends it would have been obvious to dope the $LiMnPO_4$ or $LiFePO_4$ to replace lithium with another ion based on Gong.

55. In Ground 1B, I understand that Petitioner has asserted that Claims 1-4 and 7-18 are obvious over the combination of Ohata and Kavan, further in view of Liu. Specifically, Petitioner contends that it would have been obvious to modify the process described in Ohata based on Kavan, by oxidizing the CNTs of Ohata at the levels taught by Kavan and using an active material that is $LiMnPO_4$ or $LiFePO_4$ as

taught by Kavan. Petitioner further contends it would have been obvious to dope the $LiMnPO_4$ or $LiFePO_4$ to replace lithium with another ion based on Liu.

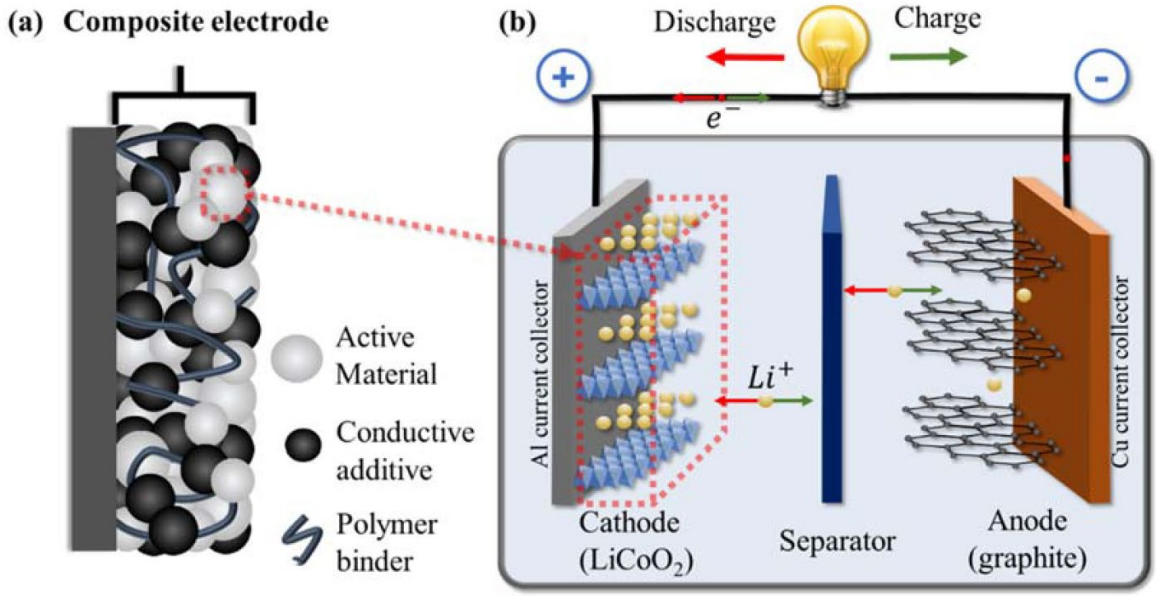
56. In Ground 2, I understand Petitioner has asserted that Claims 1, 2, and 7-18 are obvious over the combination of Ohata and Kavan, further in view of Ichinose. Specifically, Petitioner contends that it would have been obvious to modify the process described in Ohata based on Kavan, by oxidizing the CNTs of Ohata at the levels taught by Kavan and using an active material that is $LiMnPO_4$ or $LiFePO_4$ as taught by Kavan. Petitioner further contends that the "ratio of lithium ion to other total ions in the ion active materials" recited in the independent claims would be obvious based on Ichinose.

VIII. TECHNOLOGICAL BACKGROUND

57. Before addressing the specific grounds asserted by Petitioner, I provide a brief background of the '483 Patent and relevant technology. The '483 Patent is directed toward lithium-ion batteries, particularly compositions that makeup the electrode (either the cathode or anode) of lithium-ion batteries. LGES-1001, 2:37-47.

A. Overview of Electrodes

58. In reference to the schematic below, an electrode (cathode or anode) comprises three key parts: (1) the active material, (2) a binder, and (3) a conductive additive. MRD-2037, 2. The depicted cathode is on a current collector.



Id. The active material (1) is the electrochemically active component that directly participates in the reactions that allow the battery to store and release energy. During discharge, oxidation reaction occurs at the anode, which releases electrons to the cathode via the outer circuit. Thus, the cathode receives electrons from the outer circuit, thereby resulting in a reduction reaction at the cathode. During charge, a voltage is applied at the outer circuit, so that the reverse reactions occur at the two electrodes, i.e., reduction reaction occurs at the anode and oxidation reaction occurs at the cathode. Both electrodes must be in direct contact with the electrolyte, which is a fluid that the two electrodes are immersed in. Preferably, the electrodes are porous, so that the electrolyte can enter the pores in both electrodes, thereby enabling the area of the electrode-electrolyte interface to be high. For some electrochemical systems, such as the lithium ion battery, during charging and discharging, the active

material expands and contracts. Alternatively, the electrolyte can be a solid, but this is not common.

59. The binder (2) acts as a "glue" to hold the active material particles and electrically conductive agent together, as well as to attach the active material to the current collector. The binder thus enables the composition to be an integral mass (rather than loose particles) and provides sturdiness and handleability to the mass.

60. A conductive agent (3) is typically included in the electrode composition to help provide a continuous electrically conductive path in the electrode composition. This path helps ensure that electrons are able to flow from the anode to the external circuit (not shown), and for the electrons to flow from the external circuit to the cathode. If the active material is not conductive or poorly conductive, as in the case of active materials in the form of oxides, a conductive agent is indispensable for increasing the electrical conductivity of the electrode. In the typical case where the binder is not conductive, the binder cannot contribute to the formation of a conductive path and a conductive agent is key to forming a conductive path. The binder also serves to hold the units of the conductive agent together and to hold the conductive agent and the active material particles together. Therefore, a mixture of active material particles, binder and conductive agent is widely used in forming an electrode that is electrically conductive and mechanically sturdy.

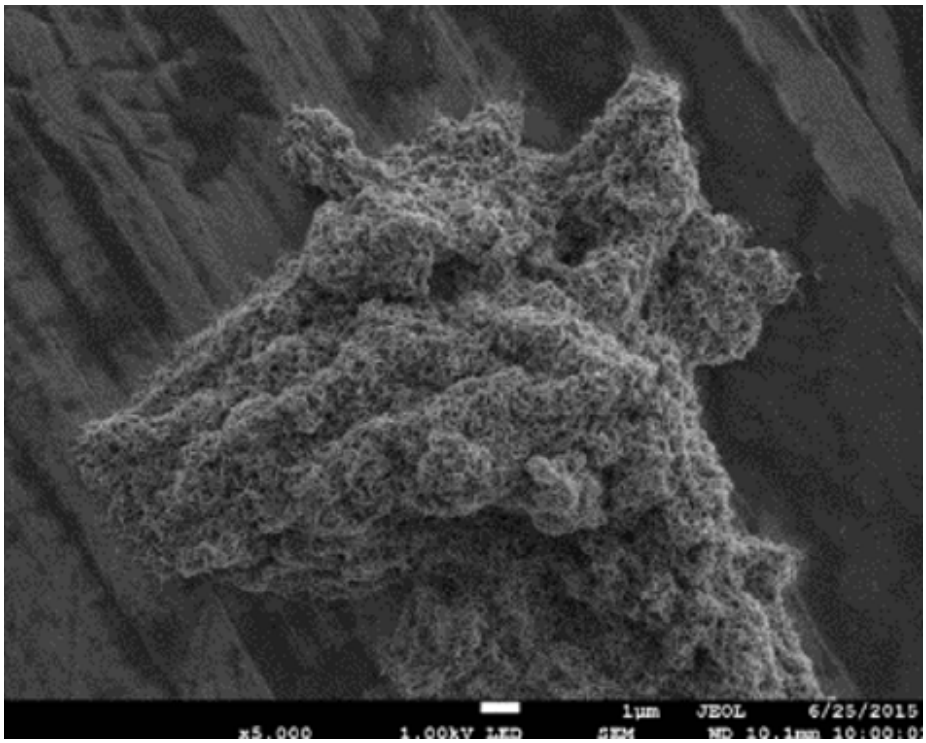
61. The conductive agent is typically in the form of discontinuous units, such as particles, discontinuous fibers, discontinuous nanofibers, and discontinuous nanotubes. The discontinuous nature facilitates the mixing of the constituents in the electrode composition. In order to form a continuous conductive path using such discontinuous units, the units must touch one another. The phenomenon in which the units touch one another to form continuous conductive path is known as "percolation." It is helpful to have multiple paths, so that any discontinuity in one of the paths would not destroy the conduction feasibility in the overall composition. An assembly with multiple conductive paths is typically in the form of a network that involves a large number of contact points among the units of the conductive agent. Each contact point is associated with an electrical resistance, which is undesirable. Having a plurality of conductive paths helps to reduce the overall resistance of the network, but results in more contact points.

B. Efforts to Improve Electrical Conductivity

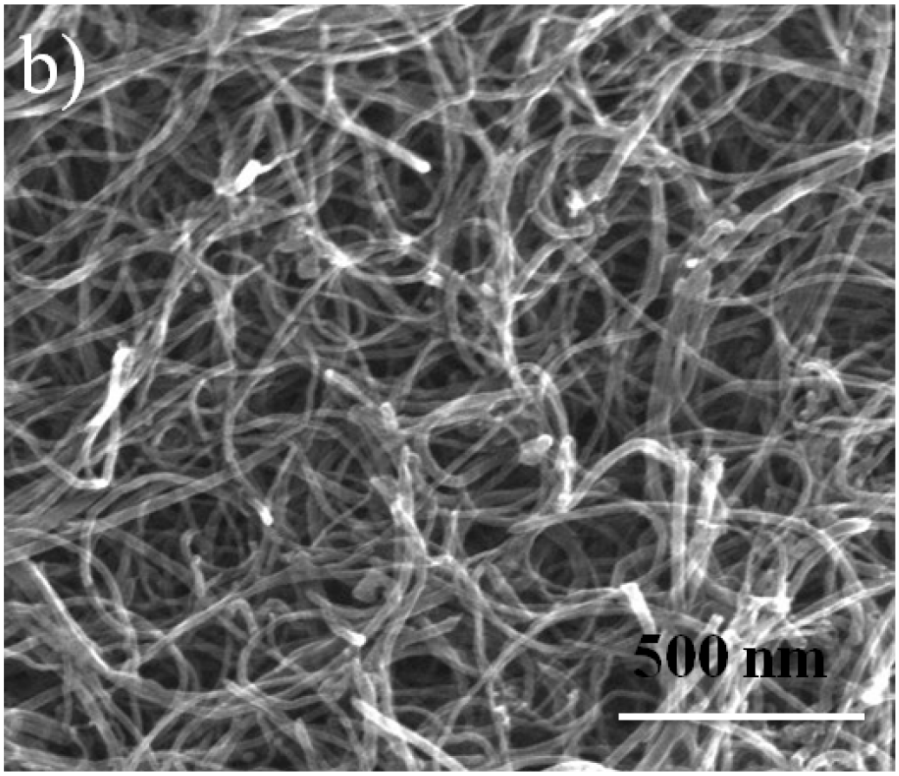
62. At the time of the invention, it was common to use carbon black as the conductive agent to try and form a continuous conductive network in lithium-ion battery electrodes. LGES-1004 ¶[0002]-[0003]. While carbon black particles are inexpensive and can be naturally chained together through Van der Waals forces to form a conductive network, it was known that the chains were susceptible to breaking apart, particularly during the mixing of the constituents in the composition

comprising the carbon black. *Id.* ¶[0003] (explaining that it was known that the shear force applied to carbon black during mixing could break the conductive chain). For this and other reasons, carbon nanotubes ("CNTs") were being explored as an alternative conductive agent. LGES-1011 ¶[0009] (explaining that in prior art methods "carbon nanotubes are used as an electrically conductive additive instead of carbon black").

63. CNTs were of particular interest because of their high electrical conductivity and mechanical strength, making them prime candidates for use as conductive agents. *Id.* ¶¶[0005]-[0006]. Unlike carbon black particles, CNTs are formed as tubes held together by internal bonds that are much more resilient to shear forces and which can more readily provide a continuous conductive path through the composition. However, one of the key challenges with CNTs is that they are created as highly entangled bundles (also called "raw" bundles). *Id*. ¶[0009] (explaining that "the dispersion problem of the carbon nanotubes cannot be completely solved"). A scanning electron microscopy ("SEM") image is provided below as an example of how CNTs present as a highly entangled mass in their raw state.



Another example SEM image is provided below showing how highly entangled raw CNTs present themselves:



MRD-2010, 15 (Fig. 2(b)).

64. This excessive bundling presented several problems, including higher resistance due to the number of CNT-to-CNT contact points and considerable difficulty in dispersing the CNTs throughout the electrode composition. The inability to adequately disperse CNTs throughout the electrode composition can result in agglomeration, leading to local discontinuities (e.g., voids) in the conductive network of the composition. The discontinuities can hinder the formation of a continuous conductive path, thereby degrading the electrical conductivity of the assembly. MRD-2019 ¶[0027] (explaining that agglomeration of CNTs "is undesirable because it results in the formation of voids and aggregates in the composite which adversely affects the electrical conductivity properties of the composite as well as the physical properties of the composite").

65. At the time of the invention, a key focus of those seeking to leverage CNTs as a conductive agent was trying to form the most effective continuous (also called "percolated") conductive network. For example, a Chinese patent application publication ("Cheng") explains that CNTs "can better connect electrode active materials into a continuous 'network' that is electrically conductivity, thereby improving the electrical conductivity of the electrode and utilization rate of the active material." LGES-1011 ¶[0005]. More specifically, Cheng sought to "form a continuously connected three-dimensional electrically conductive network or [p]ore

structure both in the bulk phase and on surfaces of the electrical material." *Id.* ¶¶[0009]-[0010].

66. Similarly, U.S. Patent Publication No. 2012/0058255 ("Gan") likewise teaches that its goal is to achieve a "percolated network" of CNTs that "form a continuous conductive path extending through the composite," which is "believed to be a reason why the electrical conductivity … increases when CNTs are present." MRD-2019 ¶[0041]. Figure 5 of Gan, reproduced below, depicts CNTs that have been dispersed to form a continuous network:

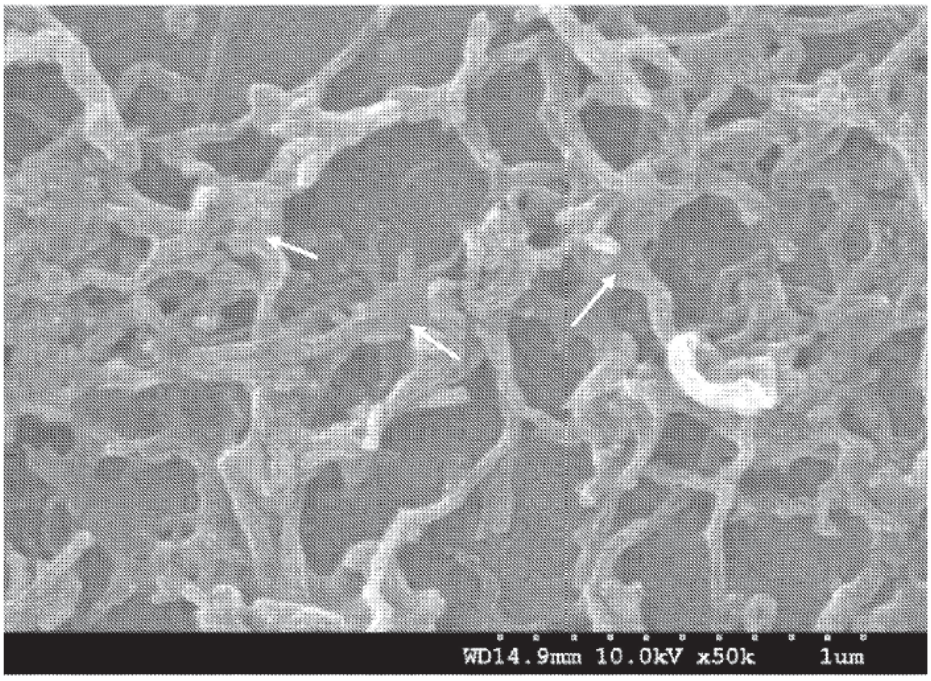


FIG.5

Id., 5. As clearly shown, the CNTs are considerably less entangled than they would

be in their raw bundled form, and they are interconnected to form a continuous network, as was widely sought at the time of the invention. To achieve these continuous networks of CNTs, efforts were made to disentangle and improve the dispersion of CNTs, resulting in a less entangled network of CNTs that was better distributed throughout the overall composition. MRD-2019 ¶¶[0019]-[0021] (explaining that oxidizing CNTs helps improve their solubility and dispersibility to form a better conductive network); LGES-1011 ¶[0010] (explaining that "uniform dispersion of carbon nanotubes" can help form a "continuously connected three-dimensional electrically conductive network structure"). Thus, a primary goal of those of skill in the art prior to the invention was to improve CNT dispersion to achieve a continuous network of CNTs, providing improved conductivity throughout the electrode composition.

C. The '483 Patent

67. While the conventional wisdom at the time was to seek to achieve a network of interconnected CNTs (i.e., a "continuous" network) among active material particles, the inventors made the unconventional discovery that discrete CNTs provide major advantages, particularly when the active material crystals are attached (e.g., ionically or covalently bonded) to the surface of the CNTs via oxidation. LGES-1001, 1:46-58. As the patent explains, "discrete" CNTs are those that are individually dispersed and separate from other CNTs. *Id.* at 1:41-43

(describing "discrete carbon nanotubes" as "individual uniformly dispersed tubes"), 3:53-55 (explaining that "discrete carbon nanotubes" refers to CNTs being "separated to give individual tubes"), FIG. 1 (depicting individual tubes separate from any other tube); *See also* MRD-2007, 8 (defining "discrete" as "separate and distinct; not attached to others; unrelated"); MRD-2024, 11:4-8 (Dr. Zhu testifying that CNTs are discrete "because" they are "fully isolated" from one another), 12:17-13:22 (testifying that "discrete" CNTs are "separated from each other").

68. They discovered that the microcracking of active material crystal—due to expansion and contraction during charging and discharging, severe mechanical vibration, and bending—could be "retarded" by bounding the active material crystals to the surface of discrete CNTs. LGES-1001, 1:46-58. In other words, when the active material (such as a silicon-based active material) undergoes expansion/contraction during charge/discharge, it tends to crack. The discrete CNTs attached to the surface can provide mechanical strengthening, helping to prevent the cracking from occurring. Additionally, having CNTs attached to the surface of the active material particles may also provide a linkage between the fractured parts of an active material particle, thereby promoting the mechanical integrity of the assembly even when cracking has occurred in one or more of the active material particles. MRD-2028 ¶[0042] (explaining how CNTs can provide a "crosslink" on cracked silicon-based active particles). A POSITA would also understand that

discrete CNTs on the surface of the active material particles are able to more freely mechanically interact with the active material than CNTs that are a part of a continuous CNT network, since the CNTs in the continuous network are more mechanically constrained than the discrete CNTs. The inventors also discovered that attaching discrete CNTs to the surface of active material could be used instead of coating the active material with carbon. LGES-1001, 1:59-2:3.

69. Thus, while those in the art at the time were seeking to achieve a continuous network of CNTs for electrodes, the inventors took the opposite approach by seeking to achieve discrete CNTs with the active material particles attached to their surfaces. The '483 Patent teaches that this provides "improved capacity, electron and ion conductivity and mechanical strength," "support and spatial stabilization of" active material particles, "improved heat transfer media to avoid thermally-induced runaway," "structural strength to the paste during manufacturing and high surface area per weight of" active material "to provide good energy density." *Id.* at 2:4-26. "The uniform dispersion of discrete tubes will also provide a more uniform voltage gradient across the cathode or anode layer." *Id.* at 2:26-31.

70. The specification explains how discrete CNTs may be formed. "During the process of making discrete carbon nanotubes …, the nanotubes are cut into segments and the residual catalyst particles that are interior to the carbon nanotubes as received from the manufacturer are dissolved." LGES-1001, 4:6-13. The cutting

of the tubes "helps with exfoliation," which refers to disentangling as between CNTs. *Id.* The inventors also explain that "[p]roper selection of the carbon nanotube feed stock related to the catalyst particle type and distribution in the carbon nanotubes allows more control over the resulting individual tube lengths and overall length distribution." *Id.* at 4:13-16. The inventors discovered that the preferred selection "is where the internal catalyst sites are evenly spaced and where the catalyst is most efficient." *Id.*, 4:16-18.

71. After applying this unique process, CNTs having an aspect ratio of 10-500 are oxidized to add functional groups to their surface, and then the oxidized CNTs are mixed directly with an active material (along with other materials), so that the active material can chemically attach to the added functional groups. LGES-1001, 4:47-62 For instance, in the '483 Patent, Examples 2 and 3 directly mix oxidized CNTs with lithium iron phosphate as the active material, Example 4 directly mix oxidized CNTs with lithium manganese phosphate, and Example 5 directly mix oxidized CNTs with titanium dioxide. *Id.* at 5:10-7:3. In each example, the surface of the oxidized CNTs is fully exposed to the active material, which allows for the active material to attach to the surface of the CNTs via the added functional groups. A POSITA would understand that this forms a strong bond between the active material and discrete CNTs.

72. Thus, the ’483 Patent discloses a process for creating well-dispersed, discrete, oxidized CNTs with active material particles attached to their surface. While improved dispersibility is one factor to achieving discrete CNTs, dispersibility and discreteness are fundamentally different concepts. Indeed, much of the cited prior art focuses heavily on improved dispersibility to achieve a ***continuous*** network of CNTs, which are by definition not discrete because they are interconnected. The inventors’ discovery—discrete CNTs having active material attached their surface, as well as the benefits associated therewith—ran contrary to this conventional wisdom. Achieving discrete CNTs is a fundamentally different concept from achieving a continuous or percolated network of CNTs, as sought by the prior art at the time of the invention.

IX. OPINIONS ON GROUND 1: OHATA-KAVAN

A. Whether Ohata-Kavan Discloses or Renders Obvious Independent Claims 1, 7, 8, and 9

73. As explained in further detail below, it is my opinion that the combination of Ohata-Kavan does not render obvious claim 1, 7, 8, or 9 of the ’483 Patent for various reasons.

1. Overview of Ohata-Kavan

74. I understand that Petitioner describes Ohata as preparing “composites of carbon nanotubes and either positive or negative electrode active materials for use

as electrodes in lithium ion batteries." Pet., 10. While that is true, Ohata is specifically trying to create an improved resin binder by embedding CNTs within the resin matrix to form its masterbatch. LGES-1004 ¶¶[0005]-[0006], [0030]; MRD-2024, 58:5-10 (testifying that Ohata is "embedding" conductive material "within the resin"). Based on Ohata's teachings, it is only after the carbon nanotubes (CNTs) are embedded in the masterbatch resin binder that they are mixed with the active material to prepare the electrodes for the lithium-ion battery. LGES-1004 ¶¶ [0005], [0032], [0046].

75. I begin first with the "Background of the Invention" of Ohata, which teaches:

> An electrode of non-aqueous electrolyte secondary batteries as typified by a lithium ion secondary battery and a lithium ion polymer secondary battery is typically produced by mixing an electrode active material with a conductive material and ***a binder*** to form a paste, which is then applied onto a current collector made of aluminum, titanium, stainless steel or the like, followed by rolling. A conductive material is used to secure the conductivity of an electrode. If the amount of conductive material is large, however, the battery capacity will be decreased.

LGES-1004 ¶[0002].

76. To address the drawback of decreased capacity, Ohata teaches that it was known to perform a "a masterbatch process, whereby a conductive material [e.g., carbon black] is uniformly predispersed ***in a binder***, in the production of a positive electrode…. As a conductive material, carbon black such as furnace black or acetylene black, and powdered graphite are used." *Id.* The "conductive material,"

for example carbon black, is pre-dispersed in the "binder" (e.g., resin) to render the binder more electrically conductive. *Id*. The binder is then mixed with the active material to bind the active material together as part of an electrode mixture material paste. *Id*. Thus, the "masterbatch" in Ohata refers to a binder with embedded conductive material. Notably, Ohata does not describe "uniformly dispers[in]g" the carbon black in the electrode material mixture paste, but rather in the binder that is later mixed with active material. LGES-1004, ¶¶[0002], [0017], [0019], [0022].

77. A POSITA would have been very familiar with binders, which is essentially used as a "glue" that hold the constituent parts of the electrode together, including the active material particles. Because binders are typically resins with high resistivity (i.e., low conductivity), it was common to embed a conductive material (e.g., carbon black) in the resin matrix to increases its electricity conductivity.

78. U.S. Patent No. 8,703,009 (MRD-2008, "Liu-009") provides an example of the type of conductive-glue-like "masterbatch" process that Ohata describes. MRD-2008. The cartoon FIG. 6 of Liu shows "how … active material is glued together by conductive glue" comprising carbon black as the embedded conductive material in PVDF. *Id*., 4:16-17, 11:28-32.

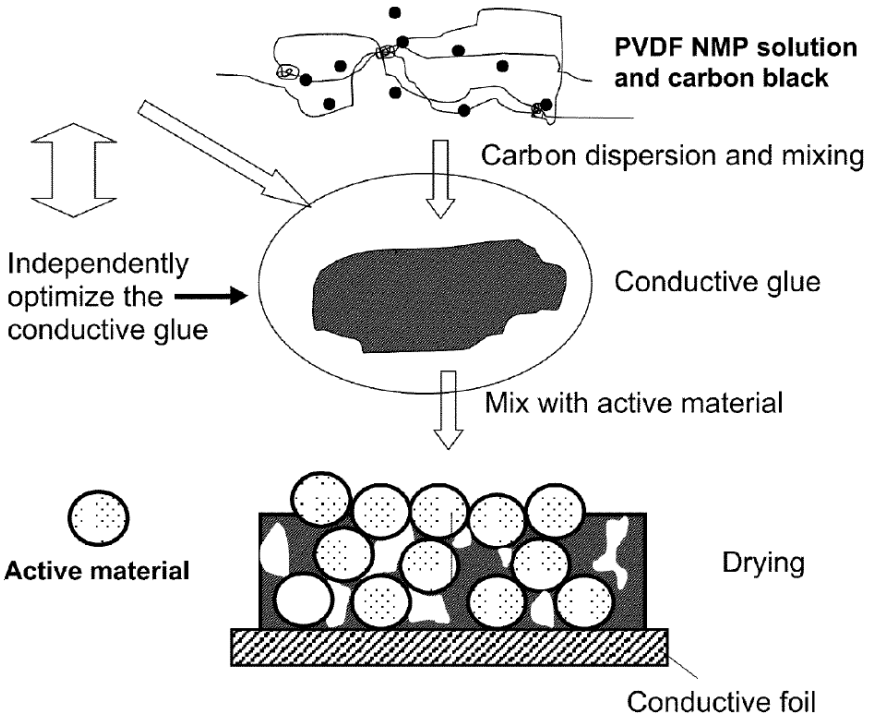


FIG. 6

Liu-009 explains that "[w]hen the carbon conductor and binder are mixed with the solvent NMP, it creates a conductive carbon glue (see Figure 6)." *Id.*, 6:25-29; MRD-2024, 33:21-34:1.

79. A POSITA would understand that having conductive material in the binder, such as carbon black, improves the binder's electrical performance, provided that the units of the conductive material are sufficiently in contact to form a network that provides a continuous electrically conductive path in the binder. MRD-2010, 8. Uniform distribution does not necessarily mean that a continuous network is formed. Ohata teaches that the continuous conductive paths are adversely affected by the local breakage in the paths, thereby degrading the continuity of the conductive paths.

For example, the local breakage of a carbon black network (which consists of carbon nanoparticles, known as primary particles, that are weakly bonded to one another) can occur during blending. LGES-1004 ¶[0003].[1]

80. A POSITA would understand, based on Ohata's teachings, that its primary goal is to address a drawback associated with dispersing carbon black and powdered graphite in a binder. LGES-1004 ¶¶[0002]-[0003]. Ohata teaches that in a masterbatch binder comprising carbon black and powdered graphite, the primary particles of the carbon black "are linked into a chain to form a conductive path," which "is likely to be damaged by shearing force" during the masterbatch process. LGES-1004 ¶[0003]. In other words, the carbon black primary particles are chained together to form a continuous conductive network within the binder. A POSITA would understand that the "chaining" referenced involves Van der Waals forces and, due to the weakness of those forces, the shearing associated with blending may break up the chains in the network of carbon black particles.

81. Ohata teaches that "[f]or this reason, the use of the masterbatch process to uniformly disperse the conductive material in a binder does not yield an electrode superior in conductivity." LGES-1004 ¶[0003]. Ohata thus teaches that the problem

[1] Increasing the aspect ratio of the units of the conductive material (e.g., the aspect ratio of CNTs) increases the chance of touching among these units, thereby increasing the chance of continuous network formation.

it attempts to address involves the breakage of the carbon black chains that are used in the binder that glues the active material particles together. *Id.*

82. "In view of this" drawback, Ohata discloses the steps of "producing a masterbatch: (a) producing a masterbatch comprising at least carbon nanotubes and a resin; (b) blending an electrode material mixture containing at least the masterbatch and an electrode active material with a dispersion medium to prepare an electrode material mixture paste." *Id.* ¶¶[0004]-[0005]. Ohata explains that "[u]nlike carbon black and powdered graphite, a conductive path to be formed by carbon nanotubes is not damaged by shearing force. Thus, even if high sh[e]aring (*sic*) force is applied to the carbon nanotubes during the preparation of a masterbatch, it is possible to obtain an electrode superior in conductivity." *Id.* ¶[0015].

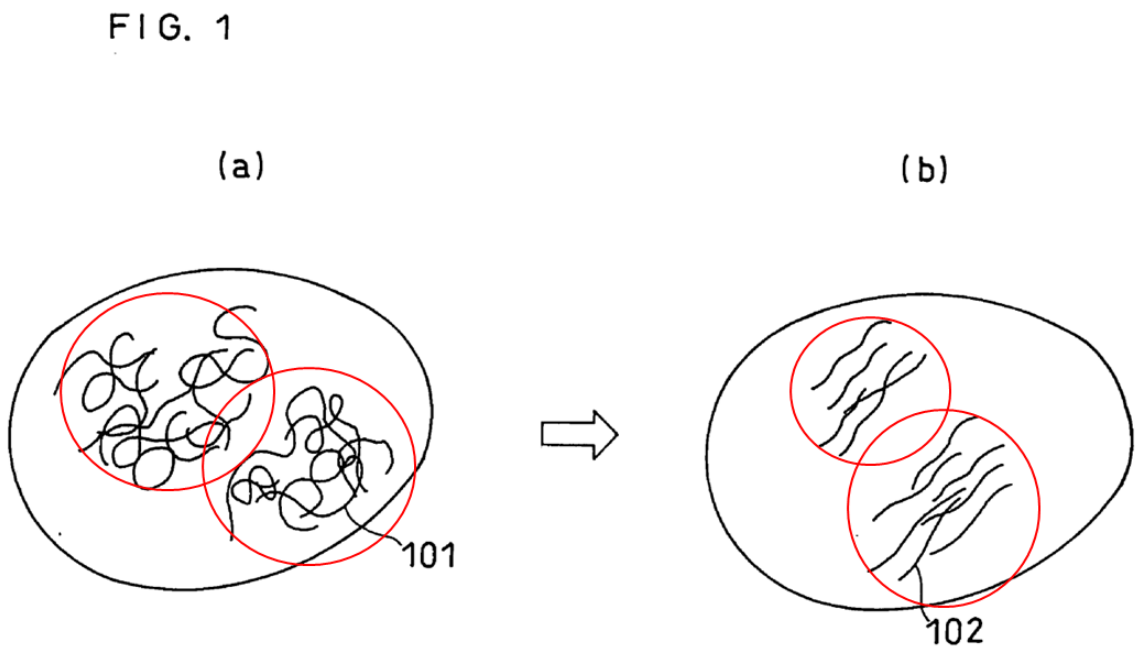
83. This statement from Ohata is consistent with the fact that the carbon-to-carbon bonding along the length of a CNT is a covalent bond, rather than one involving merely Van der Waals forces. Due to this covalent bonding, a CNT is mechanically stronger than a chain of carbon black particles, which are held together by weaker Van der Waals forces. In other words, due to the internal covalent bonding of CNTs, CNTs are physically stronger than carbon black particle chains.

84. In view of the above, a POSITA would understand that Ohata is attempting to create an improved binder—referred to as the "masterbatch"—by pre-dispersing electrically conductive carbon nanotubes in a resin. LGES-1004

¶¶[0004]-[0005], [0015]. The binder is then further mixed with an electrode active material to bind the active material together and form an electrode active material paste. *Id*. ¶¶[0005], [0023].

85. Consistent with these teachings, the first step in all embodiments of Ohata is to prepare the "masterbatch" (i.e., the binder), which is "5 to 20 parts by weight [of carbon nanotubes] per 100 parts by weight of the resin." LGES-1004 ¶¶[0005]-[0006]. In other words, the lowest end of the range is 5% by weight of CNTs to 95% by weight of resin and the highest end of the range is 20% by weight of CNTs to 80% by weight of resin. *Id*. Resin thus makes up the overwhelming majority of the masterbatch binder. *Id*.

86. In reference to annotated FIG. 1(a), which depicts two groups (red circles) of CNTs, Ohata teaches that "carbon nanotubes 101 are tangled and twisted with one another before they are blended with a resin" as part of the masterbatch process. *Id*. ¶[0016]. Ohata contends that during the masterbatch process, the CNTs are "unraveled and straightened by blending them with a resin, as shown in FIG. 1(b)." *Id*.



Ohata, FIG. 1 (annotated by Patent Owner)

87. According to Ohata, one of the purposes of blending CNTs with resin is to unravel and straighten them, which are "expected to form an excellent conductive path," "serve[] to increase the mechanical strength of the electrode plate," and may "produce a secondary battery excellent in cycle characteristics." LGES-1004 ¶¶[0016]-[0017], [0021]. However, a POSITA would understand that there is another very important reason for the masterbatch process—namely to use the masterbatch as a binder with embedded conductive material (i.e., the CNTs).

88. While Ohata provides 15 examples of a positive and/or negative electrode prepared using the masterbatch, **Example 1** serves as the basis for most examples. LGES-1004 ¶¶[0029]-[0047].

89. In **Example 1**, the masterbatch is prepared by blending 15 parts by weight of CNTs and 85 parts by weight of polyvinylidene fluoride ("PVDF") using an extruder. LGES-1004 ¶[0030]. The nanotubes have an average aspect ratio of 100. *Id.* The masterbatch—again consisting largely of resin—is then used to prepare a "positive electrode material mixture paste" by mixing 3.3 parts by weight of the masterbatch with $LiCoO_2$ as an active material and 45 parts by weight of N-methyl-2-pyrrolidone (abbreviated "NMP"), which is used to disperse the masterbatch into the mixture paste. *Id.* ¶¶[[0030], [0032]. The paste is then applied to a substrate to create the electrode plate, which is cut into a predetermined shape to create the positive electrode. *Id*. ¶[0032]. Ohata does not teach mixing additional resin as part of the positive electrode material mixture in this example, but instead relies solely on the masterbatch as the binder. *Id*.

90. The negative electrode is also created, but without using the masterbatch as a binder. LGES-1004 ¶[0034]. Instead, "3 parts by weight of styrene butadiene rubber" is instead used "as a binder." *Id.* A POSITA would thus understand that in Example 1, the positive electrode uses the masterbatch as the binder and the negative electrode uses a different resin binder.

91. **Examples 2 to 8** follow the steps of Example 1, except for the differences reflected in Table 1. *Id*. ¶[0040]. As shown in the table, these examples

also include a masterbatch comprising at least 80 parts resin and at least 15 parts CNTs. *Id*.

92. **Example 9** follows Example 1, except that vinylidene fluoride-hexafluoropropylene copolymer is used as a resin for the masterbatch instead of PVDF. *Id*. ¶[0041].

93. **Examples 10 to 14** follow Example 1, except that the CNTs used have different diameters and aspect ratios as reflected in Table 2. *Id*. ¶[0042].

94. **Example 15** prepares a negative electrode using the same masterbatch from Example 1. LGES-1004 ¶[0046]. The corresponding positive electrode is created using PVDF alone as the binder, instead of the masterbatch. *Id*. ¶[0044].

95. Therefore, Ohata teaches that its "masterbatch," the binder with embedded CNTs, is used to hold the active material together. Indeed, in Example 1 of Ohata, 3.3 parts by weight of masterbatch is used as the binder for the positive electrode material mixture. LGES-1004 ¶[0032]. However, for the negative electrode material mixture, the masterbatch is not used at all. *Id*. ¶[0034]. Instead, 3 parts by weight of styrene butadiene rubber is used as the "binder," in lieu of the masterbatch. *Id*. A POSITA would understand that this is because the masterbatch is the binder in the positive electrode of Example 1, while another binder (styrene butadiene rubber) is used for the negative electrode. MRD-2017 ¶[0009] (discussing Ohata and explaining that its "masterbatch" is the binder for the active material).

96. A POSITA would understand that Ohata's process is fundamentally different than the process described in Kavan. Unlike Ohata, Kavan does not (i) immerse its oxidized CNTs in resin to form a binder as an initial step, and then (ii) mix the resin-covered CNTs with the active materials. Instead, Kavan prepares a "powder precursor material" by first mixing its oxidized CNTs with *water* and an active material powder (TiO_2, $LiMnPO_4$, or $LiFePO_4$) and stirring overnight, which leaves the CNT surfaces exposed (or "naked"). LGES-1005, 2 ("Nanotubes were dispersed in water under short sonication. To this solution a powder material … was added … and stirred overnight. The suspension was subsequently evaporated to dryness. The electrodes were prepared as follows: powder precursor material, either pure or carbon-containing (see above) was mixed with 5 wt% of polyvinylidene fluoride (PVDF) dissolved in N-methyl-2-pyrrolidone."). A POSITA would understand that Kavan mixes naked CNTs with the active material so that the active material can attach to the surface of the CNTs, providing the "anchoring" benefits described by Kavan. *Id.*

97. Thus, in Kavan, the naked oxidized CNTs and active material are pre-mixed into a powder before mixing that powder with the binder, so that the active material can take advantage of the functional groups of the oxidized CNTs. *Id*. This is also true in the '483 patent. LGES-1001, 5:10-28 (Example 1 mixing naked oxidized CNTs with the active material to allow for attachment); LGES-1001, 5:30-

52, 5:54-6:3, 6:15-45, 6:48-7:3 (same in Examples 2, 3, 4, 5, and 6, respectively). Specifically, by leaving the functional groups of the CNTs exposed when mixed with the active material, the active material can "anchor" to the CNTs surface as described in Kavan.

98. In contrast to both Kavan and the '483 patent, the "masterbatch" process of Ohata involves initially embedding the CNTs in a resin as a binder (which prevents the surface of the CNTs from being exposed to the active material), and then mixing the binder (i.e., the masterbatch) with the active material. A POSITA would understand that Ohata considered this to be an important process, because Ohata believed that dispersing naked CNTs with the active material is "difficult taking the dispersibility of the carbon nanotubes in the resin into consideration." LGES-1004, ¶[0021]. Thus, Ohata chose a much different approach to dispersibility that involves embedding the CNTs in the resin binder and then mixing the binder with the active material to achieve better dispersion. *Id*. This is an important fact to keep in mind for purposes of certain of my opinions discussed below.

2. Whether Ohata-Kavan teaches or renders obvious active material that is "attached to the surface" of discrete CNTs.

99. I understand that the Petitioner alleges that the Ohata-Kavan combination results in CNTs with lithium-ion active material "attached to their surface." Pet., 42-44. Specifically, Petitioner argues that the oxidation of the CNTs

creates functional groups on the surface of the CNTs, resulting in ionic bonding between the active material and the surface of the CNTs. Pet., 43. I understand that Petitioner cites to Kavan to support this assertion. *Id.* Thus, I understand that Petitioner relies on the teachings of Kavan alone to support its position that the active material of the Ohata-Kavan combination is "attached to the surface" of the CNTs.

100. I disagree with this assertion, because there is an important and meaningful difference between how Kavan (by itself) and the proposed combination of Ohata-Kavan prepare their electrode material mixtures.

101. In the Ohata-Kavan combination, Petitioner relies on the masterbatch process of Ohata, with the CNTs oxidized pursuant to Kavan. Pet., 18. Therefore, the proposed Ohata-Kavan combination begins with the masterbatch process to initially create a binder with embedded CNTs as taught by Ohata.

102. Kavan, on the other hand, does not teach or suggest any form of masterbatch process, and certainly does not fully submerge its nanotubes in resin as is done in Ohata. Instead, Kavan mixes its naked oxidized CNTs with active material and water, so that the CNTs are fully exposed to the active material to allow the active material to attach to the functional groups of the CNTs. LGES-1005, 2 ("Nanotubes were dispersed in water under short sonication. To this solution a powder material … was added … and stirred overnight. The suspension was subsequently evaporated to dryness. The electrodes were prepared as follows:

powder precursor material, either pure or carbon-containing (see above) was mixed with 5 wt% of polyvinylidene fluoride (PVDF) dissolved in N-methyl-2-pyrrolidone.”).

103. Petitioner’s invalidity theory does not account for the fact that the Ohata-Kavan masterbatch fully immerses and blends the CNTs in fluorocarbon resin as an initial step, which forms the binder used to bind the active material of the electrode mixture together in a paste. LGES-1004 ¶¶[0005], [0022]-[0023]. It appears that the Petitioner and its expert believe that the only reason Ohata is creating the masterbatch is to straighten and unravel the CNTs. Pet., 10-11, 19, 34-37; *see also* MRD-2024, 42:25-44:22 (Dr. Zhu identifying several purposes of the masterbatch, but not identifying serving as a binder as one of those purposes). However, when Ohata is read in the full context of its teachings and the problem it attempts to solve from the prior art, it is clear that the primary purpose of the masterbatch is to act as a conductive binder for subsequent use in holding the active material together.

104. A POSITA would understand that the masterbatch process of Ohata-Kavan results in resin coating the surface of the oxidized CNTs. This coating would prevent the active material from “attach[ing] to the[] surface” of the oxidized CNTs as claimed. Specifically, the coating would prevent the active material from “anchoring” to the functional groups of the oxidized CNTs, and likewise prevent any

form of bonding (including primary bonding and secondary bonding, with the primary bonding including ionic, covalent and metallic bonding, and the secondary bonding including Van der Waals forces and hydrogen bonding) between the active material and the surface of the oxidized CNTs. The resin would be an interposed layer that prevents any type of bonding from occurring. I address this concept extensively in the following passages.

105. A POSITA would understand that when a small proportion of nanotubes (e.g., 5-20 parts by weight) are mixed with a large proportion of fluorocarbon resin (e.g., 100 parts by weight) as taught by Ohata, the nanotubes become embedded within, and are fully coated by, the fluorocarbon resin. LGES-1004 ¶[0006]; MRD-2009, 2 ("In a CNT–PVDF–NMP suspension, PVDF molecular chains would *coat onto CNT surface due to the strong interaction between PVDF and CNTs*."); LGES-1014, 3 (explaining that functionalized CNTs become "***completely covered*** with matrix" when mixed with resin); MRD-2024, 65:21-66:9 (Dr. Zhu testifying that the resin covers a "significant amount" of CNT surface). Numerous objective references prove this point as set forth below.

106. As one example, field emission scanning electron micrographs (FESEM) of a composite of 2% by weight functionalized multi-wall CNTs ("f-CNT") to 98% by weight polyvinylidene fluoride ("PVDF") are depicted below in the excerpt of Figure 2(c)-(d) from MRD-2010:

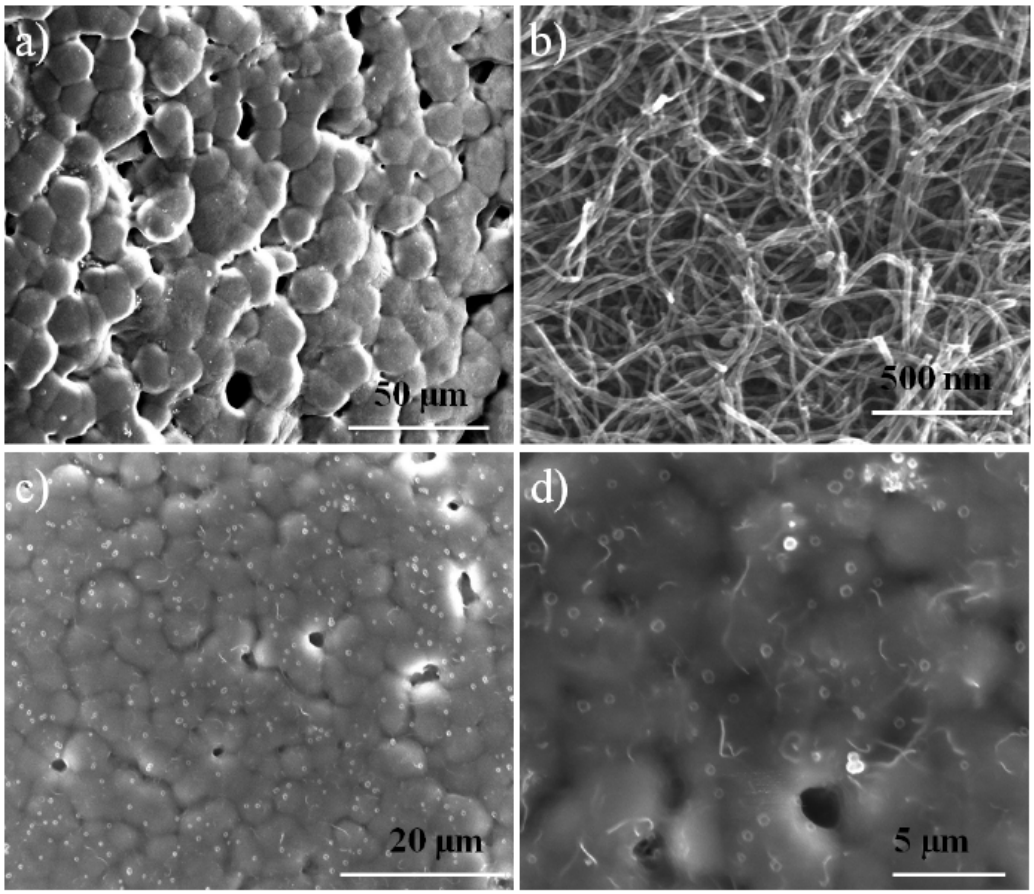


Figure 2 (MRD-2010)

MRD-2010, 15.

107. I first note that PVDF is a fluorocarbon resin used in the masterbatch of Ohata. LGES-1004 ¶[0022]. In Ohata, the fluorocarbon resin is the binder material that the CNTs are embedded within. Figure 2(a) depicts the PVDF. MRD-2010, 15. Figure 2(b) depicts the functionalized CNTs. *Id*. Figures 2(c) and (d) depict the functionalized CNT-PVDF composite, which shows the nanotubes in contact with the PVDF and dispersed by the PVDF. *Id.*, 11-12 ("When sufficient concentration is there, CNTs start forming network and connectivity ***in the matrix***

so that drastic rise in conductivity was observed in the composite.") (Emphasis added). The dark circles in Figures 2(c) and (d) are voids in the PVDF matrix.

108. The CNT networking is not visible due to the resin covering it, but some of the CNTs in the network that are relatively close to the surface of the examined specimen are partly visible, being clearly embedded within the PVDF matrix. *Id*. (explaining that at 2 wt% of CNTs a "conductive network" is formed due to the "percolation behavior"); *Id.* 12 ("microspheres of polymer have been formed throughout the composites and carbon nanotubes are homogeneously dispersed within the polymer 3D scaffold with end to end connections in the polymer."). Additionally, Figures 2(c) and 2(d) are at a fairly low magnification further obfuscating the CNT network just beneath the resin surface that is formed throughout the PVDF.

109. The visibility of those CNTs is likely due to the partial pull-out of the CNTs from the resin surface during the peeling of the composite from its substrate prior to SEM examination of the composite. The pull-out of a CNT causes the protrusion of a limited length of the CNT while the remaining length remains embedded in the PVDF matrix. The pull-out is an artifact resulting from the specimen preparation that involves peeling; it does not reflect the real structure, which is the structure prior to the peeling. At any rate, only a small number of CNTs experienced the pull-out, indicating that the vast majority of the CNTs are not

observed by SEM, due to their being fully embedded in the PVDF matrix. There could be one or more other causes of observing the end regions of embedded CNTs under the SEM. An example of such a cause is the slight chemical etching of the surface of the specimen prior to SEM examination. Since the polymer is more prone to be etched than the CNTs, the etching removes a part of the polymer in the surface region without removing the CNTs, thereby enabling the end regions of the CNTs to be revealed. Note that an SEM can only observe what is on the surface, not what is under the surface.

110. In another example, multi-wall CNTs were ultrasonically dispersed and then mixed with a solution of PVDF in dimethyl sulfoxide[2] to obtain 3%, 5% and 9% by weight of CNTs in PVDF. MRD-2011, 2-3. The 5% and 9% weight percentages fall within the 5 to 20 parts by weight range of Ohata. LGES-1004 ¶[0021]. The FESEM results are depicted below in FIG. 1:

[2] Dimethyl sulfoxide is a solvent, similar to the NMP solvent used in Ohata. LGES-1004 ¶¶[0024], [0032], [0046].

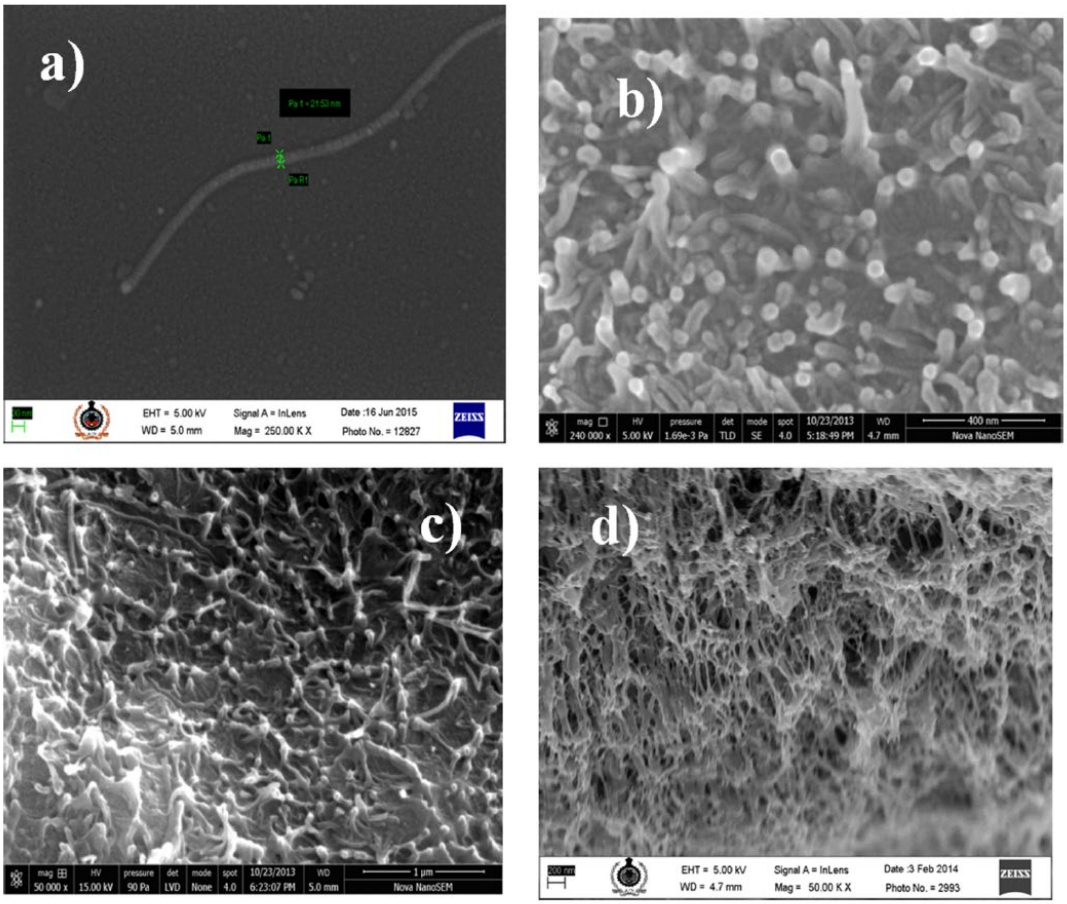


FIG. 1. FE-SEM images of MWCNT in the PVDF matrix. (a) shows a single MWCNT, and images of well dispersed MWCNTs for 3wt%, 5wt% and 9wt% samples in the PVDF matrix are shown in b),c) and d) respectively.

MRD-2011, 3.

111. As shown in FIGs. 1(b)-(d), at all three weight percentages the CNTs are heavily embedded within the PVDF matrix. In FIG. 1(b), the CNTs are partially protruding from the PVDF matrix, such that the protruded length is typically equal to approximately about 3 times (on the average) of the CNT diameter. With the CNT diameter of around 15 nm, the protruded length is around 45 nm on the average. The length of the CNT is around 10–30 μm. Hence, the protruded length ranges from about 0.15% to above 0.45% of the CNT length. This means that the degree of CNT

protrusion is very small and that the vast majority of the CNT length (ranging from about 99.55% to 99.85% of the CNT length) is embedded in the PVDF matrix. The protrusion is likely an artifact resulting from how the SEM specimen is prepared. An example of the SEM specimen preparation method involves slight chemical etching of the SEM specimen surface in order to remove the PVDF matrix at the top surface of the specimen for the purpose of revealing the CNTs. A POSITA would understand that the real structure would have no protrusion, with all the CNTs fully embedded.

112. FIGs. 1(b), 1(c) and 1(d) visibly shows that the CNTs are coated by PVDF. MRD-2011, 3 ("Figure 1 shows the field-emission SEM micrographs of the MWCNTs ***in PVDF matrix***."). In FIG. 1(b) at 400 nm scale, the CNTs with a diameter ~15 nm appear as thick "fingers" having diameter about 50 nm (larger in diameter than the CNTs themselves), suggesting that they are heavily coated by PVDF. *Id.*, 3. In FIG. 1(c) at a 1 μm scale, the nanotubes also appear thick (about 100 nm in diameter), again suggesting the presence of PVDF covering the CNTs. *Id*. In FIG. 1(d) at a 200 nm scale, there are visible CNTs that appear as if they are trapped in a "web," which is the PVDF matrix.[3] *Id*.

113. In another example, an SEM image in FIG. 3(c) depicts 3% by weight of multiwalled CNTs mixed with PVDF:

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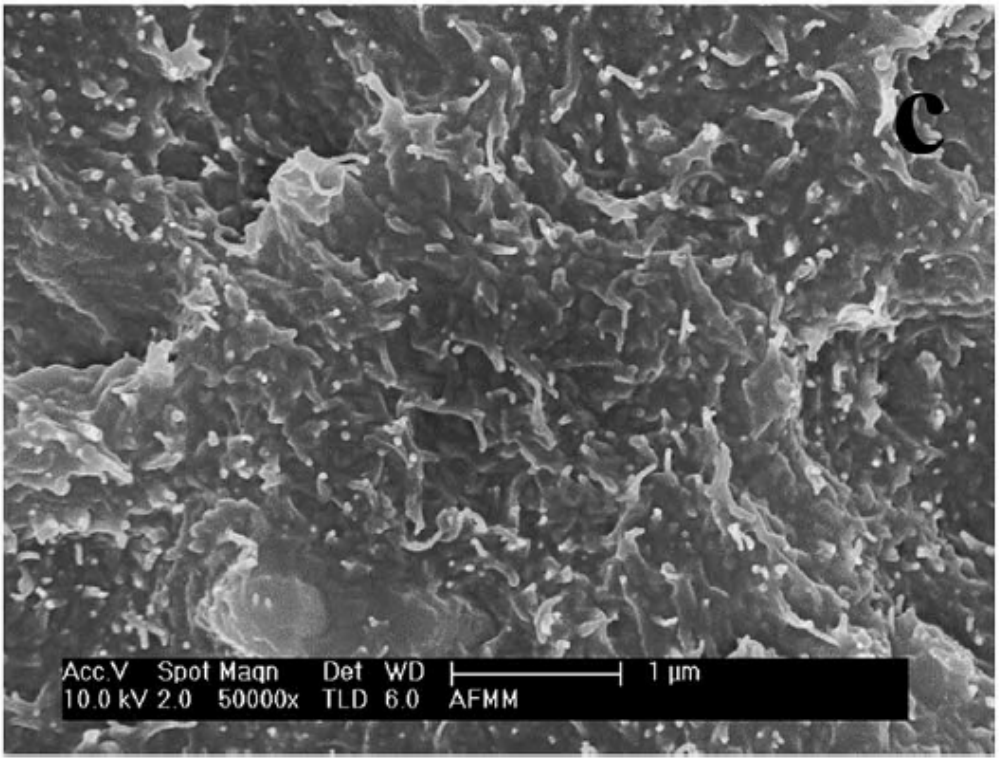
[3] The bottom right of Figure 1(d) is blurred, as it is out of focus. MRD-2011, 3.



MRD-2012, 6. The CNTs appear as if they are embedded within a viscous substance, which is the PVDF matrix. *Id.* Indeed, the reference specifically describes them as "CNTs ***in PVDF matrix***." MRD-2012*,* 3 (emphasis added); *see also* MRD-2013, 3, Figure 2 (showing how PVDF presents as domains of the matrix, even after the flow associated with heating).

114. The foregoing references demonstrate that the masterbatch of Ohata-Kavan would result in oxidized CNTs heavily coated with binder resin to form a viscous "glue" like material, similar to the "glue" depicted in Figure 6 of Liu-009. In fact, Liu-009 explains that when carbon black is mixed with PVDF prior to adding the active material, the PVDF will be "bonded to" the carbon black. MRD-2008,

7:55-62 (explaining that "the binder has previously and preferentially ***bonded to the CB [i.e., carbon black]***").

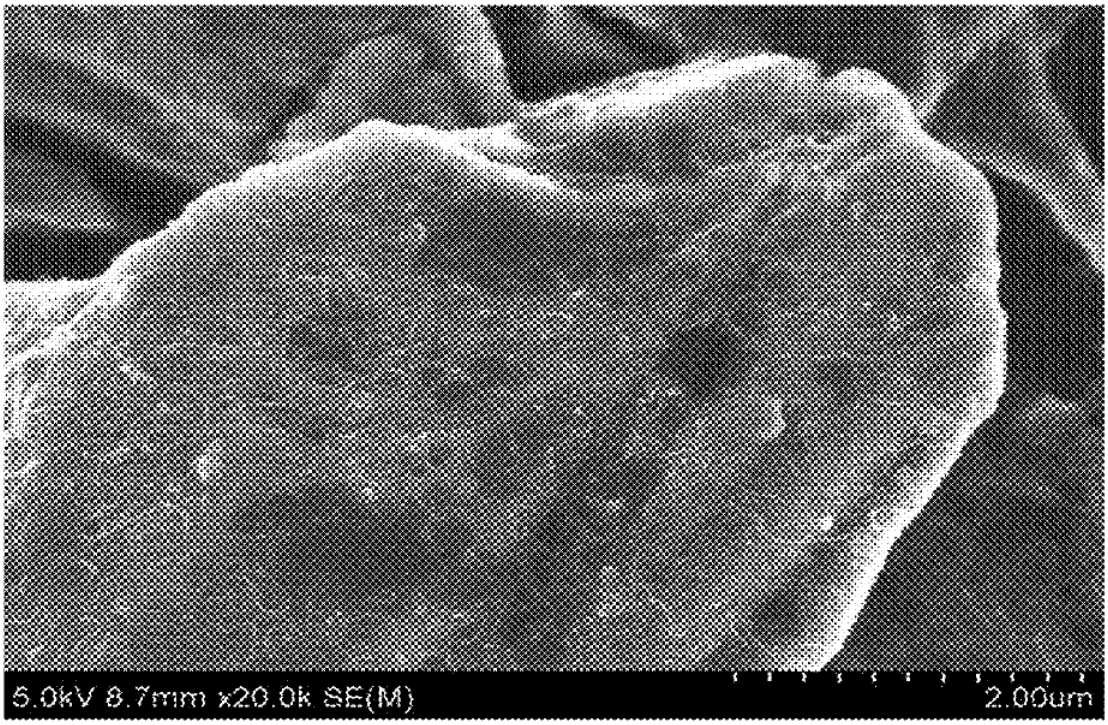
115. A POSITA would understand that PVDF molecules likewise bond to oxidized CNTs. Specifically, PVDF and oxidized CNTs attract one another due to the dipole-dipole interaction between the highly polar fluorine-carbon covalent bonds of the PVDF molecules and the presence of functional groups (including functional groups with polar covalent bonds) on the surface of the oxidized CNTs. This interaction allows for significant interfacial adhesion between PVDF and oxidized CNTs. In other words, the oxidized CNTs would not only be embedded and coated with the PVDF matrix, but the PVDF coating would be more strongly bound to the oxidized CNTs due to the interaction. MRD-2009, 2 ("In a CNT–PVDF–NMP suspension, PVDF molecular chains would *coat onto CNT surface due to the strong interaction between PVDF and CNTs*."). I note that Dr. Zhu testified that he was unaware of this interaction between PVDF and the surface of oxidized CNTs. MRD-2024, 45:16-46:14.

116. Therefore, a POSITA would understand that the proposed combination of Ohata-Kavan would result in a masterbatch comprising oxidized CNTs that are coated with, and embedded within, the fluorocarbon resin matrix. This is the intentional design of Ohata, because the masterbatch acts as the binder ("glue"), but with embedded CNTs to improve binder conductivity. Thus, the goal of Ohata is to

achieve CNTs embedded within and coated by the resin particles, while the exterior of the binder remains exposed to the active material to glue the active material particles together, thereby enhancing the mechanical behavior of the electrode as a whole.

117. As a comparison point, Figure 4 of U.S. Patent Publication No. 2024/0274804 provides an example of CNTs in contact with the surface of an active material particle:

FIG. 4



MRD-2028 ¶¶[0114]-[0115]. However, this example follows a process more similar to Kavan's, where the naked CNTs were mixed simultaneously with the active material—not a "masterbatch" process that immerses the CNTs in resin before

mixing the CNTs with the active material. MRD-2028 ¶[0108]. The result shown above—where the CNTs are in contact with the active material—is simply not possible in Ohata-Kavan due to its unique masterbatch process. Ohata-Kavan thus cannot attach as claimed.

118. A POSITA would understand that the subsequent steps of Ohata-Kavan do not remove or eliminate the resin coating on the CNTs. After the Ohata-Kavan masterbatch is prepared, it is used to prepare the electrode material mixture paste. LGES-1004 ¶[0005]. The step involves using the masterbatch as the binder by mixing the masterbatch with a dispersion medium (such as NMP) and active material particles to form the electrode material mixture paste. LGES-1004 ¶¶[0023]-[0024], [0046]. For instance, in Example 1 for the positive electrode, Ohata discloses mixing 3.3 parts by weight of the masterbatch with 100 parts by weight of active material and 45 parts by weight of NMP. LGES-1004 ¶[0032]. NMP is a solvent that disperses the PVDF by dissolving it to break the matrix up into PVDF domains[4] so that they can be dispersed throughout the electrode material mixture, providing localized glue-like bonds between adjacent active material particles. LGES-1004 ¶[0046] (referring to NMP "as a dispersion medium").

[4] PVDF domains can be thought of as islands of PVDF matrix with entrained CNTs. The domains can be spread throughout a composition to disperse the binder throughout.

119. This dispersion results in smaller binder particles throughout the electrode mixture, but the CNTs are still embedded within and coated by the PVDF (which is bonded to the CNTs). A POSITA would understand that the Ohata-Kavan masterbatch process does not teach or suggest filtering PVDF after creation of the material mixture, which would be required to eliminate the PVDF domains from the electrode material mixture paste. MRD-2024, 41:5-25 (Dr. Zhu testifying that the resin is not eliminated). A POSITA would understand that using an organic solvent (e.g., NMP) to disperse PVDF embedded with CNTs would still leave the conductive agent "coat[ed]" with the PVDF. MRD-2015, 1:31-34 ("PVDF dissolved in the organic solvent ***tends to coat particles*** of the active material and ***the conductive agent,*** so that PVDF is not distributed effectively between these particles.") (Emphasis added).

120. I cite to additional references that further demonstrate this. FESEM images Figures 2 and 3 (reproduced below) show that even after PVDF and CNTs have been mixed with NMP, the CNTs are still embedded within, and coated by, the PVDF:

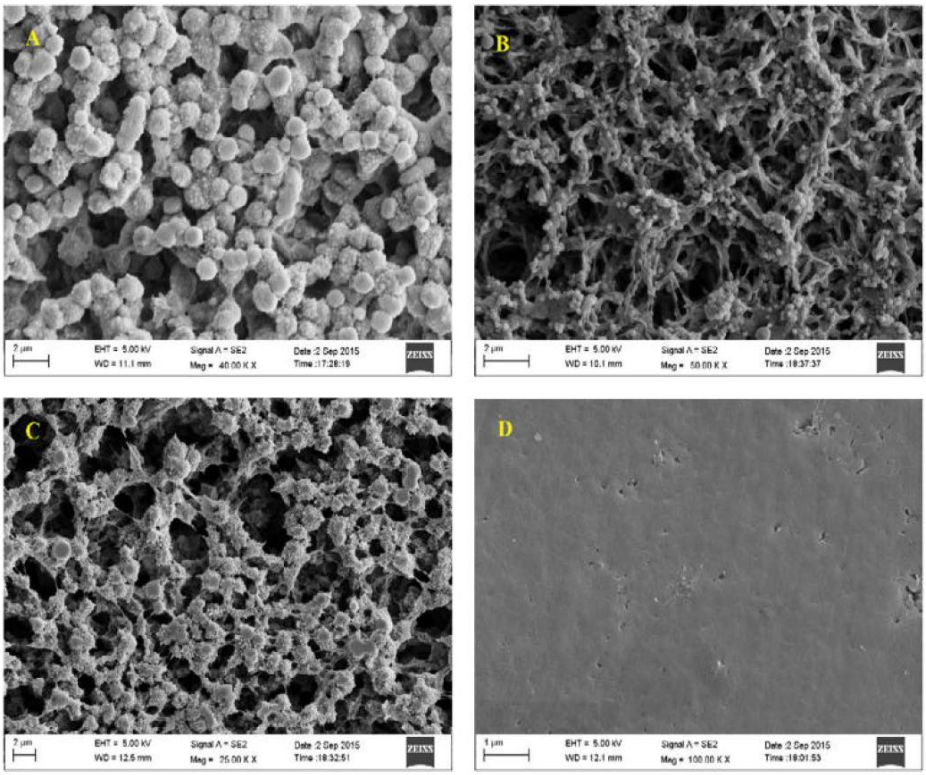


Fig. 2. (A–D): FESEM image of (A) PVDF, (B) PVDF with CNT, (C) PVDF with carbonic acid functionalised CNT and (D) PVDF with sulphonic acid functionalised CNT.

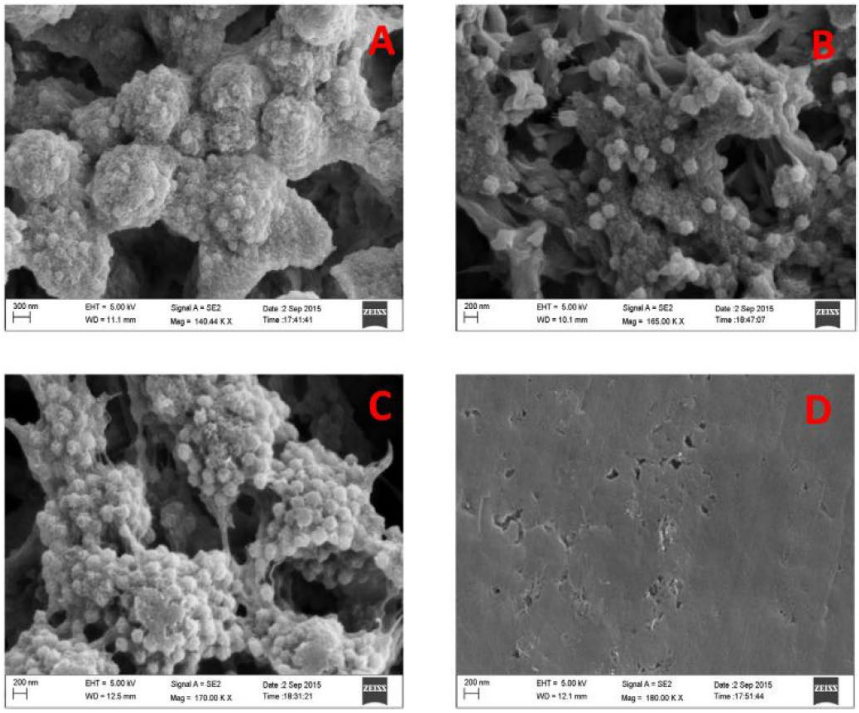


Fig. 3. (A–D) High Magnification FESEM image of (A) PVDF, (B) PVDF with CNT, (C) PVDF with carbonic acid functionalised CNT and (D) PVDF with sulphonic acid functionalised CNT.

MRD-2014, 8. The "grainy" features in Figs. 2(B), 2(C), 3(B) and 3(C) are the CNT-containing PVDF domains. Additional, higher magnification FESEM images shown in Fig. 3 depict the PVDF matrix coating the CNTs more clearly.

121. Similarly, once the CNTs of the Ohata-Kavan masterbatch are blended with the resin, the entire surface of the CNTs becomes covered with resin (e.g., PVDF), which is not removed by the solvent (e.g., NMP) used during the electrode material mixture process. Rather, the solvent simply disperses the PVDF as domains, which still have the CNTs embedded within them.

122. An SEM image of CNTs is shown in Figure 2(f) below and an electrode comprising CNTs (2% by weight), PVDF (3% by weight), and lithium iron phosphate (95% by weight):

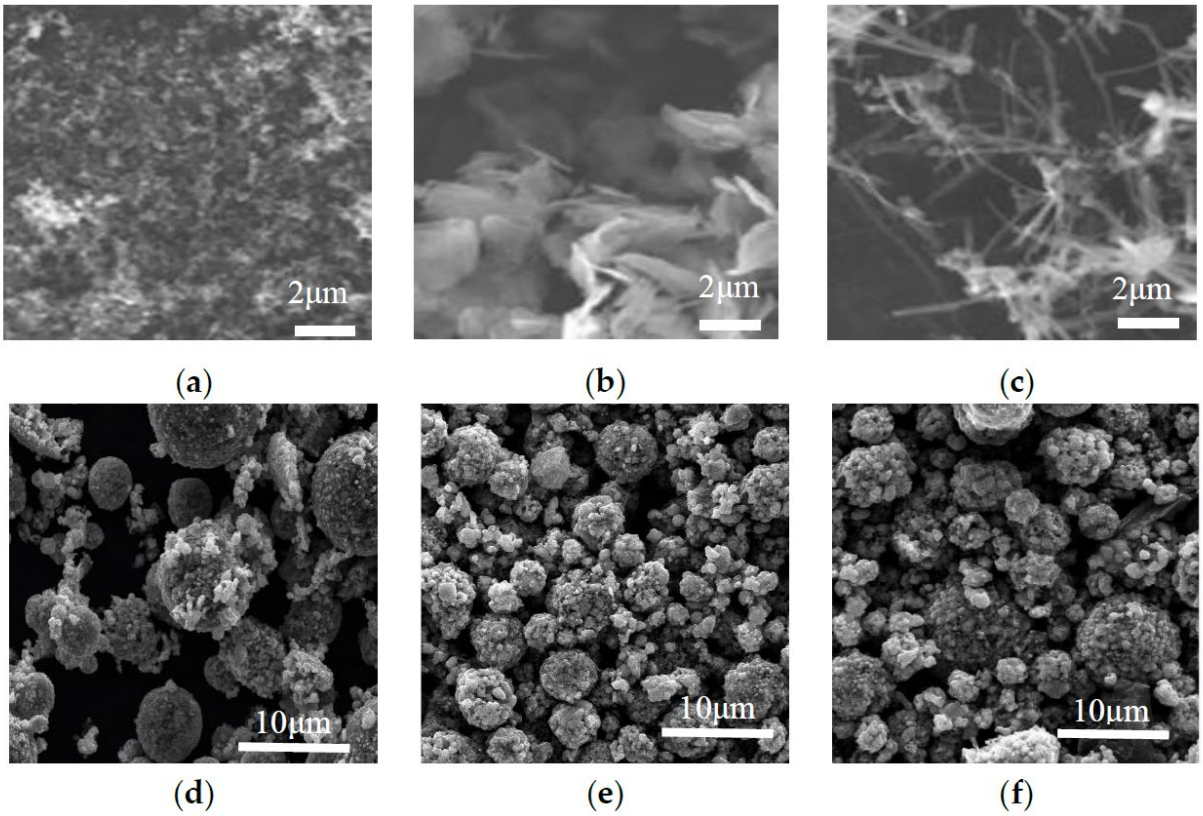


Figure 2. SEM of conductive agents and electrodes with different conductive materials: the surface morphologies of Super-P and KS-15 (**a**); the surface morphologies of graphene (**b**); the surface morphologies of carbon nanotube (**c**); the electrodes image of Super-P and KS-15 (**d**); the electrodes image of graphene (**e**); the electrodes image of carbon nanotubes (**f**).

MRD-2016, 2, 4. A POSITA would understand that the CNTs are not visible in Figure 2(f), because they are entrained in the PVDF domains interspersed between (among) the active material particles. Although this process does not follow the "masterbatch" process of Ohata, the results here demonstrate that mixing NMP solvent with PVDF resin does not eliminate the PVDF domains or coating that exists. Indeed, in Ohata-Kava, the CNTs are fully coated with resin before mixing with the active material and solvent, meaning a POSITA would expect the CNTs of Ohata-Kavan to be fully covered in the resin matrix.

123. Another example, U.S. Patent Application Publication No. 2014/0319429 ("Nicolas-429") specifically identifies drawbacks of the masterbatch process of Ohata. MRD-2017 ¶¶[0009]-[0010]. Nicolas-429 proposed its own "masterbatch" process. *Id*. In Example 3, the process uses "5% by weight of CNTs, 1% by weight of PVP, 0.8% by weight of PVDF and 93.2% by weight of NMP" to form a paste, which is then mixed with $LiFePO_4$. *Id.* ¶¶[0111]-[0118]. As shown in Figure 2 below, domains of PVDF exist despite the use of a solvent (NMP) to disperse the PVDF:

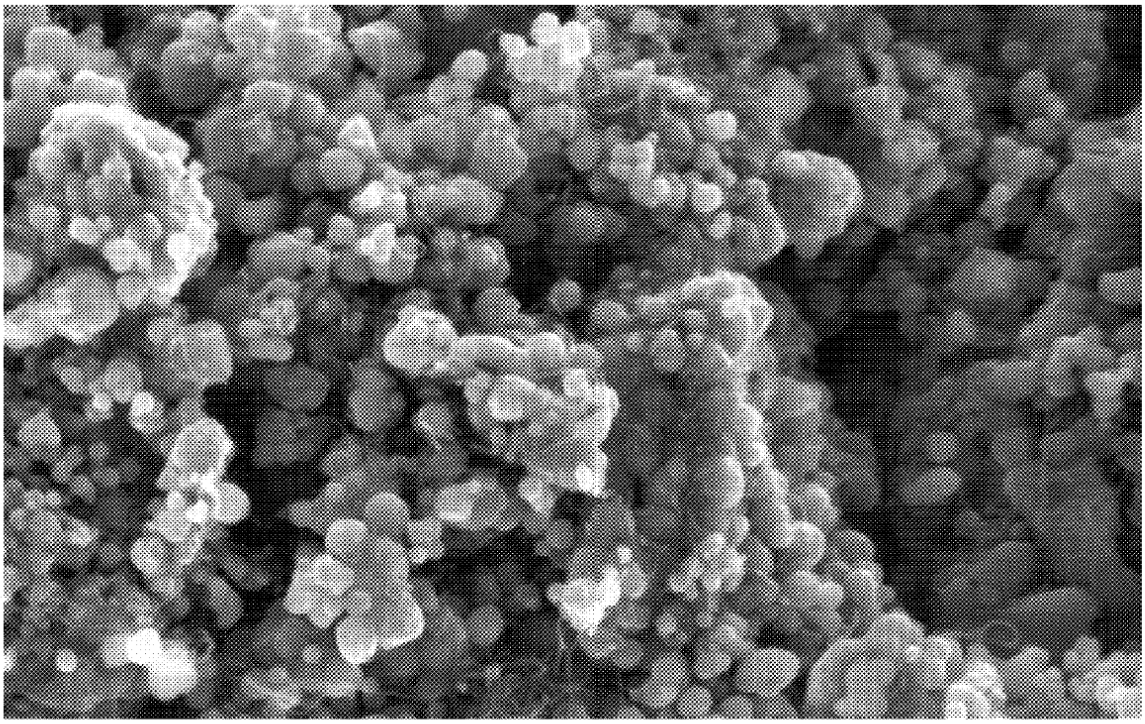


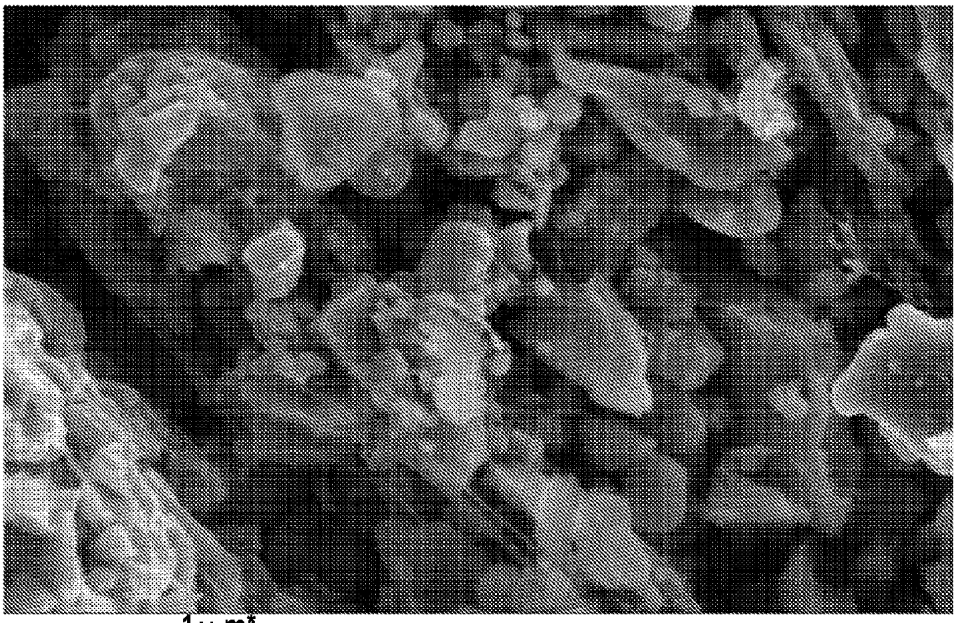
FIGURE 2

MRD-2017, ¶[0123]. Nicolas-429 explains that FIG. 2 "showed that CNTs are well dispersed ***around*** the micrometric $LiFePO_4$/C particles." *Id.* A POSITA would

understand that they are "around" the particles but not attached to the particles, because they are embedded within the PVDF domains that prevent the active material from attaching to the surface of the CNTs. A POSITA would likewise expect Ohata-Kavan to also result in CNTs embedded within PVDF domains such that the PVDF coating would prevent the attachment of the active material particles to the surface of the CNTs from occurring.

124. Another reference, U.S. Patent Publication No. 2011/0256454 ("Nicolas-454"), also references Ohata's masterbatch process. MRD-2018, ¶¶[0010]-[0011]. In FIG. 2A and 2B, Nicolas-454 provide SEM images of its own masterbatch (comprising CNTs and PVDF) that is mixed with NMP and an active material ($LiFePO_4$):

FIG. 2A



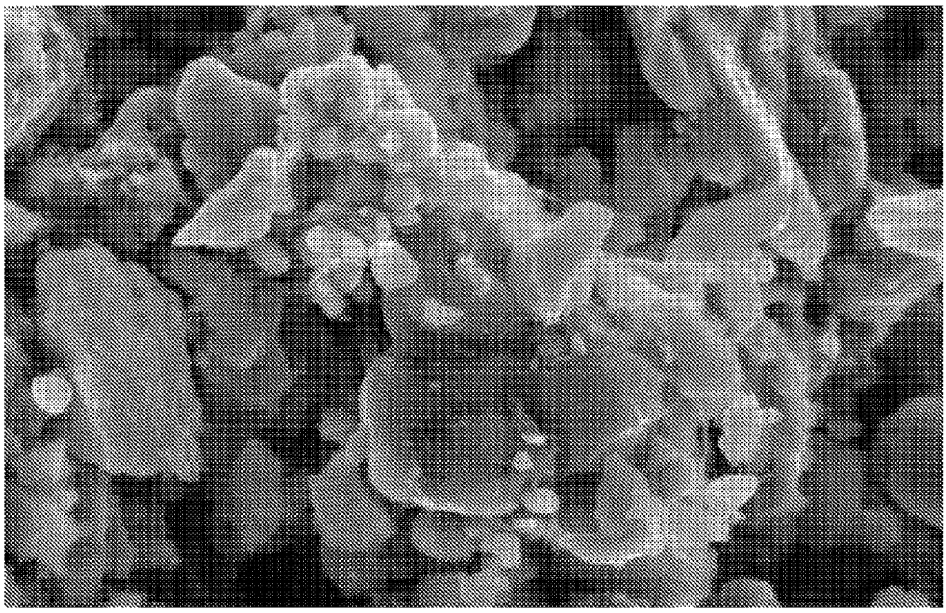
Mag = 50.00 KX 1μm* Sample ID= EHT = 5.00kV

Output To = Default PrinterDate: 22 Feb 2010

File Name = YL-1035-015-minicer tranche-05.jpg GRL

WD = 3.9mm Aperture Size= 30.00μm Detector = InLens User Name = PORTAIL

FIG. 2B



Mag = 50.00 KX 1μ m* Sample ID= EHT = 5.00kV
Output To = Default Printer Date: 22 Feb 2010
File Name = YL-1035-015-minicer tranche-12.jpg GRL
WD = 4.1mm Aperture Size= 30.00μm Detector = InLens User Name = PORTAIL

MRD-2018, ¶¶[0121]-[0131]. The CNTs are fully embedded within the PVDF domains, which is why they are not visible. *Id*.

125. As one final example, Figure 13 of MRD-2020 provides an SEM image of "cathode particles with adhering PVDF/carbon black clusters" after NMP mixing:

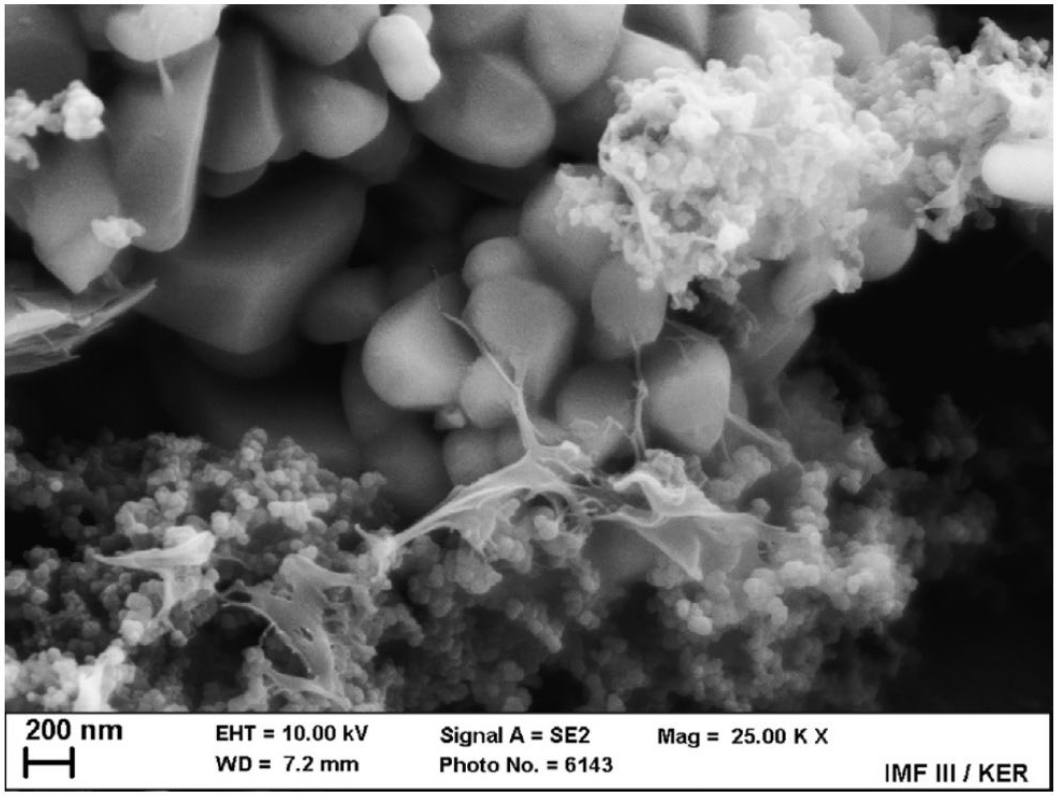


Fig. 13. SEM micrograph of a NMC cathode particles with adhering PVDF/ carbon black clusters.

MRD-2020, 7. The carbon black clusters are clearly depicted as being entrained in the PVDF domains, which present as web-like or cloudy structures that the carbon black particles are embedded in. The article explains that the "binder and CB ***form a film*** which provides an interconnecting conductive network and simultaneously links the NMC particles together. This is also consistent with the results of Zheng et al. [27], where ***the PDVF consuming effect*** of carbon nanoparticles was depicted."

Id. at 6-7.[5] Indeed, the article states that mixing CB with the binder first results in "gel formation." *Id.* at 5. The article teaches that there is a "PVDF polymer layer" that "prevents direct contact of particle surfaces," consistent with a POSITA's understanding that the masterbatch process of Ohata-Kavan would result in CNTs coated in resin, thereby preventing the active material particles from attaching to the surface of the CNTs. *Id.*, 6.

126. All of the foregoing publications demonstrate that oxidized CNTs made based on the masterbatch process of Ohata-Kavan would be fully embedded within, and coated by, the resin matrix, which would prevent the active material from attaching to the surface of the CNTs. Instead, the active material would essentially be "glued" to the surface of the resin layer separating the active material from the surface of the CNTs. The resin layer can be as thin as a single layer of molecules, and it suffices to make it scientifically impossible for the active material to attach to the surface of the CNTs. In other words, the resin layer, however thin, scientifically precludes the attachment from occurring.

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[5] Figure 14 of MRD-2020 is an SEM image of "a sample of NMC and carbon black were blended in a high speed dry mixer (Hosokawa Micron NobiltaNOB-130, Japan) at 2800 RPM for 10 min before being dispersed in the binder solution." MRD-2020, 3. Thus, there is no binder in that figure.

127. It is my opinion that Petitioner's obviousness analysis overlooks this critical fact and incorrectly assumes that the sole reason for the "masterbatch" process of Ohata-Kavan is to create discrete CNTs.[6] A POSITA would understand that the primary purpose of the masterbatch of Ohata-Kavan is to act as a binder, and that the claimed attachment of the active material to the surface of the CNTs would not be able to occur because the resin fully coats the surface of the CNTs during the masterbatch process. Unlike the '483 Patent and Kavan, which expose naked oxidized CNTs to the active material during mixing to allow for attachment, Ohata-Kavan covers the CNTs with resin, preventing the claimed attachment from occurring. It is thus my opinion that even if a POSITA would have found it obvious to combine Ohata-Kavan as proposed by Petitioner, the combination would not meet this claim limitation.

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[6] Dr. Zhu essentially testified that the order of mixing components for an electrode is irrelevant, as the result will be the same. MRD-2024, 50:7-51:4. He is mistaken, because the order of mixing steps when making a chemically complex lithium battery composition is very important to the structure of the final composition. Cooking is an apt analogy, as anyone that has ever baked understands that the order of mixing ingredients can fundamentally alter the meal being made.

3. Whether a POSITA would be motivated to combine to obtain "oxidation levels from 1% to 15%" based on Kavan.

128. I understand that Petitioner provides several reasons it believes that a POSITA would have found it obvious to oxidize Ohata's CNTs at the oxidation levels taught by Kavan. Pet., 21-24.

129. It is my opinion that a POSITA would not have had a motivation to oxidize the CNTs of Ohata pursuant to Kavan, because he or she would have readily understood that the masterbatch process of Ohata-Kavan would mitigate the benefits described by Kavan. Specifically, the functional groups associated with the oxidization would be completely covered in resin, preventing the lithium-ion active material (TiO_2, $LiMnPO_4$, or $LiFePO_4$) from "anchoring" to the surface of the CNTs as described by Kavan. *Supra* IX.A.2. A POSITA would have found it illogical to oxidize Ohata's CNTs based on Kavan, given that the masterbatch process would destroy all of the oxidation benefits described by Kavan.

130. A POSITA would have also understood that oxidizing CNTs adversely affects their desirable intrinsic properties, which would further discourage a POSITA from oxidizing as taught by Kavan. It was known that "while a greater degree of functionalization may improve the dispersibility of the CNTs, such improvement may come at a decrease in intrinsic properties of the pristine CNTs." MRD-2019, ¶[0024]. It was not only known that oxidation of CNTs shortens them, but also that it damages the structure of the pristine CNTs and reduces their electrical

conductivity. LGES-1009, 1-2 (describing shortening of tubes and damage to tube sidewalls); *see also* MRD-2024, 19:13-17, 22:1-24:3 (Dr. Zhu acknowledging negative effects of oxidizing CNTs). For example, oxidation creates defects in the CNTs sidewalls, degrading their electrical conductivity properties. These defects can also cause "unzipping," which occurs when the CNTs are opened up to form a roughly flat, ribbon-like structure rather than a tube structure. Although a POSITA may have determined, as Kavan did, that the benefits of "anchoring" provided by oxidation offset these drawbacks, those benefits simply do not exist in Ohata-Kavan due to the masterbatch process covering the CNTs in resin.

131. I understand that Petitioner offers several reasons that a POSITA would have found it obvious to oxidize the CNTs of Ohata at the levels described by Kavan. It is my opinion that these reasons erroneously ignore the effects of the masterbatch process of Ohata-Kavan, as explained further below.

132. Petitioner's "first" reason is that when a phosphate olive is used as the active material, "electrochemical performance of an electrode is improved by the presence of oxidized nanotubes." Pet., 21-22. This reason is premised on the active material being able to "anchor" to the functional groups of the oxidized CNTs, thereby providing the benefits described by Kavan.

133. In Kavan, this anchoring occurs because the naked oxidized CNTs are *mixed directly* with the active material in water. LGES-1005, 2. Likewise, the '483

patent teaches mixing naked oxidized CNTs with the active material to facilitate attachment. *See e.g.*, LGES-1001, 2:4-16; 5:15-24. However, in contrast to both Kavan and the '483 Patent, in Ohata-Kavan, the CNTs are *first* covered in resin during the masterbatch process as taught by Ohata, which prevents this anchoring effect from occurring. LGES-1004, ¶¶[0005], [0012], [0015]-[0016], [0030]. Consequently, in my opinion, Petitioner's above-stated first reason does not support a motivation to oxidize as taught by Kavan. Instead, a POSITA would have readily appreciated that the oxidation benefits described by Kavan would be inapplicable to Ohata-Kavan because of the unique masterbatch process, which fully covers the CNTs in resin to prevent any such anchoring from occurring.

134. Petitioner's second reason is that "a POSITA would have been motivated to use oxidized nanotubes in furtherance of Ohata's goal to have well-dispersed nanotubes in the composite." Pet., 22. As with the first reason, this reason also overlooks the critical fact that Ohata-Kavan would cover the CNTs (and their associated functional groups) in resin. A POSITA would understand that the improved dispersion described in Kavan is due to the functional groups interacting with water. Specifically, the functional groups added via oxidation are polar, hydrophilic functional groups (e.g., —COOH or —OH) on the surface of the CNTs, which enhances the CNTs' interaction with water, helping to reduce aggregation and promote better dispersion. MRD-2024, 27:17-28:5 (Dr. Zhu discussing how

functional groups are hydrophilic). In Ohata-Kavan, the naked oxidized CNTs are not exposed to water, but instead are first covered in resin. Because Kavan only teaches that naked oxidized CNTs mixed with water can help improve dispersion, Kavan does not support the assertion that oxidizing the resin-covered CNTs of Ohata-Kavan would improve dispersibility.

135. Additionally, even if oxidation generally would have been understood to help disperse CNTs in the resin of Ohata-Kavan, I understand that Petitioner's only basis for obviousness of the claimed oxidation level is based on the teachings of Kavan. In other words, Petitioner relies solely on Kavan to teach or suggest oxidation levels within the claimed range of 1% to 15%. As I explained above, however, Kavan relies on a fundamentally different interaction between water and the functional groups—not a resin and the functional groups—and so a POSITA would have had no motivation to oxidize at the levels taught by Kavan.

136. Additionally, I understand that Petitioner asserts that Ohata alone already achieves uniformly dispersed CNTs. Pet., 35 (arguing in Ohata "a conductive material is uniformly predispersed in a binder"') (quoting LGES-1004 ¶[0002])). Based on Petitioner's allegation that Ohata already achieves uniform dispersal without oxidizing its CNTs, a POSITA would have had no motivation to oxidize them to improve dispersion. This is particularly true given that it was well-known that oxidation would adversely affect the intrinsic properties of CNTs,

including by shortening them and introducing defects along the sidewalls of the CNTs. LGES-1009, 1, 5; MRD-2024, 19:13-17, 22:1-24:3 (Dr. Zhu acknowledging detrimental effects of oxidation).

137. I understand that Petitioner's third reason is that oxidation can help purify the CNTs. Pet., 23. I first note that nothing in Ohata or Kavan teaches or suggests that the CNTs have impurities. Kavan actually teaches to the contrary. It expressly states that it uses "purified" CNTs, which a POSITA would understand to refer to CNTs lacking impurities. LGES-1005, 2 ("For oxidative functionalization, 1g of *purified* nanotubes was mixed….")). As such, there would have been no motivation to oxidize for purposes of removing impurities.

138. I understand that Petitioner also asserts that "a POSITA would have been motivated to use oxidized nanotubes in the Ohata-Kavan electrode material mixture paste." Pet., 21. However, it is my understanding that the obviousness issue here is not whether a POSITA would have simply been motivated "to use oxidized nanotubes," but whether a POSITA would have been motivated to use oxidized CNTs *at the claimed level of 1% to 15% by weight of the CNT*. The only basis Petitioner provides for the assertion that the claimed range was obvious is based on Kavan's oxidation level. As discussed above, however, the oxidation level of Kavan is premised on the goal of "anchoring" to provide the benefits taught by Kavan. Ohata-Kavan's masterbatch process precludes these benefits from materializing

because the CNTs are fully covered in resin. A POSITA would have thus had no motivation to oxidize at the levels taught by Kavan. Additionally, a POSITA would have had an additional motivation to *not* oxidize at the levels taught by Kavan, because of the well-known disadvantages of oxidizing CNTs, and the fact that a POSITA understood that the "anchoring" benefits of Kavan would not be achieved in Ohata-Kavan

139. Petitioner's "fourth" reason is based on applying a known technique to a known structure ready for improvement to yield predictable results. Pet., 23. But the alleged "predictable results" based on functionalization of the carbon nanotubes ignores the effects of the Ohata-Kavan masterbatch process, which undermines any motivation to combine, as explained in detail above. Moreover, a POSITA would have understood that the "predictable result" would have been CNTs covered in resin, which would preclude the attachment and benefits described by Kavan from occurring.

140. It is also my opinion that a POSITA would be strongly discouraged from following Kavan for at least two reasons.

141. First, Ohata teaches that "[a]lthough it is possible to add a resin during the step of preparing an electrode material mixture paste, the addition of the carbon nanotubes is difficult, taking the dispersibility of the carbon nanotubes in the resin into consideration." LGES, 1004 ¶[0021]. In other words, Ohata teaches away from

exposing the naked CNTs to the active material at the same time, which is how Kavan "anchors" the active material to the oxidized CNTs. LGES-1005, 2. A POSITA would be discouraged from following the path set forth in Kavan—which relies on oxidizing naked CNTs and then mixing them with active material to take advantage of the functionalization of the CNTs—because it is exactly the process that Ohata teaches makes CNT dispersion difficult.

142. Second, a POSITA would have been discouraged from oxidizing Ohata's CNTs pursuant to Kavan, because it would have been understood that the benefits of "anchoring" taught by Kavan would not be achieved because the masterbatch process covers the CNTs in resin. This discouragement would have been even more considerable, given that it was well-known that oxidizing the CNTs per Kavan would come at the cost of damaging the intrinsic properties while providing none of the benefits taught by Kavan.

4. Whether a POSITA would have had a reasonable expectation of success with the combination.

143. I understand that one consideration in the obviousness analysis is whether a POSITA would have had a reasonable expectation of success in achieving the claimed invention. It is my opinion that a POSITA would not have had a reasonable expectation of success in combining Ohata-Kavan such that the lithium-ion active material is "attached to th[e] surface" of the oxidized CNTs as claimed.

144. The basis for my opinion is that the Ohata-Kavan combination embeds the oxidized CNTs in resin before mixing with the active material. Each of the Petitioner's reasons for a reasonable expectation of success appears to assume that Ohata-Kavan exposes the CNTs to the active material in a manner similar to the process of Kavan (by itself). But the Ohata-Kavan combination follows the masterbatch process that is fundamentally different from the process of Kavan. A POSITA would understand that the oxidized CNTs in Ohata-Kavan would be covered in resin, preventing the lithium-ion active material from accessing the functional groups to attach to the surface of the oxidized CNTs. As such, a POSITA would not have a reasonable expectation of success in combining Ohata-Kavan to achieve active material "attached to the[] surface" of the oxidized, discrete nanotubes as claimed.

5. Whether the Ohata-Kavan combination teaches or renders obvious "discrete carbon nanotubes."

145. Petitioner characterizes "discrete" CNTs as "generally individually distinct nanotubes" (Pet., 37) that are "fully isolated" or "separate" from one another. LGES-1003 ¶[0083] ("[L]ooking again to Ohata's illustrative example, provided below, it can be seen that most of the nanotubes are depicted as being discrete, non-agglomerated, and exfoliated. Indeed, a POSITA would have understood a carbon nanotube that is, as shown below, fully isolated from each other to be discrete, non-

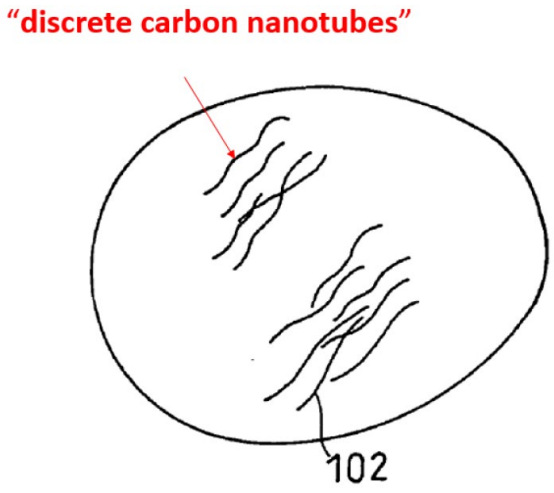
agglomerated, and exfoliated."); MRD-2024, 11:4-8 (testifying that "discrete" CNTs are "fully isolated" from one another), 12:17-13:22 (testifying that "discrete" CNTs are "separated from each other").

146. It is my opinion that this interpretation is consistent with the plain and ordinary meaning of "discrete" as understood by a POSITA at the time of the invention. This is consistent with various teachings from the specification. LGES-1001, 1:39-43 ("discrete, i.e., individual, uniformly dispersed tubes"), 3:52-55 ("discrete" CNTs are "separated to give individual tubes"). This is also consistent with the ordinary meaning of "discrete." *See* MRD-2007, 8 (defining "discrete" as "separate and distinct; not attached to others; unrelated").

147. I understand Petitioner alleges that Ohata-Kavan results in "discrete" CNTs. Pet., 34-37. Petitioner relies on Ohata's statement that its CNTs "are tangled and twisted with one another" but then are "***unraveled and straightened***" by blending them with a resin as part of the masterbatch process. *Id*., 35-36 (emphasis in original) (citing LGES-1004 ¶[0015], FIG. 1(b)). I also understand that Petitioner argues "that a POSITA would have found it obvious that at least some of these 'unraveled and straightened carbon nanotubes' are discrete because they are generally uniformly 'dispersed' as individual, distinct nanotubes (separated into individual tubes) in the resin." *Id.* at 35-36. Petitioner annotates Figure 1(b) of Ohata

(reproduced below) to identify CNTs that it contends are "discrete." LGES-1004, ¶[0013].

148. Petitioner's annotation of FIG. 1(b) from Ohata is reproduced below, which Petitioner uses to identify CNTs consistent with its interpretation of discreteness.



Ohata, FIG. 1(a) (annotated by Petitioner)

A POSITA would not understand this figure to demonstrate that Ohata-Kavan results in "discrete" CNTs. Ohata itself calls FIG. 1 a "schematic" diagram, which conceptually illustrates the concept of disentangling CNTs by shearing. LGES-1004, ¶¶[0012]-[0013]. A POSITA would not rely on such a schematic as a real-world representation of actual masterbatch results. It would instead be understood for what it is—an illustration intended to conceptually depict the well-known concept of CNT disentanglement via shear forces.

149. A POSITA would understand that Ohata's masterbatch process results would actually be reflected by SEM or TEM images, similar to how both the '483 Patent and Kavan evidence their findings. For example, an actual SEM image depicted in FIG. 5 of U.S. Patent Publication No. 2012/0058255 ("Gan") shows CNTs mixed in a resin to form a conductive polymer composite:

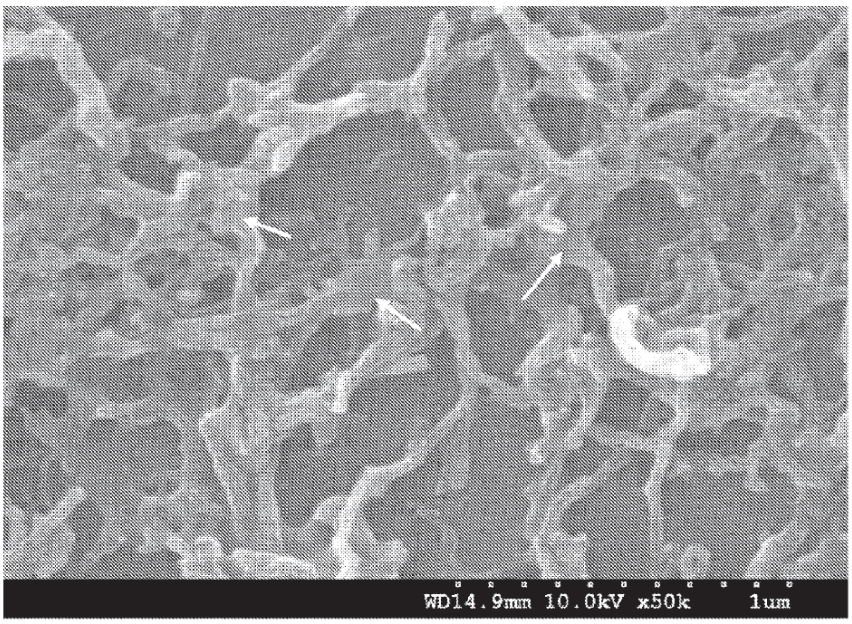


FIG.5

MRD-2019, 4, ¶[¶[0014], [0041]. Gan does not purport to achieve discrete CNTs, but this image shows how the CNTs of Ohata's masterbatch process would be randomly oriented (at least not aligned), which facilitates the formation of a continuous network of CNTs embedded within the binder that glues the active material particles together.

150. A POSITA would understand that Ohata's masterbatch would result in a similar interconnected network of CNTs. Despite this, FIG. 1(b) depicts the CNTs as somehow being oriented in nearly the exact same direction and generally parallel to one another, rather than at random orientations throughout the resin, which is implausible. A POSITA would thus recognize that FIG. 1 is an unrealistic, conceptual drawing intended to demonstrate the concept of CNT disentanglement.

151. Additionally, a POSITA would understand that the goal of Ohata is to create a continuous network of CNTs embedded in the binder, providing improved electrical conductivity among the active material particles. LGES-1004 ¶[0004] (explaining that "it is an object of the present invention to provide an electrode superior in ***conductivity*** with a small amount of conductive material"); LGES-1004, ¶¶[0018]-[0020] (explaining that when the CNT's diameter is too large, the CNT's length is too short, or the aspect ratio is too small, "excellent ***conductive paths*** may not be formed in some electrodes.")). This was a well-known and common goal at the time of the invention. LGES-1011 ¶[0005] ("Carbon nanotubes have good electrical conductivity, and the fibrous structure thereof can better connect electrode active materials into a ***continuous 'network'*** that is ***electrically conductive***…."); MRD-2019 ¶[0041] (explaining that the "presence of such ***continuous*** conductive path through the composite is believed to be a reason why the electrical conductivity of the conductive polymer material increases when CNTs are present.").

152. A POSITA would understand that Ohata is attempting to achieve this goal of a continuous network of CNTs in the binder to improve electrical conductivity of the binder that is positioned among the active material particles. Consistent with this goal, Ohata teaches a prior method of pre-dispersing carbon black (i.e., a "conducting material") in resin binder as part of a "masterbatch" process. LGES-1004, ¶[0002]. The naturally linked "chain" of carbon black particles forms a "conductive path" in the binder, which increases the electrical conductivity. *Id*. ¶[0003]. However, Ohata teaches that the shearing force associated with mixing the masterbatch breaks the conductive path, and therefore, "does not yield an electrode superior in conductivity." *Id.* Ohata's proposed solution is to use CNTs to form the continuous network rather than carbon black, because CNTs have strong internal bonds that make them much more resistant to shear force damage. *Id*. ¶[0015]. Indeed, Ohata did not seek to achieve discrete CNTs as part of its electrode material mixture paste, because this would decrease the likelihood of forming a conductive network, contrary to Ohata's goal of achieving an "electrode superior in conductivity." *Id*. ¶¶[0004], [0015]. A POSITA would not understand Ohata to teach or suggest achieving discrete CNTs, as they would have been expected to run contrary to the goal of creating a continuous, electrically conductive network.

153. A POSITA would understand that the only reason Ohata seeks to "unravel" and "straighten" the CNTs is so they can be better dispersed to form a

continuous network better distributed throughout the binder. This is because it was well-known that heavier entanglement of CNTs "is undesirable because it results in formation of voids and aggregates in the composition which adversely effects the electrical conductivity properties of the composite. . ." MRD-2019 ¶[0027]; LGES-1011 ¶[0073] (explaining that agglomeration of CNTs makes it "difficult to form an effective conductive network"). Just as a heavily wound spiderweb is more difficult to spread apart, heavily entangled CNTs are more difficult to disperse. Ohata seeks better dispersion of its CNTs so that it can provide a continuous network of CNTs throughout the entire binder. Ohata is thus seeking to achieve an interconnected network of CNTs, not discrete CNTs attached to the surface of the active material. *Id*.

154. Even if it is assumed that the *masterbatch* of Ohata-Kavan could comprise discrete CNTs, a POSITA would not expect those CNTs to remain discrete when mixed with the active material and dispersion medium as a part of the process for forming the *electrode material mixture paste*. LGES-1004 ¶[0023]. As shown by FIG. 5 of Gan (reproduced below), the random orientation of CNTs in a fluid facilitates the CNTs connecting to one another to forming a continuous conductive network. MRD-2019, 4, ¶¶[0014], [0041].

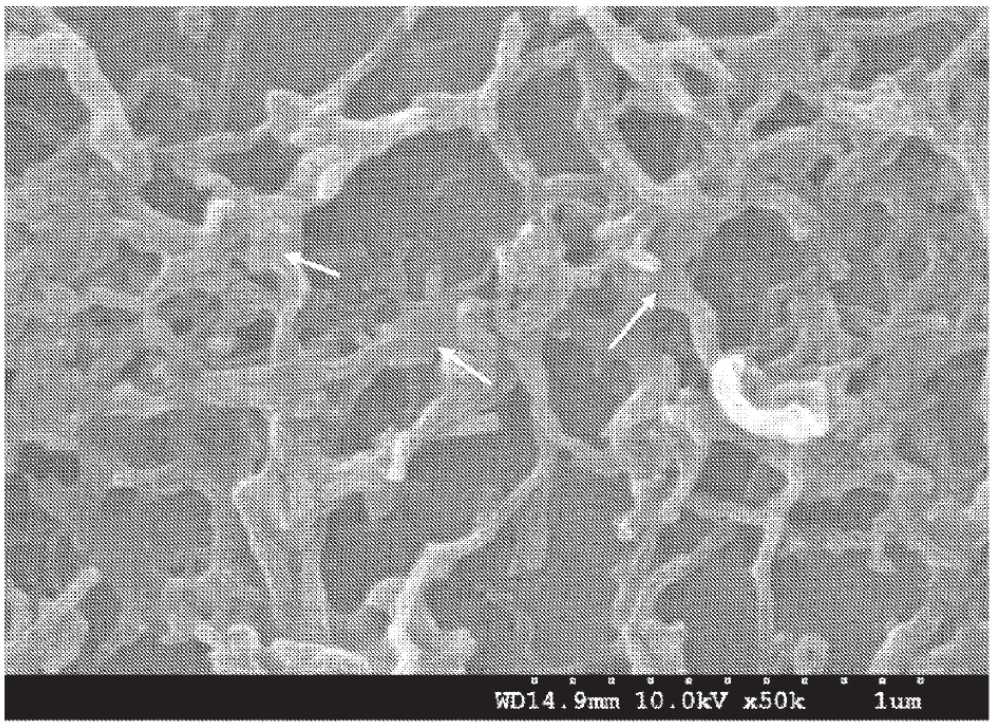


FIG.5

155. The formation of a continuous conductive network is only further facilitated when *oxidized* CNTs are mixed in a polymer (e.g., the resin of Ohata-Kavan). *Id*. This is because the functionalization of the CNTs "[r]educes contact resistance between CNTs incorporated into the conductive polymer material by drawing the CNTs close together" and "[p]rovides a conductive bridge between CNTs." MRD-2019, ¶¶[0018]-[0021]; MRD-2026, 50:17-53:6 (Dr. Zhu agreeing with Gan's described effects). A POSITA would understand that the formation of a continuous network of CNTs is a primary goal of Ohata—it seeks to achieve a continuous network of CNTs. *Id*. A POSITA would also understand that the only

reason Ohata teaches "unraveling" and "straightening" the CNTs is to make it easier to disperse them throughout the binder so that a continuous network is obtained throughout the entire binder—avoiding the network "voids" described by Gan. In view of the above, a POSITA would not expect the *electrode material mixture paste* of Ohata-Kavan to comprise discrete CNTs, even if there were discrete CNTs within the earlier formed *masterbatch*.

156. I understand that Petitioner also "alternatively/additionally" argues that "a POSITA would have understood or found obvious that the nanotubes in the combination composition are **discrete/non-agglomerated/exfoliated** because, at least in some instances, oxidation of nanotubes can help promote non-agglomeration of nanotubes." Pet., 36 (emphasis in original). It appears that Petitioner and Dr. Zhu are contending that oxidizing CNTs—in and of itself—necessarily results in "discrete" CNTs. *Id.*, 37 (making the generalized statement that "oxidized nanotubes in the combination can be present as generally individually distinct nanotubes,"). They are mistaken.

157. While oxidation of CNTs can improve their dispersibility, CNTs that are dispersed (even uniformly dispersed) are not necessarily "discrete." For example, CNTs forming a continuous network (i.e., the clear goal of Ohata) throughout an entire composition are "dispersed" throughout the composition even though the CNTs are interconnected (i.e., not "discrete"). Gan expressly teaches that

functionalized CNTs within a "conductive polymer material" will be drawn closer together and "[p]rovides a conductive bridge between CNTs," facilitating the formation of a continuous network. MRD-2019, ¶¶[0018]-[0021]. Dr. Zhu testified that he agrees with Gan, and he acknowledges that both of these effects result in CNTs ***in contact with one another*** to form a ***continuous*** conductive network. MRD-2026, 50:17-53:6. This is what a POSITA would expect to occur when the masterbatch is formed and then further mixed with the dispersion medium and active material to form the electrode material mixture paste. Consequently, a POSITA would not understand CNTs to become "discrete" simply because they have been oxidized.

B. Whether Ohata-Kavan Discloses or Renders Obvious Independent Claims 1, 7, and 9

158. All independent claims require that the lithium ion active material is "attached" to the surface of the discrete CNTs. Independent claims 1, 7 and 9 further require that the lithium ion active material is "ionically" attached to the surface. Ohata-Kavan would not result in "attachment" to the surface for the reasons discussed in Section IX.A.2. It is also my opinion that there could be no "ionic" attachment, are more specifically required by these independent claims.

159. Petitioner contends that "it was well-known that the oxidized nanotubes, as in Ohata-Kavan, 'have a negative electrostatic charge on the outer

surface of the nanotube wall' and, thus, a POSITA would have recognized that such 'negative electrostatic charge on the outer surface of the nanotube wall' would be used to enhance attachment of positively charged metal ions in the ion active material (e.g., $LiFePO_4$) to the nanotube surface via an ionic/electrostatic interaction." Pet., 43-44 (quoting LGES-1024, ¶[0057]; citing LGES-1030; LGES-1003, ¶95)). This assertion is premised on disregarding the fact that Ohata-Kavan results in oxidized CNTs coated in resin, which prevents the active material from attaching to the surface of the CNTs. Because there is no "attachment" as claimed, there can be no "ionic" attachment.

160. Moreover, a POSITA would understand that no ionic bonding would exist between the active material (TiO_2, $LiMnPO_4$, or $LiFePO_4$), the resin, or the oxidized CNTs. Specifically, the bond between the oxidized CNTs and resin would be Van der Waals forces, and the bond between the active material and resin would likewise be Van der Waals forces. Van der Waals forces are not ionic bonds, but rather are weak interactions between atoms or molecules that cannot engage in a chemical electronic bond. Van der Waals forces are very weak electrostatic forces that fall in the category of "secondary" bonding. In contrast, ionic bonds are strong bonds that fall in the category of "primary" bonding.

161. Ionic bonds are considered "primary" bonding (along with covalent bonds) that chemically bond positively and negatively charged moieties (such as

atoms and molecules) together to create a bond much stronger than Van der Waals forces. *Id.* (citing MRD-2027, 6:47-51) (LG Chem. Ltd.'s patent teaching that "the secondary particles are preferably formed by aggregating the primary particles ***via physical bonds*** such as van der Waals attraction ***rather than chemical bonds such as covalent or ionic bonds***."); MRD-2036, 15:18-21 ("organic material is bonded to the surface of the inorganic material by covalent, ionic, electrostatic, ***or*** van Der Waals bonds."); MRD-2035, 1:61-62 ("surface species may be associated with the surface of the particle by at least one of a covalent bond, an ionic bond, van der Waals interactions"); MRD-2039, abstract (describing adherence by "one or more of covalent bonds, ionic bonds ***and*** Van der Waals forces")). As these cited references demonstrate, Van der Waals forces do not constitute ionic bonds and are consistently categorized as distinct from ionic bonds. In fact, Petitioner and Dr. Zhu category chemical bonds as including "covalent[], ionic[], or … Van der Waals." Pet. 60 (citing LGES-1003 ¶145]). This is consistent with the understanding of a POSITA that ionic and Van der Waals forces fall into different, non-overlapping bonding categories.

C. Whether Ohata-Kavan Discloses or Renders Obvious Independent Claim 8

162. It is my opinion that Ohata-Kavan does not teach or render obvious discrete CNTs that are "uniformly dispersed" as recited by claim 8.

1. Whether Ohata-Kavan renders obvious the limitation "the carbon nanotubes are uniformly dispersed…"

163. I understand that the Petition does not provide an express interpretation of this term. However, Dr. Zhu testified that it "means that the nanotube does not form any initial bundled structure. Instead, they will disperse in the medium ***with certain distance between*** nanotube rather than bundled." MRD-2024, 17:14-22. In my opinion, this is consistent with the ordinary meaning of discrete CNTs that are "uniformly dispersed," which refers to them being spread consistently.

164. I understand that Petitioner relies on Ohata's teaching that "a conductive material is *uniformly predispersed* in a binder" to argue that blending the electrode active material with a dispersion medium to form an electrode material mixture paste (as taught by Ohata) "would allow the nanotubes in the resulting paste to remain uniformly dispersed, as they are in the masterbatch." Pet., 56-57 (quoting LGES-1004 ¶[0002]). Petitioner is mistaken, because Ohata does not teach that its masterbatch, which is made up of CNTs and a large amount of resin, is "uniformly" predispersed.

165. Petitioner quotes from the background of Ohata, which explains that it was known that "conductive material [carbon black or powdered graphite] is uniformly predispersed in a binder" to form a masterbatch. Pet., 56 (quoting LGES-1004 ¶[0002]). However, this section of Ohata is describing a different, prior art masterbatch process—not the masterbatch process relied on by Petitioner for in its

Ohata-Kavan combination.MRD-2024, 46:15-47:16 (Dr. Zhu acknowledging that Ohata's reference to "uniformly predispersed" refers to carbon black). In fact, Ohata's background further teaches "the use of the masterbatch process to uniformly disperse the conductive material in a binder does ***not*** yield an electrode superior in conductivity." LGES-1004 ¶[0003]. This confirms that the reference to "uniform" dispersal is about the inferior masterbatch comprising carbon black or powdered graphite—not CNTs.

166. While Ohata does teach that carbon black can be "uniformly dispersed" as part of **a** masterbatch, Ohata does not teach or suggest the same with respect to **its** masterbatch, which comprises CNTs (not carbon black) mixed with resin. LGES-1004 ¶[0005] ("The present invention relates to ... a masterbatch comprising at least carbon nanotubes and a resin;"). Ohata instead describes the difficulty of dispersing CNTs in resin. *Id*. ¶¶[0021] ("the addition of the carbon nanotubes is difficult, taking the dispersibility of the carbon nanotubes in the resin into consideration"), [0019] ("the dispersibility of the carbon nanotubes in the resin may be slightly low").

167. Given that the sole basis for Petitioner's assertion that Ohata-Kavan teaches "uniformly dispersed" discrete CNTs is a statement from Ohata about a masterbatch comprising carbon black and resin—not the masterbatch comprising CNTs and resin—there is no support for the notion that the Ohata-Kavan electrode material mixture paste would have "uniformly dispersed" discrete CNTs. In fact, it

was well-known that mixing oxidized CNTs in resin draws "the CNTs closer together," which is inconsistent with Petitioner's assertion about a different masterbatch process that the CNTs would have been "uniformly dispersed." MRD-2019 ¶[0020].

2. Whether Ohata-Kavan renders obvious the limitation "wherein the carbon nanotubes are uniformly dispersed without clustering on a dimension scale of less than 1 micrometer"

168. It is my opinion that the Ohata-Kavan combination does not render this limitation obvious.

169. I understand that the Petitioner does not provide an express construction of this term. Petitioner also does not offer its understanding of this claim term. Petitioner instead argues that "the '483 patent provides no substantive discussion of this feature" and arguing that it "is inappropriate to hold the prior art to a stricter standard of disclosure than what is disclosed in the specification of the patent itself." Pet., 57, n.11.

170. Petitioner is mistaken, as the specification of the challenged patent does provide guidance as to the meaning of this phrase. The specification discloses this feature. LGES-1001, 3:26-32. Further, Dr. Zhu acknowledges that this phrase requires the discrete CNTs to be at least 1 micrometer apart, thereby delineating what qualifies as "without clustering." MRD-2024, 16:6-17:6 (explaining that the claim limitation means that the CNTs "have significant distance between them" and

that a POSITA considers "dispersed carbon nanotube[s] actually have a distance of around 1 micrometer"); *Id.*, 16:23-18:2. And Figure 2 of the '909 Patent is an SEM image at a 30,000x magnification with a dimension scale of 1 μm (1 micrometer) and shows CNTs that are spaced apart. LGES-1001, 4.

171. There is no evidence showing that Ohata-Kavan teaches or suggests this limitation, which requires examining CNTs under a microscope *with a dimension scale*. Petitioner argues that Ohata's cartoon Fig. 1(b) "shows that the nanotubes are dispersed ***without clustering***," and then concludes that a POSITA would know this to mean that they are "uniformly dispersed **without clustering on a dimension scale less than 1 micrometer**." Pet., 57-58 (emphasis in original). But there is no explanation as to how a cartoon figure that is clearly not drawn to scale and does not represent *actual* results can disclose this claim feature. Petitioner improperly equates Fig. 1(b) allegedly showing no clustering as automatically meaning the dimension scale requirement is met. However, no reasonable POSITA would have relied on a cartoon figure without a scale to determine or ascertain the spacing between CNTs or the size of potential clusters.

172. Additionally, Fig. 1(b) depicts the *masterbatch*, not the *electrode material mixture paste* containing the active ion material. In other words, even if Fig. 1(b) was understood to actually represent CNTs that are spaced a particular distance apart (or smaller than a particular cluster size), Fig. 1(b) cannot demonstrate

that the CNTs remain "without clustering" as claimed once mixed with the active material. Indeed, it was well-known that mixing oxidized CNTs in resin draws "the CNTs closer together." MRD-2019 ¶[0020]. A POSITA would thus understand that the CNTs would present themselves much differently when mixed with the active material, and would further understand that any schematic depiction of the masterbatch could not be relied on to determine the ultimate CNT spacing or cluster size.

173. I understand Petitioner argues that a POSITA would understand Fig. 1(b) of Ohata to disclose CNTs that are both: (1) at least one micrometer apart; and (2) do not form clusters of greater than 1 micrometer in size. Pet., 58. Ohata refers to Fig. 1(b) as a "schematic," which is a poorly sketched cartoon providing a conceptual illustration of how CNTs can be disentangled via shear forces. LGES-1004 ¶[0013]. A POSITA would readily understand that FIG. 1(b) is not a realistic depiction of CNTs. And a POSITA would certainly understand that the cartoon is too abstract to be relied on for purposes of comparing the distances on the dimension scale required by the claim.

174. I understand Petitioner admits that FIG. 1(b) has no scale and asserts that "a POSITA would have been able to estimate the scale based on Ohata's disclosure that the nanotubes have an average length of 1 to 100 μm." Pet., 58. Petitioner concludes "for nanotubes having a length of 100 μm, the space between

the nanotubes is depicted as greater than 1 μm" and that this estimation shows "the nanotubes are dispersed without clustering on a dimension scale less than 1 micrometer." *Id*. But without a scale in FIG. 1(b), nothing in Ohata depicts nanotubes with a length of 100 μm. I have fully reviewed Ohata and nothing in Ohata supports that FIG. 1(b) is intended to be drawn to scale or that the cartoon CNTs are supposed to represent any particular size. A POSITA would thus not rely on Fig. 1(b) as representing relative dimensions or particular sizes for any CNTs. Instead, Fig. 1(b) is a "schematic" drawing conceptually depicting how CNTs may be disentangled—that is the only purpose of that figure that a POSITA would glean from Ohata.

175. I also note that Ohata provides a broad range of potential dimensions for its CNTs. LGES-1004, ¶[0019]. A POSITA would understand that FIG. 1(b) cannot be intended to be drawn to scale because it cannot represent a range of CNT dimensions. If those same cartoon CNTs had a 1 μm average length, rather than the 100 μm selected by Petitioner, the space between them would be much less than 1 μm. But, it is impossible for anyone—including a POSITA—to determine a particular size or relative dimensions for the cartoon CNTs, because FIG. 1 does not, and is not intended to, convey either. Moreover, Ohata teaches that the diameter of the nanotubes should be no greater than 0.1 μm, which means CNTs with a 100 μm

length (as proposed by Petitioner) would have aspect ratios of at least 1,000—outside the claimed 10-500 range. LGES-1004 ¶[0018].

176. A POSITA would ultimately understand that the claim requires a minimum distance of 1 micrometer of separation between discrete CNTs. Because Ohata's disclosures do not demonstrate this, a POSITA would understand that experimentation would be required to show that the Ohata-Kavan electrode material mixture paste renders this limitation obvious, such as by taking an SEM image of the paste under a microscope. Petitioner did not do this, even though Dr. Zhu testified that there are several experimental steps that could have been taken to prove that Ohata-Kavan would achieve this limitation, such as examination of a sample under microscope or using XPS. MRD-2025, 9:1-12:9. There is simply nothing in Ohata or Kavan that would allow a POSITA to determine with any degree of certainty, that Ohata-Kavan would satisfy this limitation. Petitioner could have performed experimentation to show this but instead relied on the cartoon figure only. Indeed, the evidence shows that mixing CNTs with resin—as proposed in Ohata-Kavan—would actually draw them closer together, which is inconsistent with the goal of requiring a certain degree of spacing.

X. CONCLUSION

177. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and 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. I further declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Dated: March 30, 2025

Deborah D.L. Chung

Deborah D.L. Chung

APPENDIX A

Mar. 30, 2025

CURRICULUM VITA

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http://en.wikipedia.org/wiki/Deborah_Chung
https://www.amacad.org/person/deborah-chung
https://www.buffalo.edu/news/releases/2023/04/025.html
https://heritageproject.caltech.edu/interviews-updates/deborah-chung
http://engineering.buffalo.edu/mechanical-aerospace/people/faculty/d-chung.html
http://alum.mit.edu/www/ddlchung
https://scholar.google.com/citations?user=I1m7ZW8AAAAJ
https://www.youtube.com/watch?v=INZrNhbDK9c
https://www.youtube.com/watch?v=u_GGEbotQAM
https://www.webofscience.com/wos/author/record/675681

PROFESSIONAL INTEREST

Multidisciplinary research and teaching that are focused on materials science and engineering, particularly multifunctional structural materials (with functions including self-sensing, self-powering and vibration damping), electromagnetic shielding materials, and thermal interface materials (for microelectronic cooling). Other topics include three-dimensional printing, dielectric conductors and interface-derived viscoelasticity.

SCIENTIFIC IMPACT

A. Pioneer and the foremost international leader in the field of multifunctional structural materials (without device incorporation), with the following specific contributions.
   1. Invention of smart (self-sensing) concrete and associated development of piezoresistivity-based strain sensing in cement-based and carbon fiber composites.
   2. Discovery of the function of the interlaminar interface in carbon fiber polymer-matrix composites as a sensor, thus enabling unprecedentedly high sensitivity to changes at this damage-prone interface.
   3. Development of the self-sensing in carbon fiber polymer-matrix composite beams under flexure by surface resistance measurement, with the strain at the tensile and compressive surfaces separately and sensitively determined, and with the piezoresisitivity mechanism elucidated.
   4. Development of capacitance-based self-sensing, with applications including 3D-printing monitoring (with unprecedented ability of sensing interlayer defects in the build).
   5. Development of inductance-based self-sensing, with applications including fiber-tow twist-level sensing, strain sensing, damage sensing, and surface roughness sensing.
   6. First report of structural capacitors (i.e., capacitors in the form of structural materials).
   7. Pioneering the emerging field of high-permittivity electronic conductors, first determination of the electric permittivity of electronic conductors (carbons and metals), discovery of ferroelectricity in a metal, and discovery of the application in electret-based self-powering (with unprecedented self-charging capability), with the latter discovery allowing structures to be energy sources (a new untapped source of energy), and with elucidation of the dielectric behavior in terms of the carrier-atom interaction (carrier meaning the mobile charges) and polarization connectivity.
   8. Discovery of interface-derived viscoelasticity and the consequent unprecedented development of structural materials that are effective for vibration damping.

B. Pioneer and the foremost international leader in the field of thermal interface materials for microelectronic cooling, with the following specific contributions.
   1. Changing the paradigm of the design of thermal interface materials from thermal-conductivity-based design to conformability-based design, thereby resulting in the development of superior but low-cost thermal interface materials that excel due to conformability.
   2. Development of unprecedentedly effective thermal pastes with conformable solid components.

C. Pioneer and the foremost international leader in the field of materials for electromagnetic interference (EMI) shielding, with the following specific contributions.
   1. Changing the paradigm of the design of EMI shielding materials from electrical-conductivity-based design to interface-area-based design, thereby resulting in the development of an unprecedentedly effective EMI shielding material in the form of nickel-coated carbon nanofiber (originally known as nickel filament).
   2. Discovery of absorption-dominated EMI shielding in metals, the shielding of which has long been assumed to be dominated by reflection.

3. Discovery of unusually high EMI shielding effectiveness in exfoliated-graphite-based flexible graphite sheets, which are valuable for EMI gasketing.
4. Development of radio-wave reflective concrete and its application in automobile lateral guidance.

EXPERIENCE

UNIVERSITY AT BUFFALO, THE STATE UNIVERSITY OF NEW YORK, Buffalo, NY

*SUNY Distinguished Professor of Mechanical and Aerospace Engineering (2024-present)

*Professor of Mechanical and Aerospace Engineering (1986-2024)

*Founding Director, Composite Materials Research Laboratory, 1989-present

*Niagara Mohawk Power Corp. Endowed Chair Professor, 1991-2008

CARNEGIE-MELLON UNIVERSITY, Pittsburgh, PA

*Associate Professor of Metallurgical Engineering and Materials Science (1982-1986)

*Assistant Professor of Metallurgical Engineering and Materials Science and Electrical Engineering (1977-1982)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA（1974-77）

*Visiting Scientist at the Francis Bitter National Magnet Laboratory - Research on graphite intercalation compounds under the supervision of Professor M.S. Dresselhaus

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, CA（1971-73）

Research on superconducting alloys and amorphous materials under the supervision of Professor Pol E. Duwez

EDUCATION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA

Ph.D. Degree in Materials Science, 1977

Thesis on "The Electronic, Lattice and Structural Properties of Graphite Intercalation Compounds" under the supervision of Professor M.S. Dresselhaus

S.M. Degree in Materials Science, 1975

Thesis on "Optical Studies of Graphite Intercalated with Bromine" under the supervision of Professor M.S. Dresselhaus

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, CA

M.S. Degree in Engineering Science, 1973

B.S. Degree in Engineering and Applied Science, 1973

HONORS

PAIR Distinguished Lecturer, Hong Kong Polytechnic University, Hong Kong, Dec. 17, 2024.

Certificate of Special Congressional Recognition, in recognition of receiving the University at Buffalo President's Medal, U.S. Congress, May 2024.

President's Medal, University at Buffalo, The State University of New York, 2024.

Member, American Academy of Arts and Sciences, elected in 2023.

Ranked 1st (among 49,100 researchers) in the world in the field of carbon fibers (scholargps.com, 2022)

Ranked 1st (among 12,770 researchers) in the world in the field of electromagnetic interference (scholargps.com, 2022)

Ranked 16th (among 570,007 researchers) in the world in the field of mechanical engineering (scholargps.com, 2022)

Ranked 110th (among 4,146,930 researchers) in the world in the field of engineering and computer science (scholargps.com, 2022) https://scholargps.com/search.php?q=d.d.l.+chung&type=profile&specialty%5B0%5D=Carbon+Fibers&scholar=D.D.L.+Chung&scholar_ranks=true&scholar=D.D.L.%20Chung&first_name=D.D.L.&middle_name=&last_name=Chung

Feature article "Materials for electromagnetic interference shielding" by Chung and published in Materials Chemistry and Physics is the third most cited Materials Chemistry and Physics article in the last two years (2020-2022).

Inaugural speaker, Professor Millie Dresselhaus Memorial Lecture, MIT, 2022.

Ranked 1st in the world in the field of Building and Construction (Stanford University study, 2021)

Ranked 1st among all researchers in University at Buffalo (living/deceased, all fields combined) (Stanford University study, every year since its inception in 2018)

Ranked 13th among 315,721 materials researchers in the world (living and deceased),10th among those that are living, and 1st among those who are female (Stanford University study, 2022).

Lan Wong and Deborah Chung Center for Science and Arts, Christian Central Academy, Williamsville, NY, building dedication in 2021.

Drs. Lan Wong and Deborah Chung Analytical Chemistry Laboratory, California State University, Northridge, laboratory dedication in 2021.

Drs. Lan Wong and Deborah Chung Distinguished Lecture Series on the Path to Professional Success, California State University, Northridge, initiated in 2021.

Drs. Lan Wong and Deborah Chung Lecture Series honoring the late Prof. M.S. Dresselhaus and the late Prof. K. Biemann, School of Science, MIT, initiated in 2021.

Drs. Lan Wong and Deborah Chung Graduate Student Scholarship Fund, School of Science, MIT, initiated in 2021.
Honoree, 4th UKIERI Concrete Congress, India, March 5-8, 2019.
Top Peer Reviewer 2019. For placing in the top 1% of reviewers in Materials Science on Publons global reviewer database. Also for placing in the top 1% of reviewers in Cross-Field on Publons global reviewer database.
Albert Nelson Marquis Lifetime Achievement Award, Marquis Who's Who, 2018.
The 2018 Publon's Global Peer Review Awards for being placed in the top 1% of peer reviewers in Materials Science (ranked 5th in the world) and for being placed in the top 1% of peer reviewers in Chemistry. These awards are based on the number of reviews of manuscripts submitted to various journals for consideration of publication.
Honoree, one of the three first alumnae of Caltech, 2018 (45th anniversary of graduation)
Pu-Woei Chen and D.D.L. Chung, "Carbon Fiber Reinforced Concrete as a Smart Material Capable of Non-Destructive Flaw Detection", Smart Mater. Struct. 2(1), 22-30 (1993). This paper is one of the 25 most cited papers in the 25-year history of the journal *Smart Materials and Structures,* 2017.
Paper with M. Sharma honored as Editors' Choice in *Journal of Electronic Materials*, 2015.
U.S. Faculty Scholar, Vietnam Education Foundation, 2013-14.
Visiting Professor, Hefei University of Technology, Hefei, P.R. China, appointed in 2013.
One of the top ten best cited papers in *Composites B* in all times past, honored in 2012.
Honorary Doctorate Degree, University of Alicante, Alicante, Spain, 2011.
Guest Professor, Tongji University, Shanghai, P.R. China, appointed in 2010.
Top Reviewer in 2008, an international award in relation to the journal Carbon, Elsevier Pub., 2009.
Special Recognition Award, The American Carbon Society, 2007.
Hsun Lee Award, jointly awarded by Institute of Metal Research (Chinese Academy of Sciences) and Shenyang National Laboratory for Materials Science, to recognize research accomplishment in materials science and technology, 2005.
Invited Professor, Tianjin University, Tianjin, P.R. China, appointed in 2005.
Visiting Professor, Jinan University, Jinan, P.R. China, appointed in 2005.
Charles E. Pettinos Award, a triennial international award to recognize one person or one group for outstanding research accomplishments in carbon science and technology, The American Carbon Society, 2004.
Chancellor's Award for Excellence in Scholarship and Creative Activities, Academic Year 2002-2003, The State University of New York.
Outstanding Inventor, State University of New York, 2002.
Visiting Professor, Wuhan University of Technology, Wuhan, P.R. China, appointed in 2002.
Visiting Professor, Southeast University, Nanjing, P.R. China, appointed in 2002.
Visiting Professor, Beijing Technology and Business University, Beijing, P.R. China, appointed in 2002.
Fellow, American Carbon Society, conferred in 2001.
Honorary Professor, Shantou University, Shantou, Guangdong, P.R. China, appointed in 2000.
Fellow, ASM International, conferred in 1998.
Advisory Professor, Harbin Institute of Technology, Harbin, P.R. China, appointed in 1995.
"Teacher of the Year", 1992-93, awarded by Tau Beta Pi (New York Nu).
Ralph R. Teetor Educational Award, Society of Automotive Engineers, 1987, for being one of the top engineering educators in the U.S.
Robert Lansing Hardy Gold Medal for the most promising metallurgist in the U.S. in 1980, American Institute of Mining, Metallurgical, and Petroleum Engineers
One of the four first woman graduates of California Institute of Technology, 1973
First woman engineering graduate of California Institute of Technology, 1973
Josephine de Karman Fellowship (1972-73) for graduate and senior undergraduate students of exceptional ability

MEMBERSHIPS

Fellow, American Academy of Arts and Sciences, elected in 2023.
Fellow, American Carbon Society, 2001-present; Member, 1979-present; Advisory Board member, 1999-2005;
Member, American Ceramic Society, 1989-1990, 1994, 2018-.
Member, American Concrete Institute, 1989-1990, 1994-1996.
Member, American Society of Mechanical Engineers, 2014-18.
Fellow, ASM International (formerly known as the American Society for Metals, a professional organization for materials scientists and engineers), 1998-present; Member, 1986-present; Director of Buffalo Chapter, 1987-1994; Member of Superconductor Materials Committee, 1989-1993.
Member, Materials Research Society, 1981-2017.
Member, Society for the Advancement of Material and Process Engineering, 2007-2014.
Member, Society of Automotive Engineers, 1987-1989
Member, The Minerals, Metals & Materials Society (TMS), 1977-present. Executive Committee Member of the Three-Rivers Section of TMS-AIME, 1986. Member of the Membership Development Committee (national) of TMS-AIME, 1986-1988.

OTHER PROFESSIONAL ACTIVITIES

* Invited Specialist of United Nations Development Program to assist the technical development of the People's Republic of China, July 16 - August 5, 1986.
* Member, Committee on Materials for High Density Electronic Packaging, National Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council, 1987-1990.
* Member, Panel for selection of Presidential Young Investigators, Division of Materials Research, National Science Foundation, November 23, 24, 1987.
* Chairman, Symposium on Carbon Fibers and Composites, sponsored by American Carbon Society, Buffalo, NY, July 18-21, 1988.
* Symposium Organizer, Symposium on Mechanical Behavior of Electronic Materials and Structures in Microelectronics, Material Research Society Meeting, Anaheim, April 1991.
* Conference Chairman, Conference on Materials for Electronic Packaging, SUNY/ Buffalo, August 20-22, 1991.
* Conference Chairman, 21st Biennial Conference on Carbon, sponsored by American Carbon Society, SUNY/Buffalo, June 13-18, 1993.
* Consultant to National Power PLC, UK, 1995-96.
* Member, Proposal Review Panels, National Science Foundation, November 1997-present.
* Topical Area Chairman, 23rd Biennial Conference on Carbon, sponsored by American Carbon Society, Pennsylvania State University, July 13-18, 1997.
* Technical Co-Chair and Member of International Advisory Board, 5th International Conference on Composites Engineering, Las Vegas, NV, July 5-11, 1998.
* Member, Advisory Board, American Carbon Society, 1999-2006.
* Topical Area Chairman, 24th Biennial Conference on Carbon, sponsored by American Carbon Society, Charleston, SC, July 11-16, 1999
* Member, International Editorial Board, New Carbon Materials, 1999- present
* Member, Honorary Editorial Advisory Board, Carbon, 2001-present.
* Member, Advisory Board, Carbon Letters (formerly Carbon Science) (Korea), 2007-present.
* Member, International Editorial Board, Polymers & Polymer Composites, 2001-present.
* External Reviewer for Research Grants Council, Hong Kong, 2001-present.
* Member, International Advisory Committee, 2002 International Conference on Carbon, Beijing, China, Sept. 15-20, 2002.
* Member, Local Scientific Committee, 14th International Conference on Composite Materials, San Diego, July 14-18, 2003.
* Topical Area Chairman, Carbon 2004 International Conference, Providence, RI, July 11-16, 2004.
* Editor, Book Series on *The Road to Scientific Success: Life Experience of Prominent Researchers*, World Sci. Pub., 2004-.
* Editor, Book Series on *Engineering Materials for Technological Needs*, World Sci. Pub., 2005-.
* External Reviewer for State Natural Science Award, China, 2006.
* Nominator, Kyoto Prize, Inamori Foundation, Kyoto, Japan, 2007, 2011 and 2015.
* Associate Editor, Journal of Electronic Materials, 2008-.
* Associate Editor, Polymers and Polymer Composites, 2008-2019
* Reviewer for National Priorities Research Program, Qatar National Research Fund, 2009-.
* Member, International Advisory Committee, World Conference on Carbon, Biarritz, France, June 14-19, 2009, organized by the French Carbon Group (GFEC).
* Reviewer for King Abdulaziz City for Science and Technology, Saudi Arabia, 2009-.
* Member, International Advisory Committee, World Conference on Carbon, Shanghai, China, July 24-29, 2011.
* Member, International Experts Committee, new Doctorate Program on “Engineering of Materials, Structures and Terrain: Sustainable Construction”, Department of Civil Engineering, University of Alicante, Alicante, Spain, 2012-13.
* Member, Advisory Committee, School of Engineering, Hong Kong University of Science and Technology, Hong Kong, 2013.
* Reviewer for National Centre of Science and Technology, Kazakhstan, 2014-
* Reviewer for Office of Science, DOE, 2014-
* Reviewer of Applications for Establishment of the Hong Kong Branches of Chinese National Engineering Research Centres, 2014.
* Editor-in-Chief, Composite Materials section of SpringerMaterials, 1/2015 - 12/2016.
* Member, Editorial Board, Functional Composite Materials (journal), Springer Nature (2017-2025); Journal of Materials Science: Composites (rebranded, 2025-).
* Proposal reviewer, U.S. – Israel Binational Science Foundation, 2017.
* Member, Panel on Review of In-house Laboratory Independent Research in Materials Sciences at the Army’s Research, Development, and Engineering Centers, The National Academies, 2018-19.
* Member, Advisory Committee, Carbon 2019 International Conference, Kentucky, July 2019.
* Member, International Advisory Committee, Carbon 2020 International Conference, Kyoto, Japan, June 28 – July 3,

2020.
* Member, Advisory Board, Materials Chemistry and Physics (journal), Elsevier (2020-).
* Member, International Advisory Board, 2022 World Conference on Carbon, July 3-8, 2022, London, UK.
* Member, Editorial Board, World Scientific Annual Review of Functional Materials (journal), World Sci. Pub. (2022-).
* Member, Scientific Committee on the topic Carbon fibers and composites, The World Conference on Carbon 2023, Cancun, Riviera Maya, Mexico, July 16-21, 2023.
* Guest Editor, Special Issue on Carbon Films in memory of Professor Millie Dresselhaus, Materials Chemistry and Physics (2022-).
*Member, International Editorial Board, Composites Science and Technology (2024-).

BOOKS

Authored books
1. Kenji Uchino, D.D.L. Chung and R.E. Newnham, *JME Materials Science: Introduction to Electrical Properties for Ceramists* (JME Zairyo Kagaku: Seramisuto no tame no Denki Bussei Nyumon), Uchida Rokakuho Publishing Co., Ltd., Tokyo, Japan, 1990, 156 pp. Book written in Japanese. Translated from English.
2. D.D.L. Chung, P.W. DeHaven, H. Arnold and D. Ghosh, *X-Ray Diffraction at Elevated Temperatures*, VCH Publishers, 1993.
3. D.D.L. Chung, *Carbon Fiber Composites*, 1st Ed., Butterworth-Heinemann, 1994; *Carbon Composites: Composites with Carbon Fibers, Nanofibers and Nanotubes*, 2nd Ed., Elsevier, 2017, 706 pages.
4. D.D.L. Chung, *Composite Materials for Electronic Functions*, Materials Science Foundations, Vol. 12, i-iii, 1-77, Trans Tech Publications Ltd., Switzerland, 2000.
5. D.D.L. Chung, *Applied Materials Science*, CRC Press, 2001.
6. D.D.L. Chung, *Composite Materials: Functional Materials for Modern Technologies*, 1st Ed., "Engineering Materials and Processes" Book Series, Brian Derby, Series Editor, Springer, 2003; *Composite Materials: Science and Applications*, 2nd Ed., Springer, 2010.
7. D.D.L. Chung, *Multifunctional Cement-Based Materials*, *Civil and Environmental Engineering* Book Series, Mike Meyer, Series Editor, Marcel Dekker, 2003.
8. D.D.L. Chung, Book series titled *Engineering Materials for Technological Needs*, Vol. 2, *Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications*, World Scientific, 2010; Vol. 4, 2nd Ed., 552 pages, 2021.
9. Rebecca Chan Chung, D.D.L. Chung, Cecilia Ng Wong, *Piloted to Serve*, Deborah Chung, 2012; Enhanced Edition, 2020.
10. D.D.L. Chung, Book series titled *Engineering Materials for Technological Needs*, Vol. 3, *Carbon Materials: Science and Applications*, World Scientific, 2019, 382 pages.

Edited books
1. Ephraim Suhir, Robert C. Cammarata, D.D.L. Chung and Masahiro Jeno, *Materials Research Society Symposium Proceedings*, Vol. 226 (Mechanical Behavior of Materials and Structures in Microelectronics), Symposium held April 30 – May 3, 1991, Anaheim, CA, Materials Research Society, Pittsburgh, PA, 1991.
2. D.D.L. Chung and E.A. Heintz, *Extended Abstracts*, 21st Biennial Conference on Carbon, American Carbon Society, 1993.
2. D.D.L. Chung, *Materials for Electronic Packaging*, Butterworth-Heinemann, Boston, MA, 1995.
3. D.D.L. Chung, Book Series titled *The Road to Scientific Success: Inspiring Life Stories of Prominent Researchers*, World Scientific Pub., Singapore, Vol. 1, 2006; Vol. 2, 2014; Vol. 3, 2023.
4. D.D.L. Chung, Book Series titled *Engineering Materials for Technological Needs*, World Scientific Pub., Singapore, 2005-. Vol. 1: *High Performance Construction Materials*, Caijun Shi and Y. L. Mo (eds.), World Scientific Pub., Singapore, 2008. Chinese translation, Chongqing University Press, China, 2011.

PATENTS (issued)
1. D.D.L. Chung, "Low-Density Graphite-Polymer Electrical Conductors", U.S. Patent 4,704,231 (1987).
2. D.D.L. Chung, "Composites of In-Situ Exfoliated Graphite", U.S. Patent 4,946,892 (1990), Canadian Patent 1,330,609 (1994).
3. D.D.L. Chung, "Exfoliated Graphite Fibers and Associated Method", U.S. Patent 4,915,925 (1990).
4. D.D.L. Chung, "Carbon Fiber Reinforced Cement Concrete Composites Improved by Using Chemical Agents", U.S. Patent 5,032,181 (1991).
5. D.D.L. Chung, "Superconductor-Metal Laminates and Method of Making", U.S. Patent 5,059,582 (1991).
6. D.D.L. Chung, "Carbon Fiber Composites with Improved Fatigue Resistance", U.S. Patent 5,091,242 (1992).
7. D.D.L. Chung, "Carbon Fiber Reinforced Tin Alloy as a Low Thermal Expansion Solder Preform", U.S. Patent 5,089,356 (1992).
8. D.D.L. Chung, "Phosphate Binders for Metal-Matrix Composites", U.S. Patent 5,536,686 (1996); European patent application WO 9409169 (1994).

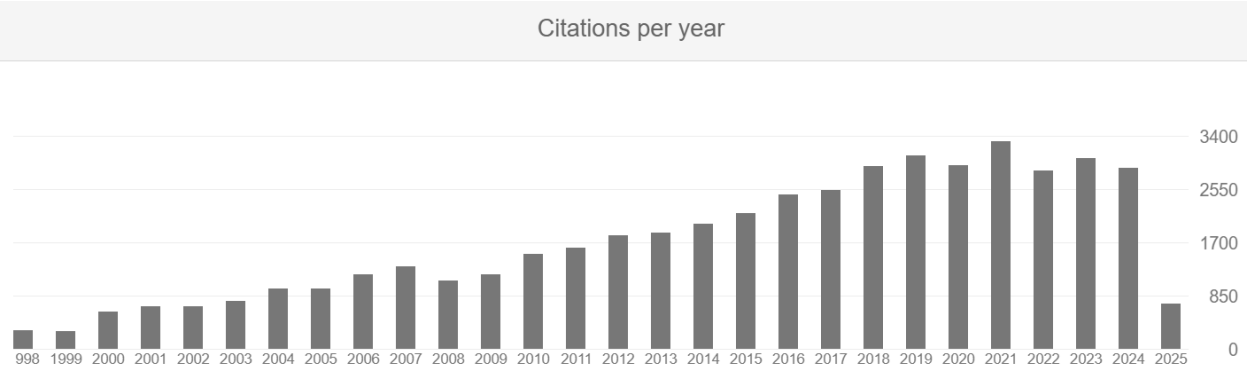
9. Yi-Han Kao, Liwei Song, D.D.L.Chung and Kevin T. Fredette, "Halogen Doped Superconductive Fullerenes", U.S. Patent 5,380,703 (1995).
10. Yi-Han Kao, Liwei Song, D.D.L. Chung, and Kevin T. Fredette, "Inter-Halogen-Doped Superconductive Fullerenes," U.S. Patent 5,561,102 (1996).
11. D.D.L. Chung and Xiaoping Shui, "Metal Filaments for Electromagnetic Interference Shielding", U.S. Patent 5,827,997 (1998).
12. D.D.L. Chung, "Particulate Carbon Complex," U.S. Patent 5,643,670 (1997).
13. D.D.L. Chung and Weiming Lu, "Mesoporous Activated Carbon," U.S. Patent 5,990,041 (1999).
14. D.D.L. Chung, "Methods and Sensors for Detecting Strain and Stress," U.S. Patent 6,079,277 (2000).
15. D.D.L. Chung, "Composite Material Strain/Stress Sensor," U.S. Patent 5,817,944 (1998).
16. D.D.L. Chung, "Conformable Interface Materials for Improving Thermal Contacts", U.S. Patent 7,535,715 (2009); Chinese Patent CN 101416304 B (2011).
17, D.D.L. Chung and Chuangang Lin, "High-Performance Interface Materials for Improving Thermal Contacts", U.S. Patent 8,013,024 (2011).
18. D.D.L. Chung and Sivaraja Muthusamy, "Cement-Graphite Composite Materials for Vibration Damping", U.S. Patent 8,211,227 (2012).
19. D.D.L. Chung and Xiaoqing Gao, "Microstructured high-temperature hybrid material, its composite material and method of making", U.S. Patent 9409823 (issued on Aug. 9, 2016).
20. D.D.L. Chung, "Thixotropic liquid-metal-based fluid and its use in making metal-based structures with or without a mold", U.S. Patent 9993996 B2 (June 12, 2018); China Patent CN 105458254A (April 6, 2016).
21. D.D.L. Chung, "Systems and method for monitoring three-dimensional printing", U.S. Patent 10449721 (Oct. 22, 2019).
22. D.D.L. Chung, "Cement-based material systems and method for self-sensing and weighing", U.S. Patent 10,620,062 B2 (April 14, 2020).
23. D.D.L. Chung. "Electrically conductive electret and associated electret-based power source and self-powered structure", U.S. Patent 11081285 (Aug. 3, 2021).

BOOK CHAPTERS

1. D.D.L. Chung, "Overview of Materials for Electronic Packaging", *Materials for Electronic Packaging*, D.D.L. Chung (Ed.), Butterworth-Heinemann, Boston, MA, 1995, p. 3-39.
2. D.D.L. Chung, "Low Thermal Expansion Composite Materials for Electronic Packaging", *Materials for Electronic Packaging*, D.D.L. Chung (Ed.), Butterworth-Heinemann, Boston, MA, 1995, p. 145-152.
3. D.D.L. Chung, "Conducting Polymer-Matrix Composites", *Materials for Electronic Packaging*, D.D.L. Chung (Ed.), Butterworth-Heinemann, Boston, MA, 1995, p. 153-171.
4. Darold C. Wobschall and D.D.L. Chung, "Ohmmeters", *The Encyclopedia of Electrical and Electronics Engineering*, Vol. 15, pp. 122-123, Wiley, 1999.
5. D.D.L. Chung, "X-Ray Diffraction for Structure Determination", *Encyclopedia of Analytical Chemistry*, R.A. Meyers (Ed.), Wiley, Chichester, UK, 2000, Vol. 15, p. 13347-13384.
6. D.D.L. Chung and C. Zweben, "Composites for Electronic Packaging and Thermal Management", *Comprehensive Composite Materials*, Vol. 6, Pergamon, 2000, p. 701-725.
7. D.D.L. Chung, "Graphite Intercalation Compounds", *Encyclopedia of Materials: Science and Technology*. K.H.J. Buschow, R.W. Cahn, M.C. Flemings, B. Ilschner, E.J. Kramer and S. Mahajan (eds.), Elsevier, Oxford, Vol. 4, p. 3641-3645 (2001).
8. D.D.L. Chung, "Applications of Submicron Diameter Carbon Filaments", *Proc. NATO Advanced Study Institute*, NATO Science Series, Series E: Applied Sciences - Vol. 372 (Carbon Filaments and Nanotubes: Common Origins, Differing Applications?, Laszlo P. Biro (Ed.)), Kluwer Academic Publishers, Dordrecht, 2001, p. 275-288; also in Nanostructured Carbon for Advanced Applications, G. Benedek et al. (Ed.), Kluwer, Netherlands, 2001, p. 331-345.
9. Shoukai Wang, Sihai Wen, Victor H. Guerrero and D.D.L. Chung, "Thermoelectric Structural Composites and Thermocouples Using Them" *Materials Research Society Symposium Proceedings*, Volume 691, Issue Thermoelectric Materials 2001: Research and Applications, Materials Research Society, 2002, pp. 177-182.
10. D.D.L. Chung, "Composites, Intrinsically Smart Structures", *Encyclopedia of Smart Materials*, ed. Mel Schwartz, Wiley, 2002, Vol. 1, p. 223-243.
11. D.D.L. Chung, "Carbon-Cement Composites", *World of Carbon* 2 (Fibers and Composites), Pierre Delhaes (Ed.), Taylor & Francis, 2003, p. 219-241.
12. D.D.L. Chung, "Functional Composite Materials", *Advances in Condensed Matter and Materials Research*, Ed. Francois Gerard, Nova Science Pub., Hauppauge, NY, 2003, p. 89-147.
13. Sihai Wen and D.D.L. Chung, "Fiber Reinforced Cement for Piezoelectricity and Pyroelectricity", ACI Special Publication SP-216, *Innovations in Fiber-Reinforced Concrete for Value*, Ed. N. Banthia, M. Criswell, P. Tatnall and K. Folliard, American Concrete Institute, Farmington Hills, MI, 2003, p. 115-128.
14. D.D.L. Chung, "Multifunctional Polymer-Matrix Structural Composites", Annual Technical Conference - Society of Plastics Engineers, Volume 62nd, Issue Vol. 2, Society of Plastics Engineers, 2004, pp.1410-1414.
15. D.D.L. Chung, "Composite Materials", *Kirk-Othmer Encyclopedia of Chemical Technology*, 5th Ed., Wiley, 2004.

16. D.D.L. Chung, “Composite Materials”, *Kirk-Othmer Concise Encyclopedia of Chemical Technology*, 5th Ed., Wiley, 2007.
17. D.D.L. Chung, G. Song, N. Ma and H. Gu, “Smart Materials and Structures”, *High Performance Construction Materials*, Caijun Shi and Y. L. Mo (eds.), Vol. 1 of Book Series "Engineering Materials for Technological Needs", World Scientific Pub., Singapore, 2008. Chinese translation, Chongqing University Press, China, 2011.
18. D.D.L. Chung, “Sensors in Composites”, *Wiley Encyclopedia of Composites*, 2nd Ed., edited by Luigi Nicolais, Assunta Borzacchiello and Stuart M. Lee. Wiley-Interscience, 2014.
19. D.D.L. Chung, “Composite Materials”, *Kirk-Othmer Encyclopedia of Chemical Technology*, 6th Ed., Wiley, 2016.
20. D.D.L. Chung, “Graphite Intercalation Compounds”, *The Reference Module in Materials Science and Engineering*, Saleem Hashmi, Editor, Elsevier, 2016.
21. D.D.L. Chung, “Self-Sensing Structural Composites in Aerospace Engineering”, *Advanced composite materials for aerospace engineering: processing, properties and applications*, Sohel Rana and Raul Fangueiro, Editors, Woodhead Pub., Elsevier, 2016, Ch. 10, p. 295-331.
22. D.D.L. Chung, "Carbon Fibers", *ASM Handbook*, Volume 21, 2016.
23. D.D.L. Chung, in, *Successful Women Ceramic and Glass Scientists and Engineers: 100 Inspirational Profiles*, L.D. Madsen, Wiley, 2016, ISBN: 978-1-118-73360-8.
24. D.D.L. Chung, “Carbon-Matrix Composites”, *Encyclopedia of Materials: Technical Ceramics and Glasses*, Elsevier, 2020.
25. D.D.L. Chung, “Sensing Materials: Self-Sensing Materials”, *Encyclopedia of Sensors and Biosensors*, Elsevier, 2023, p. 196-203.

ARCHIVAL PEER-REVIEWED INTERNATIONAL JOURNAL PAPERS
Google Scholar: h-index = 115, 49,718 citations, annual citations reaching 3,317 (as viewed on Mar. 30, 2025).
The number of citations for each year over the years is shown in the chart below, as obtained from Google Scholar.



633 archival peer-reviewed international journal papers categorized by material type are listed below. Only published peer-reviewed journal papers are listed.

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