

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ZHUHAI COSMX BATTERY CO., LTD.,
Petitioner

v.

NINGDE AMPEREX TECHNOLOGY LIMITED,
Patent Owner

Case IPR2025-00385
U.S. Patent No. 10,964,927

**DECLARATION OF MICHAEL PECHT, PH.D., PE, IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 10,964,927**

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3.	1.2: wherein, the separator comprises a porous substrate and a porous layer;	71

4. 1.3: wherein the porous layer is disposed on a surface of the porous substrate and comprises inorganic particles and a binder; 71
5. 1.4: and the porous substrate has an absolute plastic deformation rate in a first direction ranging from about 40% to about 1800%, and wherein the absolute plastic deformation rate is calculated according to an equation $(L2-L0)/L0 \times 100\%$, where L0 refers to a length of the porous substrate before stretching and L2 refers to a length of the porous substrate after the porous substrate is stretched to breakage and docked along the fracture caused by the breakage and flattened. 71
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6. 2. The electrochemical device according to claim 1, wherein the porous substrate has an absolute plastic deformation rate in a second direction ranging from about 60% to about 1800%. 77
7. 3. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: an absolute plastic deformation rate in the first direction ranging from about 40% to about 1600%; and an absolute plastic deformation rate in the second direction ranging from about 70% to about 1600%. 78
8. 4. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 50% to about 100%; and a relative plastic deformation rate in the second direction ranging from about 60% to about 100%. 78
9. 5. The electrochemical device according to claim 4, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 65% to about 90%; and a relative plastic deformation rate in the second direction ranging from about 75% to about 90%. 80

10.	6. The electrochemical device according to claim 1, wherein the binder comprises at least one selected from the group consisting of a vinylidene fluoride- hexafluoropropylene copolymer, a vinylidene fluoride- trichloroethylene copolymer, . . . polyimide, polyethylene oxide.	81
11.	7. The electrochemical device according to claim 1, wherein the inorganic particles comprise at least one selected from the group consisting of alumina, . . . magnesium hydroxide, calcium hydroxide and barium sulfate.	81
12.	8. The electrochemical device according to claim 1, wherein the porous substrate comprises a polymer film, a multilayer polymer film or a nonwoven fabric, wherein the polymer film, the multilayer polymer film or the nonwoven fabric is formed by any one or more of the following polymers: polyethylene, . . .	81
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14.	10. The electrochemical device according to claim 1, wherein the electrochemical device comprises lithium ion batteries.	83
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19. 1.4: and the porous substrate has an absolute plastic deformation rate in a first direction ranging from about 40% to about 1800%, and wherein the absolute plastic deformation rate is calculated according to an equation $(L2-L0)/L0 \times 100\%$, where L0 refers to a length of the porous substrate before stretching and L2 refers to a length of the porous substrate after the porous substrate is stretched to breakage and docked along the fracture caused by the breakage and flattened. 92
20. 2. The electrochemical device according to claim 1, wherein the porous substrate has an absolute plastic deformation rate in a second direction ranging from about 60% to about 1800%. 94
21. 3. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: an absolute plastic deformation rate in the first direction ranging from about 40% to about 1600%; and an absolute plastic deformation rate in the second direction ranging from about 70% to about 1600%.....95
22. 4. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 50% to about 100%; and a relative plastic deformation rate in the second direction ranging from about 60% to about 100%. 96
23. 5. The electrochemical device according to claim 4, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 65% to about 90%; and a relative plastic deformation rate in the second direction ranging from about 75% to about 90%. 97
24. 6. The electrochemical device according to claim 1, wherein the binder comprises at least one selected from the group consisting of a vinylidene fluoride-hexafluoropropylene copolymer, a vinylidene fluoride-trichloroethylene copolymer, polymethyl methacrylate, polyacrylic acid, polyacrylate, polyacrylonitrile, polyvinyl pyrrolidone, polyvinyl acetate, an ethylene-

	vinyl acetate copolymer, polyimide, polyethylene oxide, cellulose acetate, cellulose acetate butyrate, cellulose acetate propionate, cyanoethyl amylopectin, cyanoethyl polyvinyl alcohol, cyanoethyl cellulose, cyanoethyl sucrose, amylopectin, sodium carboxymethyl cellulose, lithium carboxymethyl cellulose, an acrylonitrile-styrene-butadiene copolymer, polyvinyl alcohol , polyvinyl ether, polytetrafluoroethylene, polyhexafluoropropylene, a styrene-butadiene copolymer, and polyvinylidene fluoride.	98
25.	7. The electrochemical device according to claim 1, wherein the inorganic particles comprise at least one selected from the group consisting of alumina , silica , magnesia, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, zinc oxide , calcium oxide, zirconia , yttria, silicon carbide, eboehmite, aluminum hydroxide, magnesium hydroxide, calcium hydroxide and barium sulfate.	99
26.	8. The electrochemical device according to claim 1, wherein the porous substrate comprises a polymer film, a multilayer polymer film or a nonwoven fabric, wherein the polymer film, the multilayer polymer film or the nonwoven fabric is formed by any one or more of the following polymers: polyethylene, polypropylene, . . .	100
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28.	10. The electrochemical device according to claim 1, wherein the electrochemical device comprises lithium ion batteries.	100
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I. INTRODUCTION

1. I, Michael Pecht, have been retained on behalf of Zhuhai CosMX Battery Co., Ltd. (“Petitioner”) to provide an analysis of U.S. Patent No. 10,964,927 (“the ’927 patent”). I understand that Petitioner is requesting that the Patent Trial and Appeal Board (“PTAB” or “Board”) institute an *inter partes* review (“IPR”) proceeding of the ’927 patent.

2. I have been asked to provide my independent analysis of the ’927 patent in light of the prior-art publications cited below.

3. I am not, and never have been, an employee of Petitioner. I received no compensation for this Declaration beyond my normal hourly compensation based on my time actually spent analyzing this patent, the prior-art publications cited below, and the issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving these patents.

II. MY PROFESSIONAL EXPERIENCE AND QUALIFICATIONS

4. A copy of my curriculum vitae (“CV”) is submitted with this Declaration as Exhibit 1009. As my CV indicates, I am a licensed Professional Engineer in the State of Maryland.

5. I have a B.S. in Physics, an M.S. in Electrical Engineering, and an M.S. and Ph.D. in Engineering Mechanics from the University of Wisconsin at

Madison. The focus of my thesis was on the stress-strain behavior of non-linear materials.

6. I worked as a civil servant electrical technician for 4 years to pay for my way through college. After graduation, I spent one year working as a NASA contractor on the Astro-1 space telescope to assess reliability issues for that telescope.

7. Since earning my Ph.D., I have had over 40 years of additional experience in the areas of design, manufacture, testing, and maintenance of electronic components, products, and systems. In particular, I have extensive hands-on experience in the design, manufacture, and testing of lithium-ion batteries.

8. I am a Fellow of five professional societies, including three that are directly pertinent in this case, including: the Institute of Electrical and Electronics Engineers, Inc. (“IEEE”), the American Society of Mechanical Engineers (“ASME”), and the American Society of Materials (“ASM”). The honors and awards that I have received for my work in that field include an IEEE Fellowship award for “effectiveness in leadership in the development and realization of an exemplary program and successful efforts to raise the level of engineering excellence and practice within and without the organization” and the ASME

Fellowship award for “promoting the art, science, and practice of mechanical engineering.”

9. I am the founder and Director of Center for Advanced Life Cycle Engineering (“CALCE”) at the University of Maryland, which is funded by over 150 of the world’s leading electronics companies. CALCE started in 1986 as a National Science Foundation center of excellence in electronic packaging. CALCE has over 100 researchers and the laboratories to design, manufacture, characterize and test, and conduct failure analysis of lithium-ion batteries.

10. I am also the George Dieter Chair Professor in Mechanical Engineering at the University of Maryland, where I have developed and taught classes in materials, design, manufacture and testing, and reliability and safety at the graduate and undergraduate level for over 40 years. I also teach a graduate course in lithium-ion batteries. In addition, I have taught formal courses for companies including Intel, Microsoft, and Dell, and professional organizations, including the ASME, IEEE, SMTA and IPC, the U.S. military, NSA, NASA, the FDA, and for agencies under the sponsorship of the United Nations.

11. In addition to teaching, I have had projects with hundreds of major international electronics companies, including Intel, Texas Instruments, Samsung, National Semiconductor, TSMC, Motorola, Potomac Photonics, Fairchild, Silicon Power, Vectron, Fujitsu, Delphi Technology, NeoPhotonics, Murata, Avago, NXP,

M/A Comm, Dell, IBM, ASE, Dell, Lenovo, Honeywell, Emerson, Medtronic, Philips, Teredyne, Hazeltine Corp., GEC-Marconi, Lockheed, GM, GE, Boeing, General Dynamics, Raytheon, United Defense, and others.

12. Specifically on the subject of lithium-ion battery design, manufacture, testing, reliability and safety, I have had contracts with: Underwriters Laboratory (UL), Ferrari, Volvo, SkyMul, Proctor & Gamble, Amazon, NASA, Crane Aerospace & Electronics, SAFT, Naval Surface Warfare Center, Blackberry, PCTEST Engineering Lab, Lansmont Corporation, Kimandia, Flexel, Nevro, Jarden Safety, Black & Decker, Harris RF Communication, Samsung, SKI, Eagle Pitcher, Honeywell, Dell, IBM, Oracle Corporation, Wentworth Technology, Emerson, DfR Solutions, Heartware, HEICO Aerospace, Huawei, Physio-Control, X-wave, and others. I also had numerous projects on batteries with the NSF, NASA, the FDA, and the U.S. Military. I am very familiar with the battery standards, datasheets, and materials and their properties.

13. I have audited over 50 lithium-ion battery manufacturers to assess quality, reliability, and safety, including Eagle Pitcher, SKI in Korea, and numerous companies in China.

14. I have testified and was a panelist on lithium-ion battery safety, for the Consumer Protection Safety Commission (CPSC) Forum, Bethesda, Maryland, July 27, 2023, and was highlighted on their promotional video.

15. I also served on various National Academy of Science / Engineering (NAE/NAS) Committees (invited to participate), including the committee for reliability growth (how to improve the reliability of U.S. military electronics-based weapon systems); committee to investigate printed circuit board manufacturing in the U.S.; and the committee to examine U.S. research needs in materials engineering.

16. I served as an expert for congressional investigations, including the Committee on Energy & Commerce to investigate automotive reliability and safety issues: Toyota sudden acceleration (2009 - 2010); GM ignition – air bag recalls; and NHTSA responses (2014).

17. I served as an FDA expert, taught electronics, and reliability courses, and aided the FDA in assessing manufacturers of medical devices, the techniques used to qualify devices, and medical device reliability and safety. I have had numerous discussions with the FDA on lithium-ion batteries used in vaping devices.

18. I served as chief editor of the ASME Open Journal, of the IEEE Transactions on Reliability, of Microelectronics Reliability and as an associate editor for the IEEE Transactions on Components and Packaging Technology. I am currently the editor in chief of the Elsevier e-Prime Journal of Electronics, Electrical Engineering and Energy.

19. I have written over thirty books and over 700 articles on various subjects related to design and manufacturing electronic products. My work has been cited approximately 60,000 times. I have 130+ published articles related to lithium-ion batteries, including their performance, reliability and safety. These are listed in his attached resume.

20. I have also given over 20 invited talks, lectures, and keynote (invited) presentations as well as numerous media (NPR, BBC, Washington Post, etc.) interviews which included discussions of lithium-ion battery design, manufacturing, testing, reliability, and safety.

21. I am a named inventor on 11 U.S. patents. I have also given a presentation on Lithium Ion Battery Separators to U.S. Patent Office for the USPTO's Patent Examiner Technical Training Program on July 28, 2015.

22. I have been the advisor of more than 150 MS and Ph.D. students, many of whom are working for companies including: Dell, Samsung, Tesla, Applied Materials, ASML, Apple, Broadcom, and Microsoft on technologies including lithium-ion batteries.

23. In 1997, I received the ISHM / IEPS William D. Ashman Memorial Achievement Award. In 1999, I received the 3M Research Award for research work in the electronics reliability area that has made significant contributions to the scientific understanding of material properties and their complex behavior. In

2008, I was awarded the IEEE Reliability Society's Lifetime Achievement Award.

In 2010, I received the IEEE Exceptional Technical Achievement Award.

24. I have written over thirty books and over 700 articles on various subjects related to electronic product design, manufacture, test, reliability and materials. My work has been cited over 16,000 times. Some of my publications on lithium ion batteries, components and assemblies include:

- Sai Dinesh Gelam, Sahithi Maddipatla, Carmen Chicone, Michael Pecht, "Core collapse in cylindrical Li-ion batteries", Journal of Power Sources, Volume 623, 2024, 235471, ISSN 0378-7753, <https://doi.org/10.1016/j.jpowsour.2024.235471>.
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25. I am also a named inventor on 11 U.S. patents.

26. In 1997, I received the ISHM / IEPS William D. Ashman Memorial Achievement Award for numerous contributions to academia and the electronics packaging industry. In 1999, I received the 3M Research Award for research work in the electronics reliability area that has made significant contributions to the scientific understanding of material properties and their complex behavior. In

2008, I was awarded the IEEE Reliability Society's Lifetime Achievement Award.

In 2010, I received the IEEE Exceptional Technical Achievement Award.

III. LEGAL PRINCIPLES

27. In forming my analysis and conclusions expressed in this Declaration, I have applied the legal principles described in the following paragraphs, which were provided to me by counsel for the Petitioner.

28. I have been informed that prior art is that which was known or used by others in the U.S., or was patented or published anywhere, before the Applicant's invention. I further have been informed that prior art includes that which was patented or published anywhere, or was in public use, on sale, or offered for sale in this country, more than one year prior to the filing date of the patent application (critical date). I have also been informed that prior art includes that which was described in a U.S. patent granted on an application for a patent (or in a published application for a U.S. patent) that was filed by another in the U.S. before the date of invention for such a claim.

A. Anticipation

29. I understand that a claim is anticipated if all of the limitations of the claim are disclosed in a single prior-art reference. Limitations may be disclosed in the prior art explicitly or inherently.

30. I understand that if the prior art teaches a composition, then the properties of that composition are necessarily present. A prior-art disclosure may

therefore *inherently* disclose a claim element reciting the properties of a composition by disclosing that composition. In other words, where a patentee claims a composition, product, or apparatus in terms of a function, property, or characteristic and the composition of the prior art is the same as that of the claim but the function is not explicitly disclosed by the reference, the reference may nonetheless anticipate the claim.

31. For that reason, the discovery of a previously unappreciated property of a prior-art composition, or of a scientific explanation for the prior art's functioning, does not render the old composition patentably new to the discoverer.

B. Obviousness

32. I have been informed that a patent claim is invalid as “obvious” in light of one or more prior-art references if it would have been obvious to a person of ordinary skill in the art at the time of the alleged invention (“POSA”), taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long felt need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others.

33. I understand that a patent cannot be properly granted for subject matter that would have been obvious to a POSA at the time of the alleged invention, and that a patent claim directed to such obvious subject matter is invalid under 35 U.S.C. § 103. It is also my understanding that in assessing the obviousness of claimed subject matter one should evaluate obviousness over the prior art from the perspective of a POSA at the time the invention was made (and not from the perspective of either a layman or a genius in that art).

34. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references.

35. A patent can be obvious in light of a single prior-art reference if it would have been obvious to modify that reference to arrive at the patented invention. To be obvious in light of a single prior-art reference or multiple prior-art references, there must be a reason that would have prompted a POSA to modify the single prior art reference, or combine two or more references, in a manner that provides the elements of the claimed invention. This reason may come from a motivation to combine, or may come from the reference(s) themselves, the knowledge and “common sense” of a POSA, or from the nature of the problem to be solved, and this reason may be explicit or implicit from the prior art as a whole. I have been informed that, under the law, the combination of familiar elements according to known methods is likely to be obvious when it does no more than

yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

36. I understand that a dependent claim contains all of the limitations of the independent claim from which it depends. Thus, to establish unpatentability, every limitation set forth in a dependent claim as well as the independent claim from which it depends must be found in the prior art or be obvious from the prior art.

C. Claim Construction

37. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning.” In determining the ordinary and customary meaning, the words of a claim are first given their plain meaning that those words would have had to a POSA. I understand that the structure of the claims, the specification, and the file history also may be used to better construe a claim insofar as the plain meaning of the claims cannot be understood. I also understand that a patentee can be his own lexicographer, providing a definition for a term that otherwise does not have an established meaning in the art. Additionally, treatises and dictionaries may be used, albeit under limited circumstances, to determine the meaning attributed by a person of ordinary skill in the art to a claim term at the time of filing. I have followed this approach in my analysis.

38. For the terms “absolute plastic deformation rate” and “relative plastic deformation rate” I have applied the definitions provided by the patentee in the claims. For all other terms, I have applied the plain and ordinary meaning as it would have been interpreted by a POSA at the time the alleged invention was made (not today).

IV. MATERIALS CONSIDERED AND BASIS OF OPINIONS

39. My opinions are based on more than 40 years of working with electronic packages, components, and reliability, as well as my teaching and research experience. My opinions are also based on investigation and study of the relevant materials, including the patent at issue and its file history, and the prior art.

40. In the course of forming my opinions I have reviewed the following exhibits of record:

Exhibit No.	Description
1001	U.S. Patent No. 10,964,927 to Guo et al. (“the ’927 patent”)
1002	Prosecution History of U.S. Patent No. 10,964,927
1004	U.S. Patent Application Publication No. 2015/0180002 to Nishikawa et al. (“Nishikawa”)
1005	Chen et al., “Deformation and fracture behaviors of microporous polymer separators for lithium ion batteries” <i>RSC Advances</i> (March 2014) (“Chen”)
1006	U.S. Patent No. 10,559,802 to Zhang et al. (“Zhang”)
1007	Zhang, “Mechanical Behavior of Shell Casing and Separator of Lithium-ion Battery” <i>Massachusetts Institute of Technology</i> (June 2017) (“Zhang Thesis”)

Exhibit No.	Description
1008	Certified English-language Translation of Prosecution History of Chinese Patent Application No. CN201810640157.9A
1009	<i>Curriculum Vitae</i> of Michael Pecht
1010	Jordan, J.L., et al., “Mechanical Properties of Low Density Polyethylene,” <i>Journal of Dynamic Behavior of Materials</i> , 2:411-420 (2016)
1011	Salakhov, I.I., “Low-Temperature Mechanical Properties of High-Density and Low-Density Polyethylene and Their Blends,” <i>Polymers</i> , 13(1821):1-21 (2021)
1012	Carr, S.H., et al., “Structural Basis for the Mechanical Properties of Polyethylenes,” Department of Defense (1983)
1015	Arora et al., “Battery Separators” <i>Chem Rev.</i> (Oct. 2004)
1016	EP Patent Application No. 0924780 A1 to Yu
1017	Xiong, B., “Contribution to the study of elastic and plastic deformation mechanisms of polyethylene and polypropylene as a function of microstructure and temperature,” <i>Materials</i> (2014)
1018	Beer, F., et al. “Mechanics of materials” (2009)
1019	Baldwin, “Properties and Performance Attributes of Novel Co-extruded Polyolefin Battery Separator Materials” (2011)
1020	Dupen, B., “Applied strength of Materials for Engineering Technology” v. 11 Revised January 2017.
1021	Hibbeler, R.C., “Mechanics of Materials,” 8th Ed. (2011)

41. I confirm that to the best of my knowledge the accompanying exhibits are true and accurate copies of what they purport to be, and that an expert in the field would reasonably rely on them to formulate opinions such as those set forth in this Declaration.

42. I may rely upon these materials and/or additional materials to rebut arguments raised by the Patent Owner. Further, I may also consider additional documents and information in forming any necessary opinions, including documents that may not yet have been provided to me.

43. My analysis of the materials relevant to this proceeding is ongoing and I will continue to review any new material as it is provided. This report presents only those opinions I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information and on my continuing analysis of the materials already provided.

V. DESCRIPTION OF THE RELEVANT FIELD AND A PERSON OF ORDINARY SKILL IN THE RELEVANT FIELD (ART)

44. I have carefully reviewed the '927 patent.

45. Based on my review of these materials, I believe that the relevant field for purposes of the '927 patent is battery construction materials and their properties.

46. In my opinion, “a person of ordinary skill in the relevant field” is a hypothetical person to whom an expert in the relevant field could assign a routine task with reasonable confidence that the task would be successfully carried out. I have been informed that evidence of the level of ordinary skill in the art can be determined based on information about the field including: the types of problems encountered, known solutions, the speed of innovation, sophistication, and the

educational level of active workers. I have considered these types of information along with my own background working with students and other professionals in the field to reach my conclusion.

47. I have been advised that a person of ordinary skill in the “relevant field” (art), (i.e., a “POSA”), must be able to make and use the claimed invention based on the information disclosed in the specification of the patent. Accordingly, where information is required to make and use the claimed invention but has not been expressly disclosed in the specification, the patentee effectively acknowledges that such information should be considered to be within the knowledge of the hypothetical POSA. Whether I use the acronym POSA or not, all of my opinions throughout this Declaration are based on the understanding of a POSA at the time of the effective filing date of the ’927 patent.

48. Based on my analysis of the ’927 patent, it is my opinion that a POSA at the date attributed to the invention would have had at least an undergraduate degree in materials or mechanical engineering and two years of experience in the study of battery materials and reliability. A higher level of education, such as a Master’s Degree in one of these same fields, could substitute for work experience. Based on my educational background and experience, I qualify as at least a POSA at the time of the alleged invention of the patent. And, based on my experience, I have an understanding of the capabilities of a person of ordinary skill in the

relevant field. I have supervised, directed, and instructed many such persons over the course of my career.

VI. THE DATE OF THE PATENTS

49. The '927 patent was filed on November 28, 2018 and claims a priority date of June 20, 2018. For purposes of my analysis here, I have been advised by counsel to assume a date of approximately June 20, 2018 as the date governing my obviousness analysis. I will note that an earlier or later date by even as much as a year would not impact the relevant analysis in this report.

VII. BACKGROUND OF CONVENTIONAL BATTERY SEPARATOR TECHNOLOGY

50. All batteries have a cathode and an anode, with a separator between them. The separator keeps the anode and cathode from touching. It has long been known that batteries have a risk of thermal runaway if the separator is punctured, especially if the puncture is caused by a conductive object that shorts the circuit between the cathode and anode. For that reason, battery separators have been made from materials that are resistant to puncture. *See generally, e.g.*, EX1008, 0006-07 (CN105449140A); EX1016. Flexible polymers and resin coatings have long been used in separators based on their puncture-resistant material properties of elastic and plastic deformation. EX1016.

51. A common battery separator architecture includes a porous substrate like a polymer film, and a coating or resin layer. *See generally, e.g.*, EX1006. The

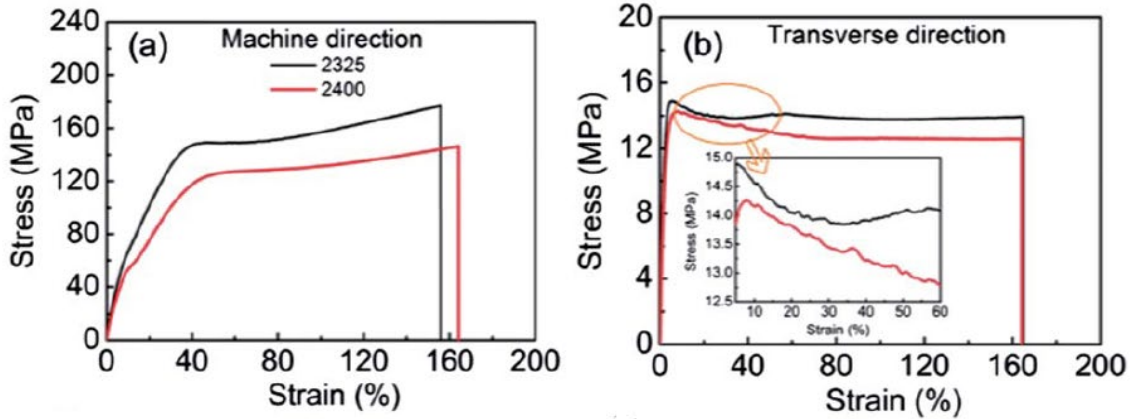
coating is typically a porous layer that includes a binder (adhesive) and a filler (organic or inorganic particles). *Id.* In a battery separator, the binder (adhesive) acts as a glue to hold the various components of the separator together, ensuring its structural integrity, while the filler is added to modify specific properties like porosity, wettability, and thermal stability, often by providing additional surface area for the electrolyte to interact with the separator matrix. *Id.*

52. The stress-strain curve of a material expresses how a material responds to a force (stress), where stress (σ) is defined as: $\sigma = F/A$, where F is the force applied to the separator and A is the cross-sectional area of the material. EX1005, 14907. Strain (ϵ) is defined as: $\epsilon = (L - L_0) / L_0$, where L is the measured length of the material and L_0 is the original length. *Id.* When a force is applied to a material, it initially deforms in an elastic manner. *Id.*, 14908. This elastic deformation or stretch will recover, or bounce back to its original length upon the removal of the force. *Id.* However, if the force is increased, there reaches a stress (called the yield strength) where plastic deformation occurs. *Id.* This plastic deformation is the stretch that will not recover—it results in a permanent deformation. *Id.* The limit of the elastic and plastic deformation (together the “elongation”) is the total deformation until the breaking point. *Id.*, 14908-10. The maximum stress on the stress-strain curve is the ultimate tensile stress (strength). *Id.* As noted, the transition point between the elastic and plastic deformation of the

material is the yield strength. *Id.* The slope of the linear (elastic) portion of the curve is called the Young's modulus or elastic modulus. *Id.* Plotting stress-strain curves, measuring yield strength and ultimate tensile stress, and calculating the Young's modulus is how material scientists have analyzed polymer films for decades. *See generally, e.g.,* EX1005; EX1017.

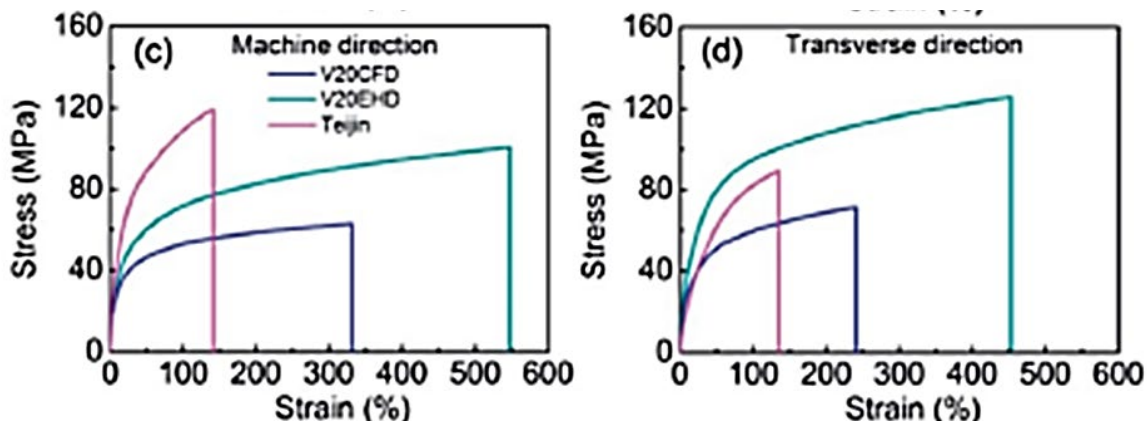
53. Chen et al., "Deformation and fracture behaviors of microporous polymer separators for lithium ion batteries" ("Chen") performs tensile tests on five commercially available battery separators in two orthogonal directions (called the machine and transverse directions or MD and TD). EX1005, 14904, 14906-07. Chen reports the stress-strain curves and analyzes the material deformation (i.e., elongation) of the separator. EX1005, FIG. 3, 14908. Separators made using both wet and dry processes were tested. *Id.* Wet process separators tend to have more isotropic behavior (i.e., similar properties in both the transverse and machine directions). EX1005, 14908-11. Percent strain (ϵ) is measured by the following standard equation: $\epsilon = (L - L_0) / L_0 \times 100\%$. *Id.*

54. Figure 3 below shows stress-strain curves for the dry-processed battery separators in both the machine and transverse directions. EX1005, FIG. 3, 14908. Both curves show elastic and plastic behavior. EX1005, 14908.



EX1005, FIG. 3 (excerpted).

55. Figure 3 below shows stress-strain curves for wet processed separators in both the machine and transverse directions. EX1005, FIG. 3, 14908. These also show elastic, followed by plastic, deformation. *Id.* (Teijin separator).



EX1005, FIG. 3 (excerpted).

56. Chen also gives measured Young's (elastic) modulus, tensile strength, and strain at break, shown in the table below. The plots above, considered in view of these measurements below, and common knowledge regarding the nature of the separator material (they become almost completely plastic early in the stress-strain

curve) demonstrate that the separators about double in length due to predominantly plastic deformation.

Separator	Direction	Measured modulus ^a (MPa)	Tensile strength (MPa)	Strain that non-linearity occurred (%)	Strain at break (%)
2325	MD	935 ± 43	175.2 ± 9.1	0.79	155.9
	TD	510 ± 24	14.7 ± 1.9	0.61	164.9
2400	MD	873 ± 37	146.5 ± 7.4	0.85	164.3
	TD	502 ± 28	13.4 ± 2.2	0.76	164.2
V20CFD	MD	675 ± 25	65.3 ± 5.3	0.68	333.2
	TD	781 ± 39	72.6 ± 6.7	0.72	241.5
V20EHD	MD	696 ± 48	102.7 ± 7.8	0.65	547.7
	TD	823 ± 52	127.8 ± 9.1	0.87	453.2
Teijin	MD	733 ± 41	120.6 ± 9.6	0.63	142.2
	TD	622 ± 36	90.1 ± 8.5	0.54	134.9

^a The Young's modulus was calculated from the slope of the linear stress-strain curve in the strain range of 0–0.5%.

EX1005, Table 2.

57. Again, strain is measured by the following standard equation: $\epsilon = (L - L_0) / L_0$, where L is the length of the material when subjected to a stress and L_0 is the original length of the material. EX1005, 14908-911. The elastic strain is reversible. *Id.* The Young's modulus is the slope of the line in the linear portion of the stress-strain curve—a value that is easily calculated. EX1005, Table 2, 14909.

58. Most elastic strain in a polymer material occurs early in the stress strain curves (i.e., up to a yield stress). After the yield stress, plastic deformation of the material occurs more predominantly. EX1017, 42. The yield stress can be measured as the stress at a yield peak in the stress-strain curve. *Id.*; EX1005, 14911.

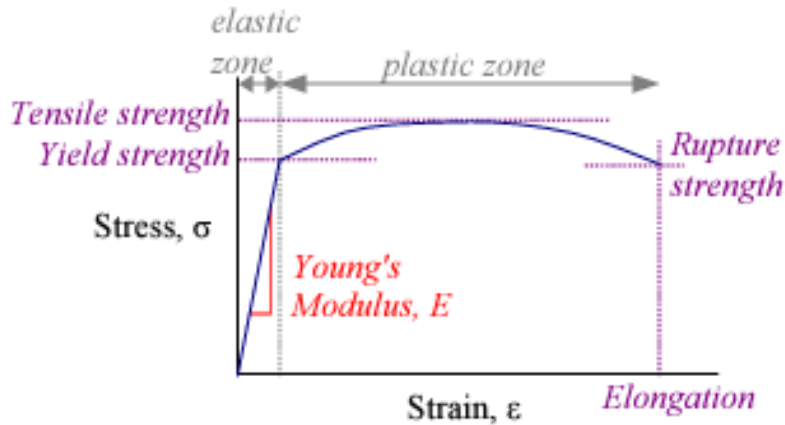
59. The yield stress may also be estimated using an “offset method.” In the offset method a line with a slope equal to Young's modulus is drawn parallel to

the stress strain curve at an offset strain (typically 0.2-2%). The value of stress at the point where the line and the stress-strain curve intersect provides an approximation for the yield stress. EX1018, 61; EX1019, 8; EX1021, 87.

60. When a stress-strain curve is not available, the elastic portion of the strain can be estimated using the Young's modulus. For example, the elastic portion of the strain is estimated by drawing an "elastic line" with a slope equal to Young's modulus at any stress state and reading off the strain value difference from that stress state to where the Young's modulus intersects the stress = 0 as illustrated in EX1020 (reproduced below). EX1018, 65; EX1020, 18.

61. In other words, the elastic strain is equal to the strain between the intersection of the elastic line and the strain axis and the strain at which breakage occurs. *Id.* Here, Young's modulus = stress at breakage/ elastic strain. *Id.* Thus the elastic strain = stress at breakage/ Young's modulus. *Id.*

62. The estimated elastic strain is multiplied by 100% to convert to percent elastic strain. *Id.* The strain at break (elongation) represents the total deformation of the material, which is the sum of both elastic and plastic strain. Thus the plastic strain= strain at break – elastic strain. EX1005, 14909, 14910.



EX1020, 18 (using slightly different terminology, e.g., “tensile strength” in this reference is what I call ultimate tensile strength above, and “rupture strength” is what I call strength at breaking).

63. Baldwin reports a stress at yield, strain at break, ultimate stress, and Young’s modulus for five commercially available battery separators. EX1019, 8. Baldwin also provides a stress-strain curve for each separator. *Id.* The values obtained from a tensile test in the MD direction, and elastic strain calculation for each method are given below. As shown, all of the separator materials about double in length due to predominantly plastic deformation, which is expected for polyolefin materials.

TABLE 2.—AVERAGE EXPERIMENTAL MACHINE DIRECTION TENSILE
STRENGTH RESULTS FOR EXXONMOBIL SEPARATOR FILMS

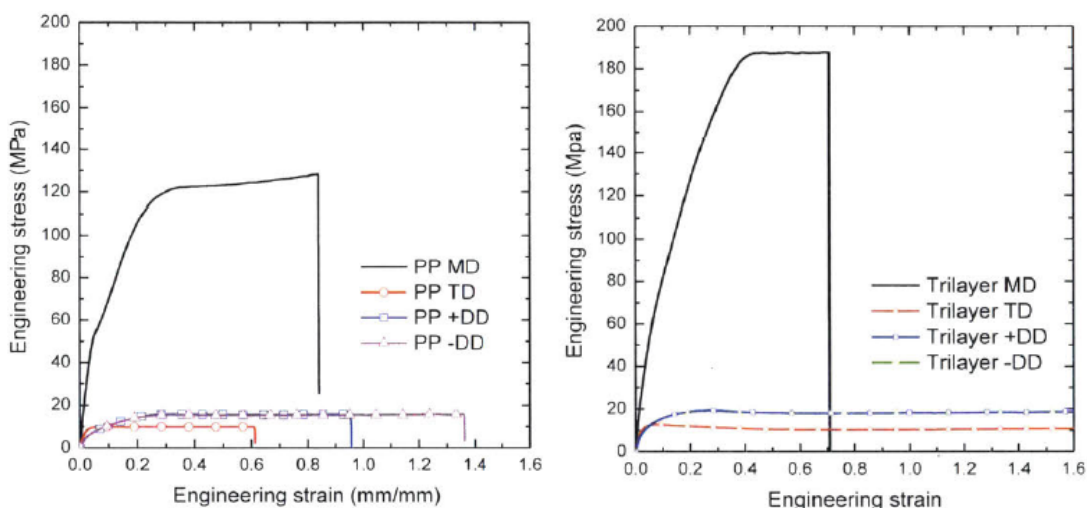
Material	Displacement at break, μm	Strain at break, percent	Ultimate stress, MPa	Ultimate strain, percent	Stress at yield, MPa	Young’s modulus, MPa
V20CFD	16532	222.6	32.91	205.0	18.3	153.2
V25CGD	19490	251.6	49.93	231.1	24.3	178.0
V20EHD	19030	240.2	50.96	205.04	26.14	210.3
V25EKD	17128	226.6	46.11	172.70	22.44	138.0
E16MMS	18190	235.3	57.28	216.2	16.30	156.6

EX1019, 8

Separator	Elastic strain Shown in Baldwin	Plastic strain Shown in Baldwin
V20CFD	25%	$222.6\% - 25\% = 197.6\%$
V25CGD	23%	$251.6\% - 23\% = 228.6\%$
V20EHD	20%	$240.2\% - 20\% = 220.2\%$
V25EKD	24%	$226.6\% - 24\% = 202.6\%$
E16MMS	17%	$253.3\% - 17\% = 236.3\%$

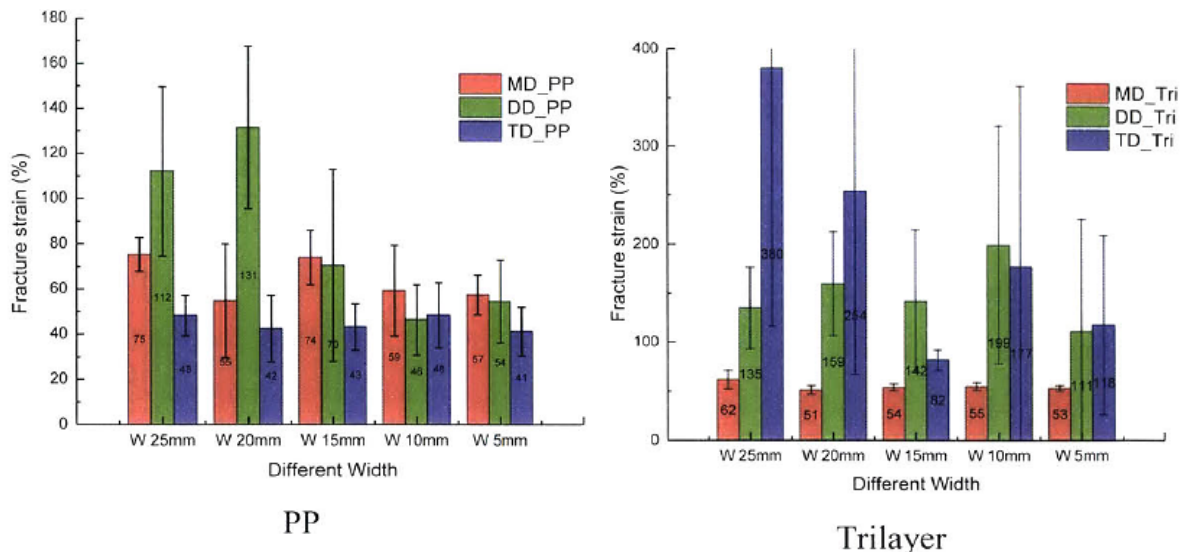
64. Other examples of stress-strain curves for polymer-based battery separators are found in Zhang Thesis. *See* EX1007 (testing the mechanical properties of commercially-available battery separators). Zhang Thesis's tensile tests were performed on various geometries of test strips using the ASTM D882 standard—a well-accepted methodology in the art. EX1007, 67.

65. The stress-strain curves for a polypropylene dry-process separator (PP) and a tri-layer dry-process separator (trilayer) are reproduced below. EX1007, 68, FIGs. 3-1 (b)-(c).



EX1007, FIGs. 3-1 (b)-(c).

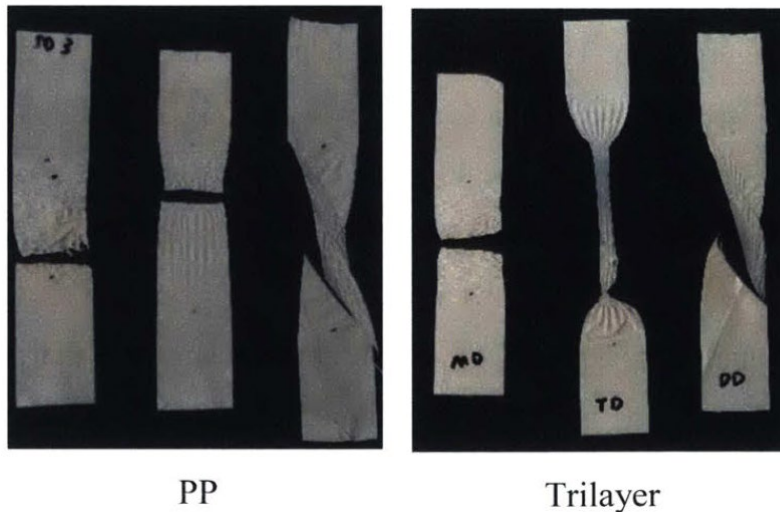
66. In these plots, MD refers to the machine direction, TD to the transverse direction, and DD to a diagonal direction (about 45 degrees from TD and MD). *Id.* Note that these strain values would need to be multiplied by 100 to be expressed as percentages. Zhang Thesis also plots how one can obtain different strain at fracture (breakage) by just changing the widths of the materials. EX1007, 70, FIG. 3-2 (a). In other words, the amount of elastic and plastic strain for materials like polypropylene can be tailored by just modifying the sample dimensions.



EX1007, FIG. 3-2 (a) (excerpted).

67. As shown, these separators each exhibit elastic-plastic stress-strain behavior with large amounts of plastic deformation. *Id.* Zhang Thesis also shows images of the battery separators after tensile testing by a procedure similar to the

one recited in the '927 patent claims, namely, stretching until break, docking, and flattening. EX. 1007, 69, 70. These images clearly depict substantial absolute and relative plastic deformation for the polypropylene (PP) and trilayer separators. EX. 1007, 69-71.

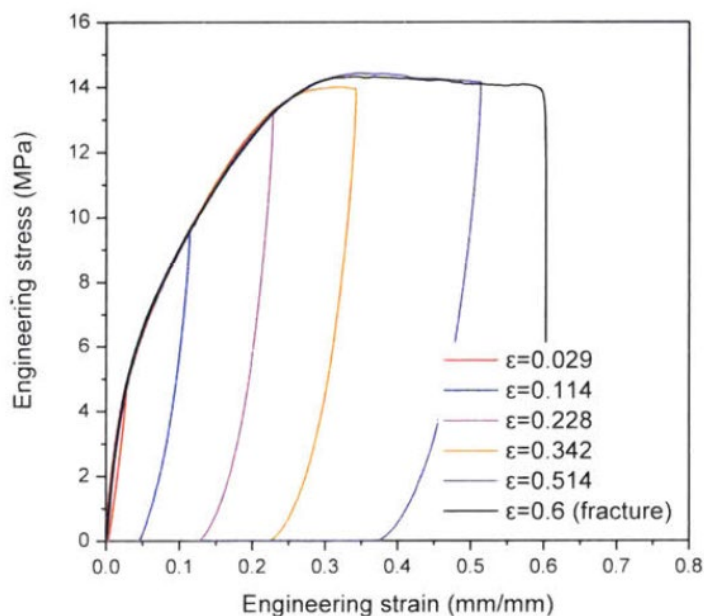


EX1007, FIG. 3-2 (b) (excerpted).

68. However, a POSA would know that significant and predominantly plastic deformation would occur based on the stress-strain plots and would not need to see these photos. That is, even without recording numeric measurements for L0 and L2 (per the procedure defined in the patent claim), a POSA would visually recognize (even without the above photos) that predominantly plastic deformation has occurred.

69. Zhang Thesis also performed a series of tests where a polymeric separator is stretched to different strains and then force (the load) is removed so, the elastic part of deformation rebounds and the plastic strain remains in the

material. EX. 1007, FIG. 4-18. An example of such tests for a polymeric separator without coating is shown below. *Id.* It can be observed from this example that a large portion of the material deformation remains after removal of the force. *Id.*



EX. 1007, FIG. 4-18

70. For example, when the material has reached a strain of 0.514 (51.4%) and the force is removed, the remaining plastic strain in the material is 0.38 (38%). *Id.* That means the ratio of plastic strain to total strain is 73%. *Id.*

71. Accordingly, battery separators having an absolute and relative plastic deformation rate within the claimed range were well known in the art, as were the various polymer films and other separator components associated with these properties. *Id.* Furthermore, as noted the ranges of elastic and plastic deformation

could be made wider by changing manufacturing processes and even sample dimensions.

VIII. THE '927 PATENT

72. The claims of the '927 patent are apparatus claims that recite the standard components of a battery: an anode, a cathode, and a separator comprising a porous substrate (polymer film) and a porous layer (binder and inorganic filler). EX1001, 1:45-55.

73. Claim 1, the sole independent claim, recites that the porous substrate has an absolute plastic deformation rate in a certain percentage range, where the plastic deformation rate is measured according to a recited protocol. Given the equations, a POSA in this art would understand the term “rate” to mean an amount of strain. The dependent claims progressively narrow the absolute plastic deformation rate range, add a relative plastic deformation rate range, or recite large Markush groups listing common materials for use as the battery separator components.

74. Importantly, the plastic deformation rate limitations are not method steps, nor do the claims recite product-by-process limitations. Nothing about the plastic deformation rates or the way they are measured recites an action that must be performed. Rather, the plastic deformation rates as recited merely identify an

innate physical property of the polymer film that is used as the porous substrate.

EX1001.

75. The patentees claim to have discovered that the plastic deformation rate of the substrate polymer layer of a battery separator is key to whether the resulting separator will pass a given nail penetration test. EX1001, Table 1. The tests performed and described in the specification involve primarily polyethylene films coated with a polyacrylonitrile binder and alumina (Al_2O_3). *See* EX1001, Table 1.

76. The '927 patent was filed as Patent Application No. 16/202,346 on November 28, 2018. It claims the benefit of Chinese Patent Application CN 201810640157.9 A. EX1008. The claims of the related Chinese patent are very similar to the '927 patent, except that in China the applicant was forced to add limitations to the relative plastic deformation rate to the independent claim to overcome clarity, support, and prior-art rejections. EX1008.

77. In the first Office Action, the Chinese Examiner cited CN105449140A as prior art and found that the claims lacked an inventive step over this art. EX1008, 0006-07. This reference discloses a separator and a lithium-ion secondary battery, and specifically discloses the following technical features (see paragraphs [0013]-[0026], [0147], and [0155]-[0157] of the description): (1) a porous substrate selected from at least one of polyolefin, polyimide, polyurethane,

and polyisocyanate; (2) the surface of the separator may be coated with an inorganic particle coating and/or an organic particle coating (equivalent to “a porous layer, and the porous layer is disposed on a surface of the porous substrate and comprises inorganic particles”); (3) the separator has puncture resistance and an elongation at break of 150%-900% in a transverse direction an elongation at break of 55%-600% in a longitudinal direction. EX1008, 0006.

78. The Examiner also observed that the cited prior art disclosed that when the battery is pierced by a nail or other needle-like foreign bodies, a porous substrate with good ductility (ductility refers to a material’s ability to undergo significant plastic deformation (permanent shape change) under tensile stress (without fracturing)) is used to extend with the foreign body and wrap the foreign body by means of its good plastic deformation capacity, thus improving the safety of the battery. EX1008, 0006. On this basis, to select a suitable porous substrate, those skilled in the art could readily conceive of evaluating the plastic deformation capacity of the porous substrate via such an index of relative plastic deformation rate and determining the suitable ranges of the relative plastic deformation rate in the first and/or second directions through a limited number of tests. EX1008, 0006-07.

79. The Examiner found that the cited reference did not disclose that the porous layer further comprises a binder, but observed that fixing inorganic

particles on a porous substrate with a binder is a conventional technical means in the art. EX1008, 0008. The Examiner found that all of the other limitations added by the dependent claims were also found in the cited prior art reference. EX1008, 0006-08.

80. The Applicant did not dispute the Examiner's findings. EX1008, 0011. Instead, the Applicant argued that the claims recite the absolute plastic deformation rate of the porous substrate, rather than the separator as a whole, which distinguished the claimed range from the disclosure of the cited reference. *Id.* The Applicant also argued that the absolute plastic deformation rate was measured differently than the properties taught by the cited art. EX1008, 0012-13.

81. In response, the Examiner observed that the method of calculating the absolute plastic deformation rate was not recited in the claims as they were then presented, and therefore the claims lacked clarity—the Chinese version of an indefiniteness rejection. EX1008, 0017. The Examiner also rejected the claims as lacking support (the Chinese version of a written-description rejection) because the application does not explain how to achieve the desired plastic deformation rate—only how to measure it. *Id.*

82. The Applicant, in response to the clarity rejection, amended the claims to add the same equation and absolute plastic deformation measurement that appears in claim 1 of the '927 patent. EX1008, 0022. In response to the lack of

support rejection, the Applicant argued: “it should be known to those skilled in the art that the plastic deformation rate of the porous substrate is mainly affected by the stretching conditions in the process of preparation.” EX1008, 0024. In other words, as noted in Section VII above, the amount of elastic and plastic deformation can be tailored to a wide range of values by the manufacturing (stretching) process. The Applicant went on to say, “it would be known to those skilled in the art that for porous substrates with different materials and molecular weight, their desired absolute plastic deformation rates can be obtained by changing a stretching ratio (i.e., ratio by which a substrate is stretched in each direction during fabrication).” *Id.* In other words, the Applicant represented that it was well known in the art how to achieve the plastic deformation rates recited in the claims. *Id.*

83. These amendments and arguments overcame the clarity and support rejections, but did not overcome the prior-art rejection. The Examiner still found that the claimed absolute plastic deformation rate was inferable from the cited reference. EX1008, 0028-29.

84. Once again, the Applicant did not contest the Examiner’s findings. EX1008, 0038-40. Instead, the Applicant amended the independent claim to recite the relative plastic deformation rate disclosed in claims 4 and 5 of the ’927 patent. EX1008, 0036-37. The Examiner did not explain why this amendment led to allowance, but issued the claims as amended. EX1008, 0041-42.

85. Meanwhile, in prosecution before the USPTO, the Examiner rejected the claims over U.S. Patent No. 5,746,916 to Kamo. EX1002, 0054, 0055. The Examiner found that Kamo disclosed all the limitations of the separator, i.e., the porous substrate, porous layer, composition components, and physical properties. *Id.* That is, the materials with those material properties claimed in the Chinese version and the '927 were known.

86. Kamo did not, however, disclose the use of the resulting membrane as a battery separator according to the Examiner. EX1002, 0056, 0057. Instead, it was disclosed as a separator for medical devices, food industries, or water or air purification. *Id.* The Examiner allowed the claims on that basis. *Id.* The Examiner did not, however, consider any of the prior art which I cite below, that discloses all the limitations of the claimed separator specifically for use as a battery separator.

IX. GROUND 1: CLAIMS 1-10 ARE ANTICIPATED BY NISHIKAWA

87. U.S. Patent Application Publication No. 2015/0180002 to Nishikawa published on June 25, 2015. Nishikawa anticipates claims 1-10. Specifically, Example 1 of Nishikawa discloses a porous separator for a lithium ion battery that satisfies every one of the limitations of each of claims 1-10.

1. 1.P: An electrochemical device, comprising:

88. To the extent the preamble is limiting, Nishikawa discloses an electrochemical device. EX1004, ¶11. Namely, Nishikawa discloses “a nonaqueous electrolyte battery.” EX1004, ¶10. A battery is an electro-chemical device. Indeed,

it is the same electro-chemical device that is recited in the body of the '927 patent claims.

2. 1.1: a cathode; an anode; and a separator;

89. Nishikawa discloses, “A nonaqueous electrolyte battery including a positive electrode, a negative electrode, and the separator for a nonaqueous electrolyte battery of any one of <1> to <7> disposed between the positive electrode and the negative electrode.” EX1004, ¶12. A cathode is a positive electrode and an anode is a negative electrode. *Id.* Batteries typically have a cathode, anode, and a separator between the two. EX1015, 4420.

3. 1.2: wherein, the separator comprises a porous substrate and a porous layer;

90. Example 1 of Nishikawa discloses a separator comprising a polyethylene porous substrate that is coated on both sides with a porous layer, specifically a vinylidene fluoride/hexafluoropropylene copolymer (binder) and magnesium hydroxide (inorganic particles). EX1004, ¶¶147-150.

91. Nishikawa goes on to explain, “The separator for a nonaqueous electrolyte battery of the invention includes a porous substrate and an adhesive porous layer.” EX1004, ¶16. Nishikawa further explains, “The adhesive resin contained in the adhesive porous layer is not particularly limited as long as it can adhere to electrodes.” EX1004, ¶67. Nishikawa also discloses a “functional layer,”

which “may be a porous layer made of a heat-resistant resin or a porous layer made of a heat-resistant resin and an inorganic filler.” EX1004, ¶47.

92. The porous substrate and porous layer of Nishikawa play the same roles in Nishikawa’s separator that those structures play in the claimed separator: the porous substrate separates the anode and cathode while allowing ions to flow between the two, while the porous layer improves properties like the thermal shrinkage performance of the separator, enhancing battery safety. EX1004, ¶¶9-10, 12.

4. 1.3: wherein the porous layer is disposed on a surface of the porous substrate and comprises inorganic particles and a binder;

93. Nishikawa discloses, “[t]he adhesive porous layer is provided on one side or both sides of the porous substrate.” EX1004, ¶16. The adhesive porous layer contains an adhesive resin and a filler. EX1004, [0086]. The adhesive in Nishikawa is a binder as claimed. EX1004, ¶109. Its purpose is to adhere (or bind) to the porous substrate. EX1004, ¶75. The inorganic filler is the claimed inorganic particles. The sides of Nishikawa’s porous substrate are surfaces of the substrate onto which the porous layer is disposed. EX1004, ¶35. The porous layer (adhesive resin and filler) of Example 1 is deposited onto both sides of Nishikawa’s polyethylene porous substrate. EX1004, ¶¶147-150.

94. Nishikawa further explains that the adhesive porous layer contains a filler that may be an inorganic substance. EX1004, [0084]. “Examples of inorganic fillers include metal oxides such as alumina and metal hydroxides such as magnesium hydroxide.” EX1004, [0084]. Nishikawa thus discloses a porous layer disposed on a surface of the porous substrate and comprises inorganic particles and a binder. EX1004, ¶¶37, 48, 109.

5. **1.4: and the porous substrate has an absolute plastic deformation rate in a first direction ranging from about 40% to about 1800%, and wherein the absolute plastic deformation rate is calculated according to an equation $(L2-L0)/L0 \times 100\%$, where L0 refers to a length of the porous substrate before stretching and L2 refers to a length of the porous substrate after the porous substrate is stretched to breakage and docked along the fracture caused by the breakage and flattened.**

95. Nishikawa discloses the numeric values for several properties of the porous substrate that teach a plastic deformation rate as defined in the patent, and within the claimed range. EX1004, Table 1. This disclosure can be considered an express (albeit indirect) disclosure of the plastic deformation rate via other metrics, as well as an inherent disclosure of the plastic deformation rate associated with the porous substrate as disclosed. *Id.*

96. Specifically, Nishikawa discloses, “[i]t is preferable that the porous substrate has an elongation of 50% or more and 200% or less in the MD direction or the TD direction.” EX1004, ¶50. “The lower limit is more preferably 80% or

more, and still more preferably 100% or more.” *Id.* Here, elongation is the total of elastic and plastic deformation. *Id.* It reflects $L1 - L0$, as those lengths are defined in the ’927 patent. EX1001, 4:14-27.

97. The total elongation of a material ($L1 - L0$) in combination with its tensile strength (stress at breakage) and Young’s modulus (a proxy for $L1 - L2$ as those lengths are defined in the ’927 patent) are inputs from which a POSA could approximate the claimed absolute plastic deformation rate ($((L2 - L0)/L0 \times 100\%)$). Even though it does not directly provide a value for the plastic deformation rates of its porous substrates, Nishikawa nonetheless discloses these values in the same way that a reference discloses, for example, the density of an object by providing its mass and volume. EX1004.

98. Importantly, the equation recited in claim 1 does not reflect some new discovery or new physical property of materials. It is the standard way of expressing the change in a component of a value (plastic deformation) isolated from that value (total deformation) as a percentage. *See*, for example, in Hibbeler’s book *Mechanics of Materials*. *See generally*, EX1021 81-91. By specifying how the values used in the equation were obtained (stretching to break, docking, and measuring), the claim merely clarifies what “plastic deformation” represents to put the numeric range into context.

99. As an analogy, consider a claim that recites Composition X, wherein the melting point of the composition is 20-30°C, as measured by a mercury thermometer. The claim is a composition claim, the melting point is a recited property, and the specified method of measurement merely clarifies what the temperature denotes—it does not add a method step. A prior-art reference that describes Composition X melting at 77°F as measured by an alcohol thermometer anticipates the claim. It anticipates the claim even though it expresses the temperature using a different scale, because a POSA would know how to convert from Fahrenheit to Celsius, and would understand the difference in scale to be nothing more than two ways of expressing the same information.

100. Of course, a POSA would know that a mercury thermometer is more accurate than an alcohol thermometer, and would understand that while 77°F equals 25°C, the temperature measured on an alcohol thermometer does not necessarily equal the temperature measured on a mercury thermometer.

Nonetheless, where, as in this analogy, the claim recites a temperature *range* and the prior art discloses a value that is well within that range (albeit by a different measurement technique) the POSA would still understand the claim to be anticipated. The difference in accuracy of an alcohol thermometer is not enough to risk bringing the measured value (77°F = 25°C) outside the claimed range (20-30°C).

101. The plastic deformation rate claimed here presents the same situation. The claim recites a porous substrate with an absolute plastic deformation rate that falls within a large range. It provides the method by which that range was obtained (stretching to break, docking, flattening, measuring, and calculating) merely to clarify what is meant by “absolute plastic deformation rate” and the recited numbers. EX1001, 4:14-54.

102. The prior art also discloses porous substrates with absolute plastic deformation rates well within this same range, even though the prior art uses a different means of measuring that property (plotting stress-strain curves or measuring stress at breaking, tensile strength, and Young’s modulus), and expresses it in different terms. EX1004, ¶¶53, 54, Table 1. A POSA would nonetheless understand the porous substrates of the prior art to have the claimed property.

103. As in the analogy, the values disclosed in the prior art are so comfortably within the claimed range, a POSA would know that any differences in the method of measurement can be disregarded. *Id.* The absolute plastic deformation rate of the substrates in Nishikawa (and Chen and Zhang as discussed below) are so comfortably within the claimed range, a POSA would understand that they necessarily anticipate the claim despite the differences in how the values were obtained.

104. Specifically, Table 1 of Nishikawa gives measured values of Young's modulus, tensile strength, and elongation in a machine direction (MD) and transverse direction (TD) for multiple porous substrates. EX1004, Table 1. These values are given for the porous substrate alone, not the porous substrate and adhesive porous layer. For the tested separators, the strain at break is equal to the reported tensile strength. EX1004, ¶133. Nishikawa describes the MD as “the longitudinal direction of the separator that is produced in an elongated form,” and the TD as “the direction that is perpendicular to the longitudinal direction of the separator.” EX1004, ¶15.

TABLE 1

	Porous Substrate						Adhesive Porous Layer				
	Thickness	Standard Deviation/ Mean of	Elongation	Puncture	Tensile	Young's	Adhesive Resin		Filler	Areal	Standard
	[μm]	Thickness	MD/TD	Resistance	Strength	Modulus	Kind	Mw	Mass	Weight	Deviation/ Mean of Areal
				[g]	MD/TD	MD/TD			Ratio	[g/m ²]	Weight
Example 1	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	1,950,000	0.01	2.3	0.13
Example 2	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	1,950,000	0.03	2.4	0.28
Example 3	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	1,950,000	0.05	2.4	0.20
Example 4	9	0.03	81/110	405	21/14	2.4/1.3	PVDF	1,950,000	0.01	2.3	0.25
Example 5	9	0.02	100/150	420	22/16	2.3/1.2	PVDF	1,950,000	0.5	2.5	0.30
Example 6	9	0.02	150/115	380	19/13	2.0/1.0	PVDF	1,950,000	0.5	2.4	0.29
Example 7	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	600,000	0.01	2.3	0.28
Example 8	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	3,000,000	0.01	2.3	0.29
Comparative Example 1	9	0.01	82/113	411	20/14	2.4/1.3	PVDF	1,950,000	0.10	2.4	0.40
Comparative Example 2	12	0.05	210/250	305	19/15	1.1/0.7	PVDF	1,950,000	0.01	2.3	0.39
Comparative Example 3	9	0.03	45/120	320	22/10	3.1/0.9	PVDF	1,950,000	0.01	2.3	0.35
Comparative Example 4	30	0.04	70/100	850	60/44	2.2/1.2	PVDF	1,950,000	0.01	2.3	0.41
Comparative Example 5	12	0.03	110/6	190	26/2	3.0/0.5	PVDF	1,950,000	0.01	2.3	0.33

Separator

EX1004, Table 1.

105. “Example 1” (top row) of Table 1 provides the values needed to estimate a plastic deformation rate of the porous substrate. The ’927 patent describes the total deformation as the amount of elastic deformation (L1-L2) plus the amount of plastic deformation (L2-L0). EX1001, 4:22-27. These plastic and elastic deformation values can be converted to percent elastic strain and percent plastic strain by dividing each value by L0 (the original length before stretching) and multiplying the resulting value by 100%. For example, elastic strain may be defined as $(L1-L2)/L0 * 100\%$ and plastic strain may be defined as $(L2-L0)/L0 * 100\%$ (i.e., absolute plastic deformation rate in the ’927 patent, 4:52).

106. Similar to total deformation, total strain is the sum of elastic and plastic strain. EX1017, 20. Thus, the total plastic strain/absolute plastic deformation rate is calculated by subtracting the elastic strain from the total strain. As described above, elastic strain at any stress value (such as the stress at breakage) can be estimated by dividing the tensile strength by Young’s modulus. EX1018, 63-65. The elastic strain can also be estimated using a 0.2% offset. EX1018, 61; EX1019, 8; EX1021, 87.

107. In the MD: Young’s modulus is 2.4 GPa and the tensile strength (stress at breakage) is 20 N/cm. EX1004, Table 1. Table 1 reports the tensile strength in units of N/cm (i.e., force per unit width). This value needs to be converted to force per unit area, which is accomplished by dividing the tensile

strength by the thickness of the material ($9 \mu\text{m} = 9 \times 10^{-4} \text{ cm}$). *Id.* The units are also converted to GPa. *Id.* In the MD, tensile strength per unit area is:

$$\left(\frac{20 \frac{N}{cm}}{9 \times 10^{-4} cm} \right) \left(\frac{10^4 cm^2}{m^2} \right) = 2.22 * \frac{10^8 N}{m^2} = 2.22 * 10^8 Pa = 0.222 GPa .$$
 Then the

estimated elastic strain percent is tensile strength/Young's modulus *100% = 0.222 GPa/2.4 GPa *100% = 9.25%. EX1018, 63-65. The estimated absolute plastic deformation rate is equal to the elongation – elastic strain= 82%-9.25%= 72.75%.

108. In the TD, tensile strength per unit area is: $\left(\frac{14 \frac{N}{cm}}{9 \times 10^{-4} cm} \right) \left(\frac{10^4 cm^2}{m^2} \right) = 1.56 * \frac{10^8 N}{m^2} = 1.56 * 10^8 Pa = 0.156 GPa$. The estimated elastic strain in the TD direction is tensile strength (per unit area)/Young's modulus % = 0.156 GPa/1.3 GPa *100%=12 %. The estimated absolute plastic deformation is elongation (total strain) - elastic strain = 113%-12%=101%. EX1018, 63-65.

109. The plastic strain can also be calculated using the 0.2% offset method. EX1018, 61; EX1019, 8; EX1021, 87. If the yield strength is equal to the tensile strength (and the separator deforms plastically at a stress equal to the tensile strength until breakage), the 0.2% offset line will intersect the stress stain curve at a strain 0.2% greater than the elastic strain (calculated above in ¶107).

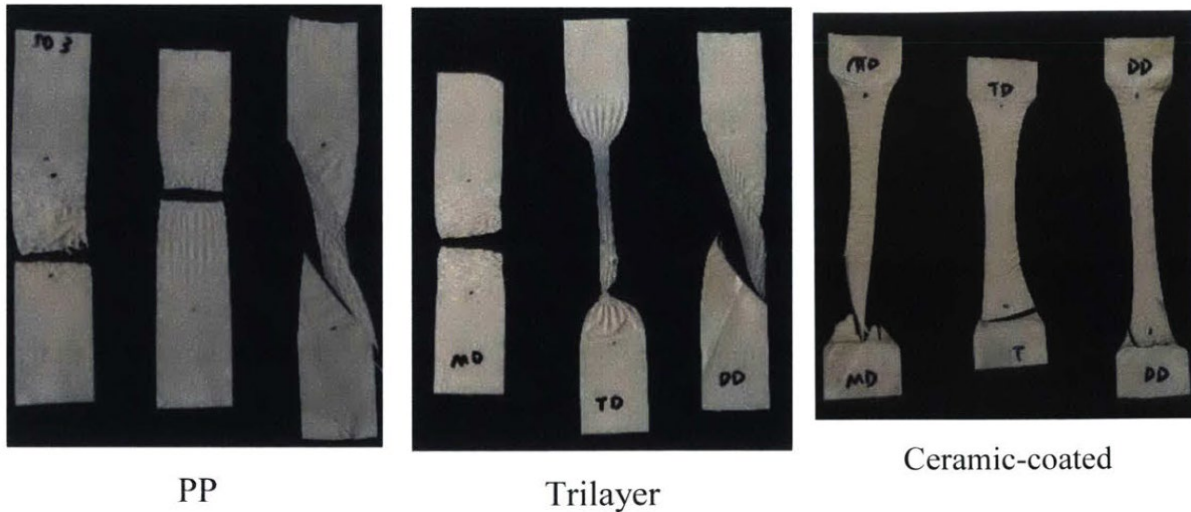
110. The results for both methods are summarized as a range below:

	Tensile strength	Young's Modulus	Elongation at break	Elastic strain	Plastic strain
MD	0.222 GPa	2.4 GPa	82%	9.25-9.45%	72.55-72.75%
TD	0.156 GPa	1.3 GPa	113%	12-12.2%	100.8-101%

111. These estimated plastic strain values, i.e. “absolute plastic deformation rate[s]” (to use the parlance of the '927 patent) both fall within the claimed range for the “first direction” recited in claim element 1.4.

112. Importantly, even without performing the calculations, a POSA would understand the plastic deformation rate of Nishikawa's porous substrate to be within the claimed range. As Nishikawa prefers, “the material forming the porous substrate is a thermoplastic resin.” EX1004, ¶37. Thermoplastic resins typically exhibit a high degree of plastic deformation. EX1017, 20. A thermoplastic resin with a high elongation at break will *necessarily* exhibit a large degree of plastic deformation, because the elongation for these materials come from the plasticity and not elasticity. *Id.*

113. Indeed, that is the property that was measured in the Zhang Thesis and shown in the post-test photographs:



EX1007, FIG. 3-2 (b) (excerpted).

All tensile tests and stress-strain curves are conducted by stretching (or loading) a sample of the separator substrate until it breaks and measuring the effects. The data reported in Nishikawa were gathered the same way. Even though Nishikawa does not reproduce pictures, a POSA would expect the post-test samples tested in Nishikawa to look like the pictures from Zhang above because all post-test samples look like this.

114. Accordingly, Nishikawa discloses all of the limitations of claim 1, expressly or inherently, and thus anticipates claim 1.

6. **2. The electrochemical device according to claim 1, wherein the porous substrate has an absolute plastic deformation rate in a second direction ranging from about 60% to about 1800%.**

115. Nishikawa discloses the additional limitations of dependent claim 2, which depend from claim 1. Nishikawa's Table 1 gives tensile strength,

elongation, and Young's modulus in a second direction, as it gives these values for both the TD and MD. EX1004, ¶50.

	Tensile strength	Young's Modulus	Elongation at break	Elastic strain	Plastic strain
MD	0.222 GPa	2.4 GPa	82%	9.25-9.45%	72.55-72.75%
TD	0.156 GPa	1.3 GPa	113%	12-12.2%	100.8-101%

116. As explained above, the tensile strength, elongation, and Young's modulus values indirectly disclose the absolute plastic deformation rate of the porous substrates in two directions. EX1004, ¶¶50, 51. Both of the plastic deformation rate values disclosed in Example 1 of Nishikawa fall within the claimed numeric range for the second direction. *Id.* Nishikawa anticipates claim 2.

7. **3. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: an absolute plastic deformation rate in the first direction ranging from about 40% to about 1600%; and an absolute plastic deformation rate in the second direction ranging from about 70% to about 1600%.**

117. As discussed above for claims 1 and 2, Nishikawa's Table 1 discloses several examples of porous substrates that have estimated plastic deformation rates in two directions that fall within the claimed ranges. For example, the plastic deformation rates for Example 1 are:

	Tensile strength	Young's Modulus	Elongation at break	Elastic strain	Plastic strain
MD	0.222 GPa	2.4 GPa	82%	9.25-9.45%	72.55-72.75%
TD	0.156 GPa	1.3 GPa	113%	12-12.2%	100.8-101%

118. Because both values fall within both claimed ranges, either the MD or TD could be the first or second direction as claimed. *Id.* Accordingly, a POSA would at least consider the MD to satisfy the first direction and the TD to satisfy the second direction, as claim 3 suggests that the TD may have a slightly higher value. Nishikawa anticipates claim 3.

8. **4. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 50% to about 100%; and a relative plastic deformation rate in the second direction ranging from about 60% to about 100%.**

119. The '927 patent provides a slightly different formulation for *relative* plastic deformation rate (the ratio of plastic deformation to elastic deformation) as opposed to absolute plastic deformation rate. EX1001, 4:51-54. Specifically, the '927 patent defines the *relative* plastic deformation rate as: $(L2 - L0) / (L1 - L0) \times 100\%$. *Id.* This is simply the absolute plastic deformation rate $(L2 - L0) / L0 \times 100\%$ divided by the percent total strain $(L1 - L0) / L0 \times 100\%$ and multiplied by 100%. *Id.*

120. Once again, Nishikawa does not provide numeric values for the percentage of elastic or plastic deformation, but it does provide elongation, tensile strength, and Young's modulus. EX1004, ¶¶53, 54, Table 1. From these values, a relative plastic deformation rate (as that term is defined in the '927 patent) can be estimated, as shown above for claim 1. *Id.*

121. Using the calculated absolute plastic deformation rate for Nishikawa's porous substrate, a POSA could readily estimate the *relative* plastic deformation rate. As described above, this is calculated by dividing the absolute plastic deformation rate by the elongation at break (total strain) and multiplying by 100%. In the MD direction, absolute plastic deformation rate/elongation at break * 100% = (72.55 or 72.75)% / 82% * 100% = 88.5-88.7%. In the TD direction, absolute plastic deformation rate / elongation at break * 100% = 101% / 113% * 100% = 89%.

	Elongation at break	Absolute Plastic strain	Relative plastic strain
MD	82%	72.55-72.75%	88.5-88.7%
TD	113%	100.8-101%	89.2-89.4%

122. These values (88.5-88.7% and 89.2-89.4%) fall within the numeric ranges recited in claim 4 (50-100% and 60-100%). Additionally, the claim uses the term "about" to modify all of the plastic deformation rates. The specification defines the term "about" to denote up to $\pm 10\%$. EX1001, 3:33-45. The estimated

relative plastic deformation rate of the porous substrate described in Nishikawa is, therefore, necessarily within the claimed range. Nishikawa therefore discloses relative plastic deformation ranges for both the MD and TD (directions) as claimed. Nishikawa anticipates claim 4.

9. **5. The electrochemical device according to claim 4, wherein the porous substrate has at least one of the following properties: [1] a relative plastic deformation rate in the first direction ranging from about 65% to about 90%; and [2] a relative plastic deformation rate in the second direction ranging from about 75% to about 90%.**

123. As discussed above for claim 4, Nishikawa discloses an estimated relative plastic deformation of 88.5-88.7% in the MD and 89.2-89.4% in the TD. These values fall within the numeric ranges recited in claim 5: 65-90% in a first direction and 75-90% in a second direction. Additionally, the claim uses the term “about” to modify all of the recited plastic deformation rates. The specification defines the term “about” to denote up to $\pm 10\%$. EX1001, 3:33-45. Nishikawa therefore discloses relative plastic deformation ranges for both the MD and TD (directions) as claimed. Nishikawa anticipates claim 5.

10. 6. The electrochemical device according to claim 1, wherein the binder comprises at least one selected from the group consisting of a **vinylidene fluoride-hexafluoropropylene copolymer**, a vinylidene fluoride-trichloroethylene copolymer, polymethyl methacrylate, polyacrylic acid, polyacrylate, polyacrylonitrile, polyvinyl pyrrolidone, polyvinyl acetate, an ethylene-vinyl acetate copolymer, **polyimide**, polyethylene oxide, cellulose acetate, cellulose acetate butyrate, cellulose acetate propionate, cyanoethyl amylopectin, cyanoethyl polyvinyl alcohol, cyanoethyl cellulose, cyanoethyl sucrose, amylopectin, sodium carboxymethyl cellulose, lithium carboxymethyl cellulose, an acrylonitrile-styrene-butadiene copolymer, polyvinyl alcohol, polyvinyl ether, polytetrafluoroethylene, polyhexafluoropropylene, a **styrene-butadiene copolymer**, and **polyvinylidene fluoride**.

124. Claim 6 depends from claim 1 and adds a large Markush group that provides a variety of options for the claimed binder. Example 1 of Nishikawa (for which the plastic deformation calculations were performed above) uses **vinylidene fluoride-hexafluoropropylene copolymer**, the first material listed in the Markush group above. EX1004, ¶¶147-150. Nishikawa therefore anticipates claim 6.

125. Additionally, Nishikawa discloses, “the functional layer may be a porous layer made of a heat-resistant resin . . . and an inorganic filler.” EX1004, ¶47. “The heat-resistant resin may be one or more kinds of heat-resistant polymers selected from aromatic polyamide, **polyimide**, polyethersulfone, polysulfone, polyether ketone, and polyetherimide.” EX1004, ¶47.¹ A POSA would recognize that this resin is a binder, because it binds the inorganic particles to each other and

¹ Emphasis and color added unless otherwise indicated.

indirectly to the substrate. Polyimide is one of the binders listed in the Markush group of claim 6 (highlighted in red). The inorganic filler is the claimed “inorganic particles.”

126. Regarding the adhesive layer, Nishikawa discloses: “The adhesive resin contained in the adhesive porous layer is not particularly limited as long as it can adhere to electrodes.” EX1004, ¶67. “Preferred examples thereof include polyvinylidene fluoride, polyvinylidene fluoride copolymers, styrene-butadiene copolymers, homopolymers and copolymers of vinyl nitriles such as acrylonitrile and methacrylonitrile, and polyethers such as polyethylene oxide and polypropylene oxide.” *Id.*

127. A POSA would recognize that this adhesive resin is also a binder, because it binds the inorganic particles directly to the porous substrate. EX1004, ¶¶12, 17. Polyvinylidene fluoride and styrene-butadiene copolymers are listed in the Markush group of claim 6.

128. Claim 6 makes clear that there can be multiple binders selected for the claimed separator, reciting, “the binder comprises at least one” of the listed materials. The porous layer of Nishikawa thus discloses the limitations of claim 6 because it discloses a number of binders listed within the Markush group, regardless of whether the porous layer is interpreted to be Nishikawa’s functional

layer, the adhesive layer, or the functional layer and the adhesive layer collectively.

EX1004, ¶67 Nishikawa anticipates claim 6.

11. 7. The electrochemical device according to claim 1, wherein the inorganic particles comprise at least one selected from the group consisting of **alumina**, silica, magnesia, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, zinc oxide, calcium oxide, zirconia, yttria, silicon carbide, eboehmite, aluminum hydroxide, **magnesium hydroxide**, calcium hydroxide and barium sulfate.

129. As discussed in reference to claim 6, Nishikawa discloses a porous layer disposed on the surface of the substrate, including a functional layer and an adhesive layer. EX1004, ¶¶47, 48. Regarding the functional layer, Nishikawa discloses, “[a]s the inorganic filler, metal oxides such as **alumina**, metal hydroxides such as **magnesium hydroxide**, and the like can be preferably used.” EX1004, ¶47. Regarding the adhesive layer, Nishikawa discloses, “Examples of inorganic fillers include metal oxides such as **alumina** and metal hydroxides such as **magnesium hydroxide**.” EX1004, ¶85.

130. Thus, Nishikawa discloses both porous layers (functional and adhesive) including inorganic particles. EX1004, ¶¶47, 85. Alumina and magnesium hydroxide are both among the organic particles listed in the Markush group of claim 7. Magnesium hydroxide is the inorganic filler used in Nishikawa’s Example 1 (for which the plastic deformation calculations were performed above). EX1004, ¶¶147-150. Nishikawa anticipates claim 7.

12. 8. The electrochemical device according to claim 1, wherein the porous substrate comprises a polymer film, a multilayer polymer film or a nonwoven fabric, wherein the polymer film, the multilayer polymer film or the nonwoven fabric is formed by any one or more of the following polymers: **polyethylene**, **polypropylene**, polyethylene terephthalate, polybutylene terephthalate, polyphenylene terephthamide, polyester, polyacetal, **polyamide**, polycarbonate, **polyimide**, polyetheretherketone, polyaryletherketone, **polyetherimide**, polyamideimide, polybenzimidazole, **polyethersulfone**, polyphenylene ether, a cyclic olefin copolymer, polyphenylene sulfide or polyethylene naphthalene.

131. The porous substrate of Nishikawa's Example 1 (for which the plastic deformation rates were calculated above) uses polyethylene. EX1004, ¶¶147-150. Nishikawa further discloses, "[e]xamples of such substrates include microporous membranes, porous sheets made of a fibrous material, such as nonwoven fabrics and paper-like sheets, and composite porous sheets including such a microporous membrane or porous sheet as well as one or more other porous layers laminated thereon." EX1004, ¶35.

132. Nishikawa goes on to explain, "[a]s a porous substrate using a polyolefin, a polyolefin microporous membrane is preferable . . . it is preferable that the polyolefin microporous membrane contains polyethylene . . . a polyolefin microporous membrane containing **polyethylene** and **polypropylene** is preferable." EX1004, ¶¶40-43. "Examples of porous sheets made of a fibrous material include . . . for example, polyesters such as polyethylene terephthalate; polyolefins such as **polyethylene** and **polypropylene**; and heat-resistant polymers

such as aromatic **polyamide**, **polyimide**, **polyethersulfone**, polysulfone, polyether ketone, and **polyetherimide**.” EX1004, ¶46. Nishikawa thus discloses numerous examples of the porous substrate from the Markush group recited in claim 8.

Nishikawa anticipates claim 8.

13. 9. The . . . device according to claim 1, wherein the porous substrate has a thickness ranging from about 1 to about 40 μm .

133. Nishikawa discloses multiple examples of porous substrates with thickness between 1 and 40 microns. Examples 1-8 listed in Table 1, for instance, have thickness of 9 microns (μm). EX1004, Table 1. Nishikawa anticipates claim 9.

14. 10. The electrochemical device according to claim 1, wherein the electrochemical device comprises lithium ion batteries.

134. Nishikawa discloses, “The nonaqueous electrolyte battery of the invention is suitable for a nonaqueous electrolyte secondary battery, particularly a *lithium ion* secondary battery.” EX1004, ¶107. Nishikawa anticipates claim 10.

X. GROUND 2A/2B: CLAIMS 1-10 ARE OBVIOUS IN VIEW OF NISHIKAWA/NISHIKAWA IN COMBINATION WITH CHEN

135. As discussed in Ground 1, Nishikawa explicitly or inherently discloses all of the limitations of all of the claims, at least in its disclosure of Example 1. Nonetheless, to the extent the Board does not agree that the absolute and/or plastic deformation rates of the porous substrate are explicitly or inherently

disclosed in Nishikawa, then those limitations are at least obvious in view of

Nishikawa (Ground 2A) or Nishikawa in combination with Chen (Ground 2B).

A. Ground 2A: Nishikawa's Example 1 satisfies every limitation of claims 1-10, including at least rendering obvious the recited plastic deformation rates.

136. Nishikawa's Example 1 discloses all of the components of the claimed lithium-ion battery and separator as discussed in Ground 1.

137. It may be alleged that Nishikawa does not directly and explicitly disclose the claimed absolute and relative plastic deformation rates of the porous substrates (rather, it discloses them indirectly or inherently). Those rates are, however, at least obvious in view of Nishikawa's disclosure of other numeric values from which those rates can be calculated using standard and well-known equations and physical relationships.

138. Furthermore, absolute and relative plastic deformation rates—as those properties are defined in the patent—are inherent properties of porous substrate materials.

139. Additionally, Table 1 of the '927 patent provides test results for the absolute plastic deformation rates of several examples of the claimed separators with and without the porous layers (i.e., porous substrate only or porous substrate plus porous layer) and found no significant difference. *Id.* Accordingly, the plastic deformation rate range of the porous substrate itself is not novel or unexpected.

Nor is a particular stretching ratio or manufacturing process claimed. A POSA would readily know how to obtain a substrate with the desired absolute plastic deformation rate—an inherent property of the substrate itself imparted by a manufacture process (as defined by the '927 patent).

140. Nishikawa similarly describes the materials, molecular weight, and preparation process for its porous substrate. EX1004, ¶¶44, 47. By the patentee's own admission, EX1008, 0024, a POSA would therefore know how to obtain a plastic deformation rate within the claimed range for any of Nishikawa's example substrates, at least by manipulating the stretching ratio. Moreover, several of Nishikawa's example substrates (including Example 1 as discussed above) *necessarily* have absolute and relative plastic deformation rates within the claimed ranges in view of their other properties as disclosed in Nishikawa's Table 1. Accordingly, to the extent the Board finds that these numeric values are not explicitly or inherently anticipated by Nishikawa, they are nonetheless obvious in view of Nishikawa's disclosure of the tensile strength, elongation, and Young's modulus.

B. Ground 2B: Nishikawa in view of Chen renders claims 1-10 obvious.

141. Nishikawa and Chen are analogous art as they both disclose lithium ion battery separators comprising a polyethylene porous substrate coated with a porous layer. The applicant and assignee of the Nishikawa patent is Teijin Limited,

a Japanese company that manufactures and sells lithium ion batteries. EX1004.

Chen is an article that tests multiple lithium battery separators, including a Teijin battery separator. EX1005, Table 1, 14905. These tests include stretching and breaking the separators as discussed in the '927 patent. EX1001, 10:25-43.

142. Chen displays the results of its tests by plotting a stress-strain curve for each separator. EX1005, FIG. 3, 14908. Stress-strain curves depict the elastic and plastic deformation of a material in a numbered graph—explicitly disclosing the absolute and relative plastic deformation rates (as those terms are defined in the patent). *Id.* If it is alleged that Nishikawa does not explicitly and inherently (Ground 1) or obviously (Ground 2A) teach all claim features, one of skill in the art would therefore look to Chen to learn more detail about the elastic and plastic deformation properties of the kind of separators described in Nishikawa.

1. 1.P: An electrochemical device, comprising:

143. To the extent the preamble is limiting, Nishikawa discloses, “A nonaqueous electrolyte battery,” which is an electrochemical device. EX1004, ¶12. The obvious combination therefore discloses this limitation.

2. 1.1: a cathode; an anode; and a separator;

144. Ground 1 demonstrates Nishikawa discloses, “A nonaqueous electrolyte battery including a positive electrode, a negative electrode, and the separator for a nonaqueous electrolyte battery of any one of <1> to <7> disposed

between the positive electrode and the negative electrode.” EX1004, ¶12. The obvious combination therefore discloses this limitation.

3. 1.2: wherein, the separator comprises a porous substrate and a porous layer;

145. Ground 1 demonstrates Nishikawa discloses its “separator . . . includes a porous substrate” and “porous layer.” EX1004, ¶16. The obvious combination therefore discloses this limitation.

4. 1.3: wherein the porous layer is disposed on a surface of the porous substrate and comprises inorganic particles and a binder;

146. Nishikawa discloses, “The adhesive porous layer is provided on one side or both sides of the porous substrate.” EX1004, ¶16. The obvious combination therefore discloses this limitation.

5. 1.4: and the porous substrate has an absolute plastic deformation rate in a first direction ranging from about 40% to about 1800%, and wherein the absolute plastic deformation rate is calculated according to an equation $(L2-L0)/L0 \times 100\%$, where L0 refers to a length of the porous substrate before stretching and L2 refers to a length of the porous substrate after the porous substrate is stretched to breakage and docked along the fracture caused by the breakage and flattened.

147. Nishikawa in view of Chen teaches element 1.4.

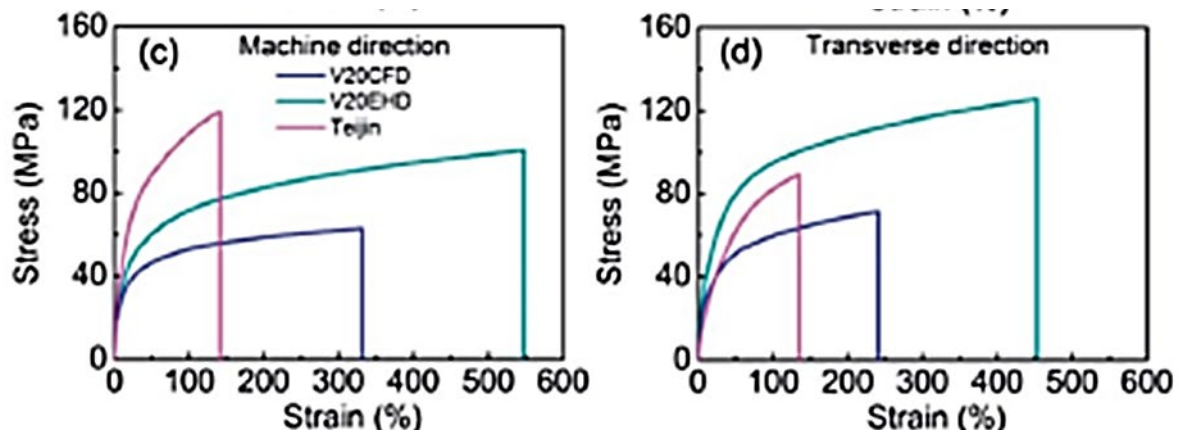
a. Nishikawa

148. To the extent the absolute plastic deformation rates of the Teijin separators disclosed in Nishikawa are not inherent (Ground 1) or obvious (Ground

2A) in view of the provided tensile strength, elongation, and Young's modulus, these values are explicitly disclosed for the Teijin separator described and tested in Chen by virtue of the provided stress-strain curves. EX1005, FIG. 3, 14908.

b. Chen

149. Specifically, Chen's Figure 3 provides a stress-strain curve for a Teijin porous substrate (pink):



EX1005, FIG. 3 (excerpted).

150. Chen explains that its tensile tests and EWF tests were performed with a CETR Tribometer (Bruker Corp.) equipped with 50 N and 100 N load cells under ambient conditions (temperature in the range of 22–26 degrees C). EX1005, 14906. The crosshead speed was set at 6 mm/min for all samples in both tensile and EWF tests, whereas the loads (F) on the MD-TT and MD-DENT specimens for Celgard 2325 and Celgard 2400 were recorded by the 100 N load cell. *Id.* The loads on all the other test specimens were recorded using the 50 N load cell. *Id.*

151. Chen also gives measured modulus, tensile strength, and strain at break, shown in the table below:

Separator	Direction	Measured modulus ^a (MPa)	Tensile strength (MPa)	Strain that non-linearity occurred (%)	Strain at break (%)
2325	MD	935 ± 43	175.2 ± 9.1	0.79	155.9
	TD	510 ± 24	14.7 ± 1.9	0.61	164.9
2400	MD	873 ± 37	146.5 ± 7.4	0.85	164.3
	TD	502 ± 28	13.4 ± 2.2	0.76	164.2
V20CFD	MD	675 ± 25	65.3 ± 5.3	0.68	333.2
	TD	781 ± 39	72.6 ± 6.7	0.72	241.5
V20EHD	MD	696 ± 48	102.7 ± 7.8	0.65	547.7
	TD	823 ± 52	127.8 ± 9.1	0.87	453.2
Teijin	MD	733 ± 41	120.6 ± 9.6	0.63	142.2
	TD	622 ± 36	90.1 ± 8.5	0.54	134.9

^a The Young's modulus was calculated from the slope of the linear stress-strain curve in the strain range of 0–0.5%.

EX1005, Table 2, 14909.

152. The '927 patent describes the total deformation as the amount of elastic deformation (L1-L2) plus the amount of plastic deformation (L2-L0). EX1001, 4:22-27. These plastic and elastic deformation values can be converted to percent elastic strain and percent plastic strain by dividing each value by L0 (the original length before stretching) and multiplying the resulting value by 100%. For example, elastic strain may be defined as (L1-L2)/L0 *100% and plastic strain may be defined as (L2-L0)/L0 * 100% (i.e., absolute plastic deformation rate in the '927 patent, col. 4 ln. 52).

153. Similar to total deformation, total strain is the sum of elastic and plastic deformation. EX1017, 20. Thus, the total plastic strain/absolute plastic

deformation rate is calculated by subtracting the elastic strain from the total strain.

EX1005, 14911.

154. Chen provides an estimate of elastic and plastic strain through analysis of atomic force microscopy (AFM) images of the wet process (i.e., Teijin) separators obtained during the tensile testing. EX1005, 14911. Chen explains that “[f]or small strains . . . the deformation was elastic and can be reversed if the load was removed,” and “[a]t higher strains nearly perfect plastic flow behavior occurred.” *Id.* Chen further explains that plastic deformation starts to occur at strains close to the strains where non-linearity started. *Id.* Thus, the point at which non-linearity occurs is an estimate of the elastic (yield) strain. In the MD, the elastic strain is about 0.63% and the estimated plastic strain is about: strain at break- elastic strain = 142.2%-0.63%=141.57%. EX1005, 14909.

155. The 0.2% offset method can also be used to estimate the elastic strain. EX1018, 61; EX1019, 8; EX1021, 87. A line with a slope equal to Young’s modulus and a 0.2% offset can be plotted and overlaid onto the stress-strain curve provided by Chen. The intersection between the line and the stress-strain curve is the yield stress. The strain corresponding to this yield stress (elastic strain) is about 5%. The plastic strain is strain at break- elastic strain = 142.2% - 5% = 137.2%. Thus, the plastic strain in the MD direction is 137.2- 141.57%.

c. Motivation to Combine

156. Nishikawa and Chen are analogous art as they both disclose lithium-ion battery separators comprising a polyethylene porous substrate coated with a porous layer. The applicant and assignee of the Nishikawa patent is Teijin Limited, a Japanese company that manufactures and sells lithium-ion batteries. EX1004. Chen is an article that tests the stress-strain related breakage rates of multiple lithium-ion battery separators, including a Teijin battery separator. EX1005, Table 1, 14905, Table 2, 14909. These tests include stretching and measuring the separators as discussed in the '927 patent. EX1001, 10:25-43.

157. A POSA would be motivated to combine the teachings of Chen with the teachings of Nishikawa because Chen provides more information about the type of battery separators disclosed in Nishikawa. A POSA would expect the teachings of Chen to be applicable to the separator disclosed in Nishikawa at least because both references disclose a Teijin separator—i.e., both references describe the properties of separators made by the same company for the same purpose.

158. Chen displays the results of its tests by plotting a stress-strain curve for each separator. EX1005, FIG. 3, 14908. Stress-strain curves depict the elastic and plastic deformation of a material in a numbered graph—explicitly disclosing the absolute and relative plastic deformation rates (as those terms are defined in the patent). *Id.* A POSA would therefore look to Chen to learn more detail about the

elastic and plastic deformation properties of the kind of separators described in Nishikawa. A POSA would be motivated to combine the teachings of these references, in part because both Nishikawa and Chen discuss Teijin separators manufactured by similar processes. EX1004, ¶45; EX1005, Introduction, 14904-05. And once combined, a POSA would have an expectation of success of the combined teachings.

159. More specifically, Chen discloses, “separators, the electrochemically inactive components in liquid electrolyte Li-ion batteries, which prevent any physical contact (internal short circuiting) between the anode and cathode electrodes while permitting the free shuttling of lithium ions in the liquid electrolyte between the electrodes throughout the separator’s interconnected porous structure.” EX1005, 14904. This is the same kind of separator disclosed in Nishikawa for the exact purpose the ’927 patent discloses for its claimed separator. EX1001, 3:62-65. Thus, not only would a POSA be motivated to combine the teachings of these references with an expectation of success, the POSA would be motivated to combine the references for the specific purpose of arriving at the claimed invention, and would expect success in doing so.

160. Chen similarly explains that it provides a test of “five micro-porous polymer separators,” EX1005, 14905, including a *Teijin PE substrate* coated with a fluorine-based compound (porous layer). This is the same PE substrate disclosed

in Nishikawa, made by the same company as the applicant and assignee of the Nishikawa patent. A POSA would therefore understand that the separator of Nishikawa could be manufactured to have the absolute plastic deformation rates depicted in Chen, or simply substitute it with the separator disclosed in Chen, and fully expect success at least because both separators are Teijin polyethylene separators.

- 6. 2. The electrochemical device according to claim 1, wherein the porous substrate has an absolute plastic deformation rate in a second direction ranging from about 60% to about 1800%.**

161. Nishikawa in view of Chen teaches claim 2.

162. To the extent it is alleged Nishikawa is deficient, using the same rationale and value inputs discussed above for limitation 1.4, the Teijin porous substrate measured in Chen has an estimated absolute plastic deformation rate of about: strain at break - elastic strain = 134.9% - 0.54% = 134.36% in the second (TD) direction, when elastic strain is the strain where non-linearity occurred.

EX1005, 1409.

163. An upper bound of elastic strain is estimated using the 0.2% offset method. EX1018, 61; EX1019, 8; EX1021, 87. A line with a slope equal to Young's modulus and a 0.2% can be plotted and overlaid onto the stress-strain curve provided by Chen. The intersection between the line and the stress-strain curve is the yield stress. The strain corresponding to this yield stress (elastic strain)

is about 3%. The plastic strain is strain at break - elastic strain = 134.9% - 3% = 131.9%. Thus, the absolute plastic deformation in the TD direction is 131.9-134.36%. Chen therefore discloses the limitations of claim 2, such that the combination of Nishikawa and Chen renders claim 2 obvious.

7. **3. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: an absolute plastic deformation rate in the first direction ranging from about 40% to about 1600%; and an absolute plastic deformation rate in the second direction ranging from about 70% to about 1600%.**

164. Nishikawa in view of Chen teaches claim 2.

165. To the extent it is alleged Nishikawa is deficient, using the same rationale and value inputs discussed above for limitations 1.4 and 2, the Teijin separator measured in Chen has both of the listed properties. The estimated plastic deformation rate in the first direction (MD) for the Teijin separator is shown to be about 137.2-141.57% and the second direction (TD) is shown to be about 131.9-134.36%. EX1005, 1409. Chen therefore discloses the limitations of claim 3, such that the combination of Nishikawa and Chen renders claim 3 obvious.

8. **4. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 50% to about 100%; and a relative plastic deformation rate in the second direction ranging from about 60% to about 100%.**

166. To the extent the relative plastic deformation rates of the Teijin separators disclosed in Nishikawa are not inherent (Ground 1) or obvious (Ground

2A) in view of the provided tensile strength, elongation, and Young's modulus, these values are explicitly disclosed for the Teijin separator described and tested in Chen. EX1005, 1409.

167. As taught by the '927 patent, the *relative* plastic deformation rate is: $(L2 - L0)/(L1 - L0) \times 100\%$. This is simply the absolute plastic deformation rate $(L2 - L0)/L0 \times 100\%$ divided by the percent total strain $(L1 - L0)/L0 \times 100\%$ and multiplied by 100%. EX1001, 4:51-54.

168. The Teijin porous substrate measured by Chen has an estimated relative plastic deformation rate in the first (MD) direction of: absolute plastic deformation rate/strain at break * 100% = (137.2% or 141.57%)/ 142.2% *100% = 96.5- 99.55%. EX1005, 14909. The Teijin porous substrate measured by Chen has an estimated relative plastic deformation rate in the second (TD) direction of (131.9% or 134.36%/ 134.9% *100% = 97.8-99.60%. *Id.*

169. While the separator materials of Chen's Teijin separator and Nishikawa's separator have slightly different measured Young's moduli, they are nonetheless similar, and both are within the scope of the '927 patent claims. The teachings of the references are therefore compatible, and any property differences due to differences resulting, for example, by the manufacturing processes, are a matter of design choice. Indeed, the '927 patent itself indicates as much by listing all of the common separator materials (including porous substrate, inorganic

particles, and binders) as interchangeable, and reciting large numeric ranges for the resulting properties. EX1001, Table 1.

170. The combination of Nishikawa and Chen renders claim 4 obvious.

9. **5. The electrochemical device according to claim 4, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 65% to about 90%; and a relative plastic deformation rate in the second direction ranging from about 75% to about 90%.**

171. To the extent the relative plastic deformation rates of the Teijin separators disclosed in Nishikawa are not inherent (Ground 1) or obvious (Ground 2A) in view of the provided tensile strength, elongation, and Young's modulus, these values are explicitly disclosed for the Teijin separator described and tested in Chen.

172. The Teijin porous substrate measured by Chen has an estimated relative plastic deformation rate in the first (MD) direction of 96.5-99.55%. The Teijin porous substrate measured by Chen has an estimated relative plastic deformation rate in the second (TD) direction of 97.8-99.60%. The claim uses the term "about" to modify all of the plastic deformation rates. The specification defines the term "about" to denote up to $\pm 10\%$. EX1001, 3:33-45. The values calculated by Chen are thus about the claimed ranges.

173. The combination of Nishikawa and Chen renders claim 5 obvious.

10. 6. The electrochemical device according to claim 1, wherein the binder comprises at least one selected from the group consisting of a **vinylidene fluoride-hexafluoropropylene copolymer**, a vinylidene fluoride-trichloroethylene copolymer, . . . **polyimide**, **polyethylene oxide**.

174. As discussed above in Ground 1, Nishikawa discloses porous layers made from **polyimide**, polyvinylidene fluoride, polyvinylidene fluoride copolymers like **vinylidene fluoride-hexafluoropropylene copolymer**, and **polyethylene oxide**. EX1004, ¶¶47, 67, Table 1.

11. 7. The electrochemical device according to claim 1, wherein the inorganic particles comprise at least one selected from the group consisting of **alumina**, . . . **magnesium hydroxide**, calcium hydroxide and barium sulfate.

175. As discussed above in Ground 1, Nishikawa discloses that the porous layer may include, “[a]s the inorganic filler, metal oxides such as **alumina**, metal hydroxides such as **magnesium hydroxide**, and the like.” EX1004, ¶¶47, 85.

12. 8. The electrochemical device according to claim 1, wherein the porous substrate comprises a polymer film, a multilayer polymer film or a nonwoven fabric, wherein the polymer film, the multilayer polymer film or the nonwoven fabric is formed by any one or more of the following polymers: polyethylene, ...

176. As discussed above for Ground 1, Nishikawa discloses that the porous substrate can include “microporous membranes, porous sheets made of a fibrous material, such as nonwoven fabrics and paper-like sheets, and composite porous sheets including such a microporous membrane or porous sheet as well as one or

more other porous layers laminated thereon.” EX1004, ¶35. Specifically, the “porous substrate” is “a polyolefin,” like “polyethylene.” EX1004, ¶¶40-43.

177. If unclear, Chen similarly discloses a Teijin battery separator with a porous substrate of polyethylene. EX1005, 14905, Table 1. Chen further discloses, “In the wet process, raw gel-like separator film is first made by extruding a heated homogenous mixture of polymer resins and plasticizers (e.g., paraffin oil, antioxidant, and other additives) into a thin film that is orientated in the MD, which is then followed by extracting the plasticizers from the film with a volatile solvent to leave the polymer pore skeleton in the film which forms the microporous structure.” EX1005, 14905. This is roughly the same manufacturing process disclosed in Nishikawa.

178. The combination of Nishikawa and Chen renders claim 8 obvious.

13. 9. The electrochemical device according to claim 1, wherein the porous substrate has a thickness ranging from about 1 to about 40 μm .

179. As discussed above for Ground 1, Table 1 of Nishikawa discloses porous substrates with a thickness of 9 microns. EX1004, Table 1, Examples 1-8. Nishikawa therefore discloses this element. If, however, a POSA wanted to make a separator with the plastic deformation disclosed in Chen, the POSA might choose the thickness of the Chen separator instead. Table 1 of Chen discloses a Teijin

separator and coating with a thickness of 15 microns. EX1005, Table 1, 14909.

Chen, therefore, also discloses this element.

180. One of skill in the art would readily understand that the thickness of the porous substrate at least *within the claimed numeric range* is a design choice that balances competing desires such as ion permeability, tensile strength, puncture resistance, weight, and space constraints. EX1015, 4424.1. A POSA could readily implement a 9-micron version of Chen's porous substrate in Nishikawa's battery, or incorporate Chen's 15-micron separator into Nishikawa's battery, or modify a 15-micron version of Nishikawa's porous substrate with a coating to obtain the other physical properties of Chen's Teijin separator. All of these design choices are equally viable, and all of them equally satisfy the claims. Accordingly, a POSA would readily combine the teachings of these references to practice different variations of Teijin separators with different thicknesses in the numeric range recited in claim 9 with an expectation of success.

181. The combination of Nishikawa and Chen renders claim 9 obvious.

**14. 10. The electrochemical device according to claim 1,
wherein the electrochemical device comprises lithium ion
batteries.**

182. Nishikawa discloses, "The nonaqueous electrolyte battery of the invention is suitable for a nonaqueous electrolyte secondary battery, particularly a

lithium ion secondary battery.” EX1004, ¶107. The combination of Nishikawa and Chen renders claim 10 obvious.

XI. GROUND 3: CLAIMS 1-10 ARE OBVIOUS OVER CHEN IN VIEW OF ZHANG

183. As discussed above in Ground 2B, Chen describes various battery separators and provides test results for deformation experiments similar to those recited in the '927 patent. EX1005, Table 2, 14909. In addition to the Teijin separator discussed in Ground 2B, Chen also describes and reports results for a Celgard separator. EX1005, Table 2, 14909. While the Teijin separator described in Chen has a porous layer disposed on the porous substrate, the Celgard separator described in Chen does not. EX1005, Table 2, 14909. A POSA would readily understand, however, that a porous layer could be added to the porous substrate of the Celgard separator described in Chen, just as it was added to the Teijin separator described in Chen.

184. In order to learn the types of porous layers appropriate to add to the Celgard separator in Chen and how to make them, a POSA would look to U.S. Patent No. 10,559,802 to Zhang. The Zhang patent is assigned to Celgard, the same company that makes two of the separators tested in Chen. Zhang even describes a Celgard separator like the Celgard separator disclosed in Chen. EX1006, 8:24-26. Zhang goes on to describe a porous layer and teaches that it

would be appropriate to add this porous layer to any kind of battery separator, preferably the Celgard separator. EX1006, 8:27-67, 9:1-13.

15. 1.P: An electrochemical device, comprising:

185. To the extent the preamble is limiting, Chen discloses, “liquid electrolyte Li-ion batteries,” which are electrochemical devices. EX1005, 14904. The combination of Chen and Zhang renders claim 1 obvious.

16. 1.1: a cathode; an anode; and a separator;

186. Chen discloses, “**separators**, the electrochemically inactive components in liquid electrolyte Li-ion batteries, which prevent any physical contact (internal short circuiting) between the **anode** and **cathode** electrodes while permitting the free shuttling of lithium ions in the liquid electrolyte between the electrodes throughout the separator’s interconnected porous structure.” EX1005, 14904. Chen, thus, discloses this limitation.

17. 1.2: wherein, the separator comprises a porous substrate and a porous layer;

a. Chen

187. As discussed above, the Celgard separators described and tested in Chen have a porous substrate, but not a porous layer. EX1005, Table 1, 14905. The Teijin separator discussed in Chen has both a porous substrate and a porous layer. EX1005, Table 1, 14905. A POSA would have therefore understood from Chen, as well as common knowledge in the art, that adding a porous layer to a

porous substrate was a known option (because it was an option chosen for the Teijin separator) and conferred certain advantages to separators (including improved properties compared to separators without coatings). A POSA reading Chen would therefore be interested in learning more about porous layers and coatings that could be added to the Celgard separators disclosed in Chen. For this, a POSA would look to Zhang.

b. Zhang

188. Zhang discloses a porous layer for separators, specifically a porous layer that can be added to a Celgard separator, like the Celgard separator disclosed in Chen. EX1006, 2:2-7. The Zhang patent is assigned to Celgard. Zhang teaches that adding its porous layer (ceramic coating) confers several benefits. Specifically, Zhang teaches that “[t]he formation of an oxidized or reduced interfacial layer between a separator and a battery electrode prevents or stops further oxidation or reduction reactions from occurring and improves the safety, cycle life and/or the high temperature performance of a lithium ion battery.” EX1006, 3:18-22.

189. Zhang describes its “separator membrane or separator for a lithium ion battery” as “includ[ing] a porous or microporous membrane coated with a ceramic coating or layer such as a layer of one or more particles and/or binders.” EX1006, 2:14-19. Zhang’s porous membrane is the “porous substrate” of the claims, and the ceramic layer is the “porous layer” of the claims.

190. Zhang goes on to explain, “[t]he preferred membrane, film, base layer, membrane separator or separator may be a microporous polyolefin (PO) substrate that can be made by a dry process (also know [sic] as the CELGARD process), wet process, particle stretch process, . . . or the like.” EX1006, 8:3-7. Zhang also teaches that “the preferred membranes are Celgard® brand membranes,” EX1006, 8:24-26, which are the membranes tested in Chen.

c. Motivation to Combine

191. A POSA would have been motivated to apply the coating taught by Zhang to the Celgard membrane measured by Chen to arrive at the separator of claim 1.2. As discussed above in Ground 2B, Chen describes various battery separators and provides test results for deformation experiments similar to those recited in the '927 patent. EX1005, 14906-07. In addition to the Teijin separator discussed in Ground 2B, Chen also describes and reports results for a Celgard separator. EX1005, Table 2. While the Teijin separator described in Chen has a porous layer disposed on the porous substrate, the Celgard separator described in Chen does not. EX1005, Table 2, 14909. A POSA would readily understand, however, that a porous layer could be added to the porous substrate of the Celgard separator described in Chen, just as it was added to the Teijin separator described in Chen.

192. In order to learn the types of porous layers appropriate to add to the Celgard separator in Chen and how to make them, a POSA would look to U.S. Patent No. 10,559,802 to Zhang. The Zhang patent is assigned to Celgard, the same company that makes the separators tested in Chen. Zhang discloses, “[i]n accordance with at least certain possibly preferred embodiments of the invention, there is provided in a secondary lithium ion battery.” EX1006, 17:35-38. Zhang explains “[o]ne side [of the separator] may be adapted to contact the cathode while the other side may be adapted to contact the anode.” EX1006, 7:64-65. Zhang even describes a Celgard separator like the Celgard separator disclosed in Chen. EX1006, 8:24-26.

193. Specifically, Zhang similarly discloses, “[t]he preferred membrane, film, base layer, membrane separator or separator may be a microporous polyolefin (PO) substrate that can be made by a dry process (also know [sic] as the CELGARD process).” EX1006, 8:3-7. This is the same manufacturing process and polyolefin substrate used in the Celgard separators described in Chen. EX1005, 14905 (Polyethylene and polypropylene are types of polyolefins.) Zhang also teaches that “the preferred membranes are Celgard brand membranes,” which are the membranes tested in Chen. EX1006, 8:24-26.

194. Accordingly, both references disclose the same kinds of polyolefin polymer membranes made by the same dry process, and sold under the same

Celgard brand name. EX1005, 14906; EX1006, 8:3-7. Zhang goes on to describe a porous layer and teaches that it would be appropriate to add this porous layer to the porous substrate of any kind of battery separator, preferably the Celgard separator. EX1006, 8:3-26. A POSA would therefore be motivated to modify the Celgard separator disclosed in Chen to add the porous layer disclosed in Zhang, at least because Zhang teaches a POSA to do exactly that.

195. Once combined, a POSA would have an expectation of success of the combined teachings, at least because Zhang teaches that its porous layer would be an improvement to the Celgard separator, and teaches that its porous layer is particularly suited to separators manufactured by the Celgard process. EX1006, 3:3-8. Specifically, Zhang teaches that “[t]he formation of an oxidized or reduced interfacial layer between a separator and a battery electrode prevents or stops further oxidation or reduction reactions from occurring and improves the safety, cycle life and/or the high temperature performance of a lithium ion battery.” EX1006, 3:18-22. Additionally, a POSA would have observed that the Teijin separator of Chen had a similar coating, and would expect that following the teachings of Zhang to modify the Celgard separators of Chen to add a similar coating would similarly succeed.

196. Zhang thus also teaches this limitation, and establishes that the separators of Chen and Zhang both have the same purpose and objectives, which

are the same purpose and objectives of the '927 patent. Specifically, both separators aim to provide improved battery safety. EX1005, 14904; EX1006, 3:18-22. They are both manufactured by similar methods in order to achieve the properties that both Chen and Zhang attribute to the porous substrates and coatings that they describe in their respective disclosures.² EX1005, 14904; EX1006, 2:20-25. Importantly, the reasons that Chen and Zhang provide testing data and manufacturing information for their respective separators is to show the elastic and plastic behavior, which is relevant to nail-test passage rates (a widely accepted indicator of battery and specifically separator safety). EX1005, 14905. Of course, a porous substrate with high puncture resistance (nail-test aptitude) must also be able to perform the other roles of a separator in a battery (cycle-time, temperature resistance), which is why such separators often have (and are tested with) porous layers applied to the porous separators.

² A porous layer is added to the separator substrate to hold sufficient liquid electrolyte to enable efficient ion transport during charging and discharging cycles. This allows ions to move freely between the anode and cathode while preventing direct electrical contact between them, essentially acting as a pathway for the electrolyte to flow through, which is crucial for the battery to function properly.

18. 1.3: wherein the porous layer is disposed on a surface of the porous substrate and comprises inorganic particles and a binder;

d. Chen

197. Because the Celgard separator tested in Chen does not have a coating, Chen does not teach any specific components of a porous layer disposed on that substrate. The Teijin separator in Chen does have a fluorine compound coating, which a POSA would understand to include inorganic particles of fluorine and a binder to adhere them to the porous substrate. *See* EX1005, Table 1, 14905. Thus, while Chen itself suggests that coatings including inorganic components are desirable for separators generally, it does not disclose any particular coating for the Celgard separators tested. Zhang, however, discloses this limitation. EX1006, 2:53-65.

e. Zhang

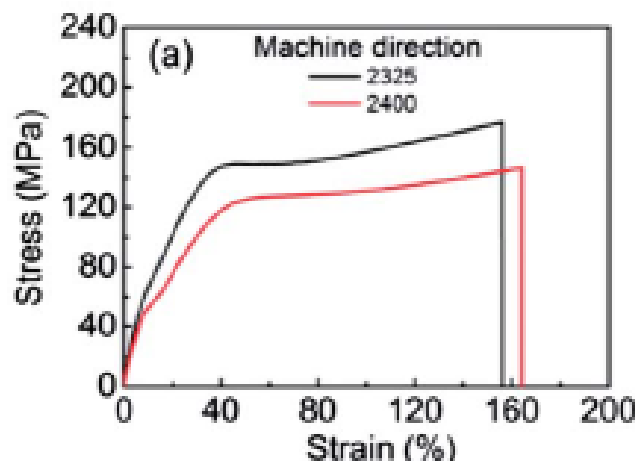
198. Zhang discloses, “[t]he ceramic coating is preferably made up of, includes or is comprised of one or more ceramic particles or materials mixed with one or more aqueous or water based binders, polymers, polymeric binders, or the like.” EX1006, 8:27-30. Ceramic particles are inorganic particles.

199. A POSA would be motivated to look to Zhang for details on how to make and apply the porous layer as discussed for limitation 1.2 above. A POSA would be motivated to apply the specific coating taught in Zhang for the same

reasons that Zhang motivates a POSA to use coatings generally—to improve the safety and performance of the battery. EX1005, 3:18-22.

19. **1.4: and the porous substrate has an absolute plastic deformation rate in a first direction ranging from about 40% to about 1800%, and wherein the absolute plastic deformation rate is calculated according to an equation $(L2-L0)/L0 \times 100\%$, where L0 refers to a length of the porous substrate before stretching and L2 refers to a length of the porous substrate after the porous substrate is stretched to breakage and docked along the fracture caused by the breakage and flattened.**

200. Chen discloses stress-strain curves and Young's modulus for two Celgard porous separators, denoted "2325" and "2400." Figure 3 shows the stress-strain curves in the MD (first direction).



EX1005, FIG. 3 (excerpted).

201. The Young's modulus and the tensile stress at breakage are used to estimate the absolute plastic deformation rate. The '927 patent describes the total deformation as the amount of elastic deformation (L1-L2) plus the amount of plastic deformation (L2-L0). EX1001, 4:22-27. These plastic and elastic

deformation values can be converted to percent elastic strain and percent plastic strain by dividing each value by L_0 (the original length before stretching) and multiplying the resulting value by 100%.

202. For example, elastic strain may be defined as $(L_1 - L_2)/L_0 * 100\%$ and plastic strain may be defined as $(L_2 - L_0)/L_0 * 100\%$ (i.e., absolute plastic deformation rate in the '927 patent, col. 4 ln. 52). Similar to total deformation, total strain is the sum of elastic and plastic deformation. Thus, the total plastic strain/absolute plastic deformation rate is estimated by subtracting the elastic strain from the total strain.

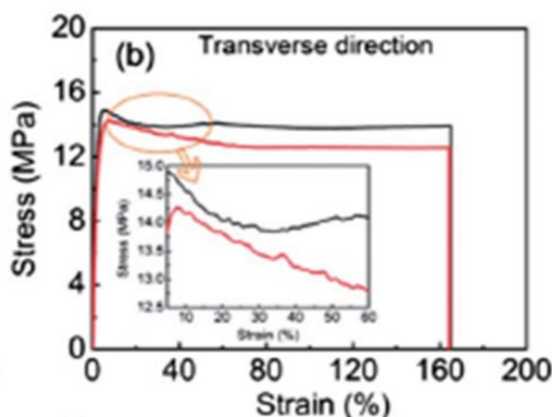
203. Chen used a combination of stress-strain curves and deformation analysis to determine the plastic and elastic strain for the dry process separators. EX1005, 14908. For example, “[t]he MD stress-strain curves of both dry processed Celgard 2325 and 2400 separators . . . are similar to the typical hard elastic polymers showing . . . elasticity (linear, non-linear), yielding, . . . cold drawing, strain hardening, and failure . . . the cold drawing behavior . . . in each stress-strain curve took place immediately after yielding.” *Id.* Chen explains that yielding occurs at about 35% strain. EX1005, 14910. This value is also read directly from the stress-strain curve. EX1005, FIG. 3. A person of ordinary skill in the art would understand that elastic deformation occurs until the yield point (~35%), after which plastic deformation (i.e., lamellae deformation) occurs. EX1005, 14910. Thus the

elastic strain is about ~35% for both the 2325 and 2400 separators. *Id.* Thus, for the 2325 separator, the plastic strain in the MD direction is strain at break - elastic strain = 155.9%-35%= 120.9%. EX1005, 14909. For the 2400 separator, the plastic strain in the MD direction is strain at break - elastic strain = 164.3% - 35%= 129.3%. *Id.*

204. The claim specifies that the recited absolute plastic deformation rate (numeric range) is the plastic deformation rate of the porous substrate itself (as opposed to the separator as a whole). The fact that Chen tests the porous substrates of the two Celgard separators without a coating confirms that the calculated plastic deformation applies to the porous substrate as claimed.

20. 2. The electrochemical device according to claim 1, wherein the porous substrate has an absolute plastic deformation rate in a second direction ranging from about 60% to about 1800%.

205. Figure 3 of Chen also discloses stress-strain curves for the 2325 and 2400 Celgard separators in the TD (second direction).



EX1005, FIG. 3 (excerpted).

206. In the TD direction, Chen identifies the yield stress (i.e., stress at yield peak) as occurring around 8% strain for both the 2325 and 2400 separators.

EX1005, 14908-09. Thus, the elastic strain is about 8%. This is further supported by the lamellae separation observed after yielding. EX1005, 14908-09, FIG. 4.

207. Using the methods described above, for the 2325 separator, the estimated elastic strain in the TD direction is about strain at break- elastic strain= $164.9\%-8\%= 156.9\%$. EX1005, 14909.

208. For the 2400 separator, the estimated elastic strain in the TD direction is about strain at break- elastic strain = $164.2\%- 8\%= 156.2\%$. *Id.*

209. Both of these estimated plastic deformation rates fall within the claimed numeric range. Chen, thus, discloses the porous substrate with an absolute plastic deformation rate in a second direction as claimed.

21. 3. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: an absolute plastic deformation rate in the first direction ranging from about 40% to about 1600%; and an absolute plastic deformation rate in the second direction ranging from about 70% to about 1600%.

210. As discussed above for claim limitation 1.4 and claim 2, the absolute plastic deformation rates of the two Celgard separators tested in Chen fall within these numeric ranges. Chen, therefore, teaches this limitation.

- 22. 4. The electrochemical device according to claim 1, wherein the porous substrate has at least one of the following properties: a relative plastic deformation rate in the first direction ranging from about 50% to about 100%; and a relative plastic deformation rate in the second direction ranging from about 60% to about 100%.**

211. The Celgard separators tested in Chen have relative plastic deformation rates that fall within these claimed ranges. As taught by the '927 patent, the *relative* plastic deformation rate is: $(L2 - L0)/(L1 - L0) \times 100\%$. This is simply the absolute plastic deformation rate $(L2 - L0)/L0 \times 100\%$ divided by the percent total strain $(L1 - L0)/L0 \times 100\%$ and multiplied by 100%. EX1001, 4:51-54.

212. For the Celgard 2325 separator, the estimated relative plastic deformation rate in the MD (first) direction is absolute plastic deformation rate / total strain = $120.9\% / 155.9\% \times 100\% = 77.5\%$. EX1005, 14909. In the TD (second) direction, the estimated relative plastic deformation rate is absolute plastic deformation rate/total strain * 100% = $156.9\% / 164.9\% = 95.1\%$. *Id.*

213. For the 2400 separator, the estimated relative plastic deformation rate in the MD (first direction) is absolute plastic deformation rate/total strain * 100% = $129.3\% / 164.3\% \times 100\% = 78.7\%$ and in the TD (second direction) is $156.2\% / 164.2\% \times 100\% = 95.1\%$. *Id.* All of these numeric values fall completely within the claimed ranges.

- 23. 5. The electrochemical device according to claim 4, wherein the porous substrate has *at least one* of the following properties: a relative plastic deformation rate in the first direction ranging from about 65% to about 90%; and a relative plastic deformation rate in the second direction ranging from about 75% to about 90%.**

214. As discussed above for claim 4, the Celgard 2325 has an estimated relative plastic deformation rate in the MD (first) direction of 77.5% and the 2400 separator has an estimated relative plastic deformation rate in the MD (first direction) of 78.7%. EX1005, 14905. Both the 2400 and 2325 Celgard separators thus have relative plastic deformation rates that fall within the claimed numeric range for the first direction. *Id.* Claim 5 only requires that the porous substrate have at least *one* of the recited numeric ranges. The porous substrate need not have both. Chen's Celgard separators thus satisfy the limitations of claim 5.

24. 6. The electrochemical device according to claim 1, wherein the binder comprises at least one selected from the group consisting of a vinylidene fluoride-hexafluoropropylene copolymer, a vinylidene fluoride-trichloroethylene copolymer, polymethyl methacrylate, **polyacrylic acid**, polyacrylate, **polyacrylonitrile**, polyvinyl pyrrolidone, **polyvinyl acetate**, an ethylene-vinyl acetate copolymer, polyimide, polyethylene oxide, cellulose acetate, cellulose acetate butyrate, cellulose acetate propionate, cyanoethyl amylopectin, cyanoethyl polyvinyl alcohol, cyanoethyl cellulose, cyanoethyl sucrose, amylopectin, sodium carboxymethyl cellulose, lithium carboxymethyl cellulose, an acrylonitrile-styrene-butadiene copolymer, **polyvinyl alcohol**, polyvinyl ether, polytetrafluoroethylene, polyhexafluoropropylene, a styrene-butadiene copolymer, and polyvinylidene fluoride.

215. As discussed above, Chen does not disclose a porous layer applied to the Celgard separators, but Zhang does. EX1006, 8:3-11. A POSA would be motivated to apply Zhang's porous layer to Chen's Celgard separators as discussed above for limitation 1.2. For those same reasons, a POSA would be motivated to select a porous layer as Zhang describes it, including Zhang's selection of the binder.

216. Zhang discloses: "The preferred water based polymeric binder can be **polyvinyl alcohol** (PVOH), **polyvinyl acetate** (PVAc), **polyacrylic acid salt**, **polyacrylonitrile**, polyacrylamide or poly(sodium acrylate-acrylamide-acrylonitrile) copolymer or copolymers of the above or blends or mixtures of the above." EX1006, 8:61-65. Zhang thus discloses several of the binders within the

Markush group recited in claim 6. The combination of Chen and Zhang thus renders claim 6 obvious.

25. 7. The electrochemical device according to claim 1, wherein the inorganic particles comprise at least one selected from the group consisting of **alumina**, **silica**, magnesia, titanium oxide, hafnium dioxide, tin oxide, cerium dioxide, nickel oxide, **zinc oxide**, calcium oxide, **zirconia**, yttria, silicon carbide, eboehmite, aluminum hydroxide, magnesium hydroxide, calcium hydroxide and barium sulfate.

217. As discussed above, Chen does not disclose a porous layer applied to the Celgard separators, but Zhang does. EX1006, 2:20-26. A POSA would be motivated to apply Zhang's porous layer to Chen's Celgard separators as discussed above for limitation 1.2. For those same reasons, a POSA would be motivated to select a porous layer as Zhang describes it, including Zhang's selection of the inorganic particles.

218. Zhang discloses, "The ceramic particles may be inorganic or organic, preferably inorganic." EX1006, 8:30-36. "Non-limiting exemplary examples of inorganic particles are **oxides** of **silicon** (SiO_2), **alumina** (Al_2O_3), **zirconium**, titanium (TiO_2) or **zinc** or mixtures thereof or carbonates of silicon, alumina, zirconium, calcium, zinc, and blends or mixtures thereof. A preferred particle is Al_2O_3 ." *Id.* Zhang thus discloses several of the inorganic particles disclosed in the Markush group recited in claim 7. The combination of Chen and Zhang thus renders claim 7 obvious.

- 26. 8. The electrochemical device according to claim 1, wherein the porous substrate comprises a polymer film, a multilayer polymer film or a nonwoven fabric, wherein the polymer film, the multilayer polymer film or the nonwoven fabric is formed by any one or more of the following polymers: polyethylene, polypropylene, ...**

219. Chen discloses that the Celgard 2325 porous substrate is a tri-layer substrate of polypropylene and polyethylene. EX1005, Table 1, 14905. The Celgard 2400 porous substrate is made from polypropylene. EX1005, Table 1, 14905. Chen further characterizes these dry-process separators (the Celgard separators) as films. EX1005, 14905. Chen thus discloses the additional limitations of claim 8, and the combination of Chen and Zhang renders claim 8 obvious.

- 27. 9. The electrochemical device according to claim 1, wherein the porous substrate has a thickness ranging from about 1 to about 40 μm .**

220. Chen discloses that the Celgard 2325 and 2400 porous separators both have a thickness of 25 microns. EX1005, Table 1, 14905. This thickness falls within the numeric range of claim 9. The combination of Chen and Zhang thus renders claim 9 obvious.

- 28. 10. The electrochemical device according to claim 1, wherein the electrochemical device comprises lithium ion batteries.**

221. Chen discloses that the devices taught (separators) are “electrochemically inactive components in liquid electrolyte Li-ion batteries.”

EX1005, 14904. The combination of Chen and Zhang thus renders claim 10 obvious.

XII. CONCLUSION

222. I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I could testify to the matters in this declaration competently if called upon to do so. I further declare 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 the Title 18 of the United States Code.

Executed on this 11th day of January in College Park, MD.

A handwritten signature in black ink that reads "Michael Pecht". The signature is written in a cursive, flowing style with a long horizontal stroke at the end.

Michael Pecht, Ph.D., PE