UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD.,
Petitioner

v.

RJ TECHNOLOGY LLC,
Patent Owner.

Case IPR2023-01183

Patent No. 7,749,641

DECLARATION OF DR. YAN YAO

APPLE 1037
Apple v. RJ Technology
IPR2023-01350

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I. INTRODUCTION

1. My name is Yan Yao. I have been retained as an expert witness to provide my independent opinion on matters at issue in the *inter partes* review of U.S. 7,749,641 ("the '641 Patent") in the IPR2023-01183 proceeding. I am being compensated at my customary rate for the time I spend on this matter. My compensation is not contingent on the content of my opinions nor the outcome of the *inter partes* review proceeding. I have no direct financial interest in any of the parties or this proceeding.

2. Unless otherwise noted, the statements made herein are based on my personal knowledge, and if called to testify about this declaration, I could and would do so competently and truthfully.

3. My CV is being submitted herewith as Ex. 2007 to this proceeding and is summarized *infra* in Section II.

4. I am not a legal expert and offer no opinions on the law. However, I have been informed by counsel of the various legal standards that apply, and I have applied those standards in arriving at my conclusions.

5. The opinions I set forth herein are my own and are based on my education, experience, training, and skill.

II. QUALIFICATIONS

6. I am currently employed as the Hugh Roy and Lillie Cranz Cullen Distinguished Professor in the Cullen College of Engineering at the University of Houston and the Principal Investigator at the Texas Center for Superconductivity. My primary research focuses on Li-ion batteries and novel battery chemistries beyond lithium-ion batteries. My research group has been funded by federal agencies (DOE, ARPA-E, NSF, ONR) and industry. I am also a Fellow of the Royal Society of Chemistry, a senior member of the National Academy of Inventors, and a senior member of the Institute for Electrical and Electronics Engineers. For more than 13 years I have conducted research on lithium-ion batteries and have taught students about lithium-ion batteries for over a decade. I have authored more than 150 papers in Nature Energy, Nature Materials, etc. with over 28,000 total citations, 10 granted US patents, and delivered 140 keynote and invited talks. I have received many awards for my research, including the Office of Naval Research Young Investigator Award, Top 1% Highly Cited Researcher by Clarivate Analytics, Scialog Fellow, IAAM Fellow, and Cullen College of Engineering Professorship.

7. I received my undergraduate Bachelor of Science degree in Materials Science at Fudan University in Shanghai China, in 2000. In 2003, I completed a Master's of Science degree in Materials Science from Fudan University. I received my Ph.D. in Materials Science and Engineering from the University of California

Los Angeles, in 2008. I then conducted postdoc research at Stanford University after working in the industry for two years.

8. In August 2012, I was appointed as an Assistant Professor at the University of Houston in the Cullen College of Engineering's Department of Electrical and Computer Engineering and an affiliated faculty member in the Materials Science and Engineering Program. I was the Principal Investigator ("PI") of several projects titled: "Aqueous lithium-ion batteries with high-energy novel organic anodes for safe and robust energy storage," (funded by the Advanced Research Project Agency-Energy); "SusChEM: Design and Manufacture of Electrodes for High Energy Density Rechargeable Sodium Batteries" (funded by the National Science Foundation); "Scialog: Advanced Energy Storage" (funded by the Research Corporation); and (CO-PI) "Developing and testing of new low-cost, safe, efficient, and renewable all-solid-state sodium batteries for grid-scale energy storage" (funded by the Advanced Research Project Agency-Energy"). I received various awards and or recognitions in this role including the TcSUH Welch Foundation Professorship Award (2012); Office of Naval Research Young Investigator Award from the U.S. Office of Naval Research (2013); the Ralph E. Powe Junior Faculty Enhancement Award (2013); the Teaching Excellence Award (2016); and the Junior Level Research Excellence Award (2016).

9. I was promoted to Associate Professor with tenure in 2017, and was made a Scialog Fellow on Advanced Energy Storage (2017); recognized by Clarivate Analytics as a Top 1% Highly Cited Researcher (2018); awarded University of Houston's Award for Excellence in Research, Scholarship, or Creative Activity (2018); and became a Senior Member of IEEE (2019). I was the proposal reviewer for several organizations including the Department of Energy ("DOE"), the American Chemical Society, and the National Science Foundation.

10. I became a Full Professor in 2020 and Hugh Roy and Lillie Cranz Cullen Distinguished Professor in 2022. During this time, I have been the PI/co-PI for research projects funded by ARPA-E, DOE, NSF, ONR, and industries. These projects include the studies "Lithium and transition metal-free high-energy fast-charging batteries" funded by ARPA-E OPEN 2021; "Multidimensional diagnostics of the interface evolutions in solid-state lithium batteries" funded by DOE's Vehicle Technology Office. In 2020 I became a Fellow of the Royal Chemical Society and Senior Membership of the National Academy of Inventors. In 2021, I was awarded the Excellent Paper of the Year by the International Mg Society for the paper "High-Power Mg Batteries Enabled by Heterogeneous Enolization Redox Chemistry and Weakly Coordinating Electrolytes." In 2022, I took part in the TAMEST Protégé Program and was awarded the Senior Level Research Excellence Award from the Cullen College of Engineering. In 2023, I was recognized as a Texas Academic

Leadership Academy Fellow. In 2024, I was made a fellow of IAAM (International Association of Advanced Materials) and was an invited speaker at the 2024 Batteries Gordon Research Conference.

11. Outside of my professorial accomplishments, I am an avid inventor of cutting-edge technologies in the field of Materials Science. I have been awarded 12 patents and completed 9 more patent applications. Many of them are related to electrochemistry and many dealing specifically with electrolytes for batteries. In 2021, I cofounded LiBeyond, LLC which strives to develop innovative battery solutions that meet or exceed the requirements for energy storage applications in the 21st century and beyond.

12. My various professional memberships include: member, NATTBatt Sodium-ion Battery Committee (2023−Present); Board member, Organic Battery Days (2017−Present); member, Molecular Foundry's Proposal Review Board (2024−Present); Electrochemical Society Battery Division Member (2012−Present); Materials Research Society (MRS) Member (2012−Present); Materials Research Society Student Award Committee (2019); Fellow of Royal Society of Chemistry (UK) (2019−Present); Senior Member of Institute of Electrical and Electronics Engineers (IEEE) (2013−Present); Treasurer, IEEE Nanotechnology Council Houston Chapter (2015−Present); Senior Member, National Academy of Inventors (NAI) (2019−Present).

III. BASES OF OPINIONS

13. In the course of conducting my analysis and forming my opinions, I have reviewed the exhibits submitted to date in this IPR, as well as the Petition, Preliminary Response, and Institution Decision.

IV. APPLICABLE LEGAL STANDARDS

14. I have been informed of the legal standards for establishing patent invalidity in *inter partes* review proceedings before the Patent Trial and Appeal Board.

A. Ordinary Skill in the Art

15. My opinions in this declaration are based on the understandings of a person of ordinary skill in the art, which I understand is sometimes referred to as an "ordinary artisan" or by the acronym "POSITA" or "POSA" (person of ordinary skill in the art), as of the time of the invention. For purposes of this Declaration, I have been instructed to use September 28, 2001 as the time of invention. I understand that the person of ordinary skill in the art is a hypothetical person who is presumed to have known the relevant art at the time of the invention. By "relevant," I mean relevant to the challenged claims of the '641 Patent.

16. I understand that, in assessing the level of skill of a person of ordinary skill in the art, one should consider the type of problems encountered in the art, the prior solutions to those problems found in the prior art references, the rapidity with which innovations are made, the sophistication of the technology, the level of

education of active workers in the field, and my own experience working with those of skill in the art at the time of the invention.

17. I am a person of more than ordinary skill in the art through my education and research experience.

B. Claim Construction

18. I have been informed that claims of the patent-at-issue in this IPR are generally interpreted according to their ordinary and customary meaning taking into consideration the so-called "intrinsic evidence" of the patent consisting of (1) the claim language; (2) the specification; and (3) the prosecution history.

19. I have been informed that claim terms may be explicitly defined in the patent specification, or they may be implicitly defined through consistent usage in the specification. I also understand that the scope of claim terms may be limited by statements in the specification or prosecution history where the applicant clearly disavows or disclaims the subject matter.

C. Anticipation

20. I understand that the petitioner must prove invalidity of a patent claim by a preponderance of the evidence, that is, the evidence must be sufficient to show that a fact or legal conclusion is more likely than not to be true.

21. I understand that a claim may be anticipated if (1) the claimed invention was patented, described in a printed publication, or in public use, on sale, or

otherwise available to the public before the effective filing date of the claimed invention; or (2) the claimed invention was described in a patent or published application, in which the patent or application names another inventor and was effectively filed before the effective filing date of the claimed invention.

22. I understand that, once the claims of a patent have been properly construed, the next step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation by-limitation basis.

23. I understand that a prior art reference "anticipates" an asserted claim, and thus renders the claim invalid, if all elements of the claim are disclosed in that prior art reference. In determining whether each and every one of the elements of the claimed invention is found in the prior art, I understand that one should take into account what a person of ordinary skill in the art would have understood from his or her examination of the particular prior art.

24. I understand that anticipation must be found in a single reference, device, or process. In other words, anticipation does not allow an additional reference to supply a missing claim limitation. I further understand that the prior art reference must disclose all elements of the claim within the four corners of the document. I further understand that the reference must disclose those elements

arranged as in the claim, and that the disclosure cannot be so sparse and ambiguous for a person of ordinary skill in the art to understand it to be disclosing the claim.

25. Moreover, I understand that any differences between a prior art reference and a claimed invention invoke the question of obviousness, not anticipation. In other words, I understand it is not sufficient for a prior art reference to disclose part of a claimed invention or that it includes multiple distinct teachings that one of ordinary skill in the art might somehow combine to achieve the claimed invention. The prior art reference must disclose the claimed invention without any need for combining various disclosures not directly related to each other. I further understand that an ambiguous prior art reference cannot be anticipatory.

26. I have been informed that the prior art reference alleged to be anticipatory must also enable one of ordinary skill in the art to make the claimed invention without undue experimentation.

27. I have been informed that the following factors enumerated in *In re Wands*, 858 F.2d 731 (Fed. Cir. 1998) guide the inquiry of whether a prior art reference is enabling (which I have been informed also bears upon whether a prior art reference renders a claim obvious):

1. The quantity of experimentation necessary,
2. The amount of direction or guidance presented,
3. The presence or absence of working examples,
4. The nature of the invention,

5. The state of the prior art,

6. The relative skill of those in the art, and

7. The predictability or unpredictability of the art.

D. Obviousness

28. I have been informed that a patent may be invalid if the claimed invention would have been obvious at the time the invention was made to a person having ordinary skill in the art. I have been informed that the following factors must be evaluated to determine whether Petitioner has met its burden of proof that a claimed invention is obvious:

1. The scope and content of the prior art relied upon by Petitioner;

2. The difference or differences, if any, between each claim of the patent and the prior art;

3. The level of ordinary skill in the art at the time the invention of the patent was made; and

4. Any objective indicia of non-obviousness, including, for example: (1) commercial success of an embodiment; (2) a long-felt need; (3) skepticism; (4) failure by others to find the solution provided by the claimed invention; (5) copying by others of the subject matter of the claim invention; (6) unexpected results of the claimed invention; (7) acceptance of others and industry praise; and (8) licensing of the patents.

29. I have been informed that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I have been informed that many, if not all, inventions rely on building blocks already

known, and claimed inventions almost of necessity will likely be combinations of what is already known.

30. I have been informed that it is important in the obviousness inquiry to identify whether a reason existed at the time of the invention that would have motivated a person of ordinary skill in the art in the relevant field to combine or modify the prior art references in the manner proposed by the Petitioner to arrive at the claimed invention. Put another way, a finding of obviousness should be supported by an apparent reason to combine or modify the prior art references as proposed by the Petitioner.

31. I have been informed that it is important in the obviousness inquiry that it is understood how the combination of references is supposed to work. An explanation of the operation of the combined references is often a prerequisite to showing that a person of ordinary skill in the art would have been motivated to make the proposed combination and would have had a reasonable expectation of success.

32. I have been informed that a finding of obviousness "requires the additional showing that a person of ordinary skill at the time of the invention would have selected and combined those prior art elements in the normal course of research and development to yield the claimed invention." *Unigene Labs., Inc. v. Apotex, Inc.*, 655 F.3d 1352, 1360 (Fed. Cir. 2011). In addition, I have been

informed that a person of ordinary skill in the art should have had a reasonable expectation of success in combining the references as proposed.

33. In assessing obviousness, I have been instructed to consider both the ordinary creativity and common sense of the person of ordinary skill in the art. I also understand that it is impermissible for common sense to be applied to fill gaps in prior art that fails to teach or suggest a limitation of the claim. I also understand that the obviousness inquiry should guard against hindsight bias or hindsight reconstruction where after-the-fact reasoning is applied to combine prior art elements using the claimed invention as a template, without establishing that, as of the date of the invention, there exists a motivation to combine or apparent reason to combine the prior art as proposed.

34. In assessing obviousness, I have been instructed that, to qualify as proper prior art for an obviousness analysis, a reference must qualify as analogous art. I have been informed that a reference qualifies as analogous art with respect to the claims if it is either: (1) from the same field or endeavor as the patent; or (2) the reference is reasonably pertinent to the particular problem addressed by the invention. I have also been informed that for a reference to be reasonably pertinent, it must logically have commended itself during the ordinary course of development to an inventor's attention in considering his problem.

35. In assessing obviousness, I have also been instructed that, as noted above, secondary considerations can often be probative evidence of non-obviousness and can serve to avoid hindsight bias. I have been instructed that secondary considerations can be sufficient to overcome a prima facie case of obviousness. I have been instructed that Patent Owner can show non-obviousness if: (1) the industry praised their work; (2) their design was copied by others; (3) their design achieved a high level of commercial success; or (4) their invention had unexpected beneficial results.

36. I have also been informed that for prior art to render obvious a claimed invention, the prior art, as a whole, must enable a skilled artisan to make and use the claimed invention and that it is insufficient to name or describe the invention if it cannot be produced without undue experimentation. I have also been informed that even though a non-enabling reference can play a role in an obviousness analysis, the evidence of record must establish that a skilled artisan could have made the claimed invention without undue experimentation. I have also been informed that the legal test for enablement in the context of an obviousness analysis is the same as the one I set forth above in my declaration in IV.C.

V. BACKGROUND

A. Technical Background of the ’641 Patent

37. Lithium-ion batteries have become ubiquitous. They are now used not only to power personal electronic devices, such as the phones, tablets, and watches but also to power electric vehicles and even to store power for residential homes and for municipal and private electric utilities.

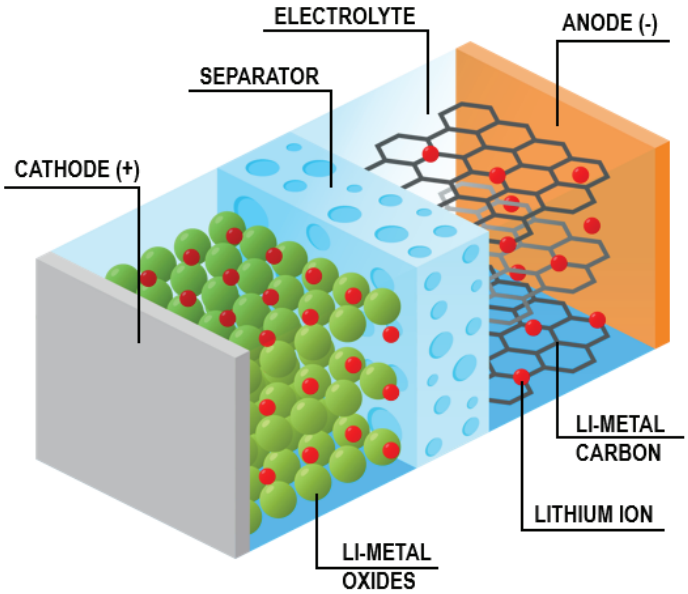
38. Lithium-ion batteries in use today are rechargeable, such that they can be charged and discharged numerous times without suffering substantial losses in the battery’s capacity. Rechargeable batteries are also called secondary batteries, and non-rechargeable batteries are called primary batteries. The terms “primary” and “secondary” are used to distinguish these two types of batteries based on their rechargeability, rather than their quality or performance.

39. Charging refers to the process of replenishing the energy stored in a battery. During charging, an external power source is connected to the battery. Discharging is the process of releasing the stored energy from the battery to power another device.

40. One reason lithium-ion batteries have become so widely used is because they have a high energy density, meaning that they efficiently store a lot of power in a relatively small volume. However, that density comes at a cost. Lithium-ion batteries can be dangerous. The chemical reactions that power these batteries

are inherently unstable and need to be conscientiously controlled and monitored. Otherwise, the batteries may overcharge, overheat, and degrade, or in extreme cases, the batteries may reach a state called thermal runaway, which may lead to fires and explosions.

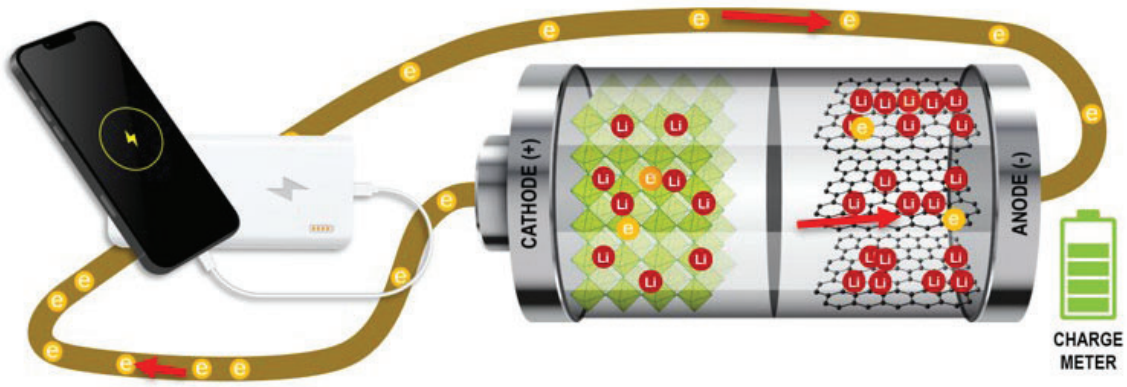
41. The basic anatomy of a secondary lithium-ion battery is illustrated in the diagram below. A lithium-ion battery includes two electrodes: the anode (negative electrode) and the cathode (positive electrode). The cathode is typically made of a lithium metal oxide compound. At the time of the invention, a common cathode material was lithium cobalt oxide ($LiCoO_2$). A common anode material is graphite, which is made of sheets of carbon (C_6).



42. Other lithium-ion battery components include the electrolyte, which allows the flow of lithium ions between the electrodes while preventing the direct

flow of electrons; the separator, which acts as a barrier to prevent direct contact of the electrodes; the current collector, which collects current from each electrode as the electrochemical reactions occur; and the case, which houses the battery. The battery typically also contains circuitry that regulates charge and discharge of the battery—sometimes called the battery management system.

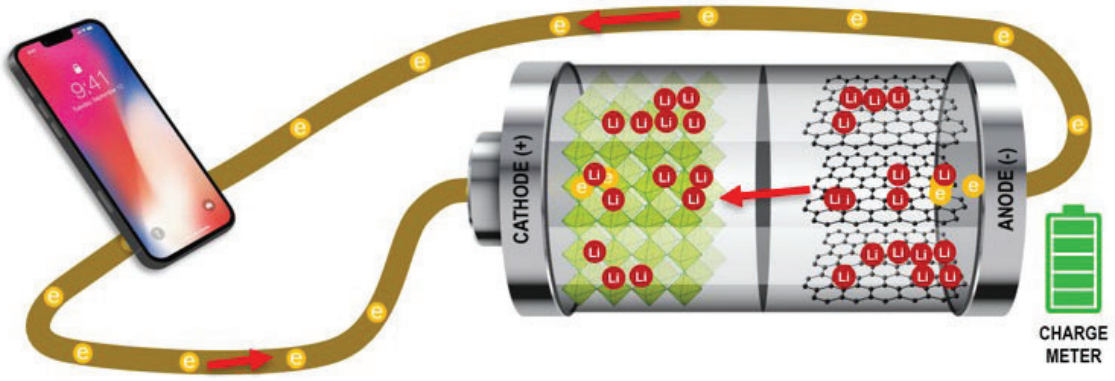
43. Next, I will describe the chemical reactions that occur during the charging and discharging of the battery. This is accomplished by the movement of positively charged lithium ions (Li^+) and negatively charged electrons (e^-) between the cathode and anode. Charging is illustrated in the image below:



44. As shown in the image, when electrical current is applied to charge the battery, the cathode undergoes a process where both electrons and lithium ions are released. The lithium ions traverse the electrolyte to reach the anode, while the electrons flow through the external circuit and also reach the anode. Once the lithium ions reach the anode, they intercalate into the anode. One key function the

anode plays is to store the lithium ions which have been pulled from the cathode through this charging process.

45. Let's now discuss discharge, which is shown in the diagram below. Discharge refers to the use of the battery to power a device, such as a smartphone. As the battery discharges, the anode releases electrons into the external circuit, where they then flow into the device as electricity, giving it power. At the same time, the lithium ions leave the anode and travel back through the electrolyte to intercalate back into the cathode. As the battery continues to discharge, more lithium ions traverse the electrolyte and intercalate into the cathode until the battery is fully discharged.

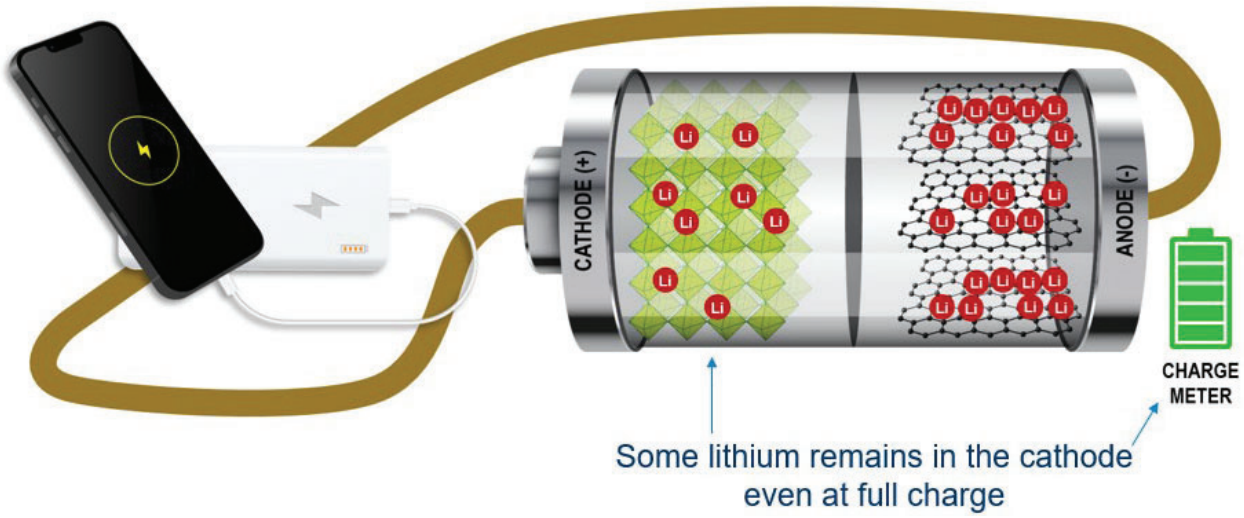


46. I will now describe some of the basic measurements for key attributes of the battery which are of relevance to this case. But first, a useful analogy. Electricity can be viewed as behaving like water in that it has attributes analogous to flow (current) and pressure (voltage). Current describes the flow of electricity,

and is measured in amperes (A). Voltage describes the amount of "pressure," e.g., the strength at which the electrons flow, and is measured in volts (V). Voltage can be thought as the driving force behind the flow of current. It is worth noting that high voltage does not necessarily mean high current. A battery can be charged with high voltage but low current, and it can be charged with a low voltage but the current may nonetheless be high.

47. The capacity of the battery measures the amount of electrical charge the battery can store. Returning to the water analogy, capacity is analogous to the size of a reservoir. Capacity is often measured in Ampere-hours (Amp-hours) or milliamp-hours (mAh), which indicates how many amperes or milliamperes of current the battery can deliver over a period of one hour. For example, a battery with 1 mAh capacity could deliver 1 mA of current for an hour.

48. As shown below, even when a battery is fully charged, some lithium typically remains in the cathode and is not moved to the anode:



49. As the ’641 Patent describes, increasing the charge cutoff voltage of a battery can increase its capacity—at least in the short term—by pulling more lithium from the cathode and pushing it to the anode. But doing so can damage the battery, ultimately leading to capacity loss, rendering the battery inoperable, and/or making the battery unsafe. For example, when the voltage is higher, the lithium ions traverse the electrolyte and intercalate into the anode with greater force, increasing the risk that both components will be damaged. Similarly, the energy can be dissipated into the system as heat, which can decompose the electrolyte and other components.

50. The failure modality most relevant to the ’641 Patent is called overcharging. When a battery is overcharged, it is charged at a voltage higher than its chemistry can accommodate. As discussed above, a battery’s voltage can be thought of as the pressure by which the components of the battery, including the lithium ions, are pushed or pulled. Overcharging pushes the lithium ions too hard

and will break the battery if done for long enough or at a high enough voltage. In the most extreme case, charging the battery at too high a voltage will cause the cathode to collapse and cause the electrolyte to oxidize, releasing flammable gasses, which ultimately causes the battery to catch fire or explode.

B. The charge cutoff voltage

51. The charge cutoff voltage is a critical design parameter for a lithium-ion battery. I explain the difference between the charge cut-off voltage of a battery (a construed term in these and other relevant proceedings) and the applied voltage during charging in later parts of my declaration but note the difference here to avoid confusion, as these concepts are different, though related, since both are relevant to charging. At the time of the ’641 Patent, it was conventional to limit the charge cutoff voltage to 4.2V or lower.

52. For example, lithium cobalt oxide ($LiCoO_2$) has been a well-studied cathode material in lithium-ion batteries, primarily due to its high energy density and stable electrochemical performance. Traditionally, the charge cutoff voltage for $LiCoO_2$ has been limited to 4.2V. It was understood that at voltages higher than 4.2V, $LiCoO_2$ can undergo irreversible structural changes and oxygen loss, which not only degrades the material’s capacity and cycling stability, but also poses risks of thermal runaway and battery failure.

53. Bradley Johnson and Ralph E. White surveyed the lithium-ion battery industry in 1998 and all of the commercial lithium-ion battery manufacturers limited the charge cutoff voltage of their batteries to either 4.1V or 4.2V.[1] They further found that when Sanyo's and Moli's batteries were charged to 4.2V, higher than their designed voltage of 4.1V, the capacity of their batteries "decreased dramatically."[2]

Table 4
Charging protocol as specified by manufacturer's product literature

Manufacturer	Current (A)	Potential limit (V)	Time (h)
Sony	1.0	4.2	2.5
A&T	1.0	4.2	2.5
Sanyo	1.3	4.1	2.5
Moli	1.2	4.1	2.5
Matsushita	0.5	4.2	2.0 u

54. Spinel lithium manganese oxide ($LiMn_2O_4$) initially attracted significant interest as a cathode material for lithium-ion batteries due to its unique crystal structure, which supports rapid lithium-ion diffusion. Because of its low cost and environmental friendliness, $LiMn_2O_4$ seemed to be a promising cathode material. However, over time, enthusiasm waned as challenges related to the

[1] Ex. 2024, Bradely Johnson & Ralph White, *Characterization of commercially available lithium-ion batteries*, Journal of Power Sources 70 (1998) 48-54 ("Johnson 1998").

[2] *Id.*, 53.

material's stability surfaced. Specifically, the dissolution of manganese in the electrolyte during battery operation led to significant issues with cycle life and capacity retention. It was known that attempting to increase the charge cutoff voltage above 4.2V caused oxidation of the electrolyte and the spinel, without the benefit of additional capacity.[3] Accordingly, as with other cathode materials, it was well-known in the art at the time of the '641 Patent that the charge cutoff voltage for spinel $LiMn_2O_4$ should not exceed 4.2V.[4]

C. The capacity ratio

55. The capacity ratio in lithium-ion batteries generally refers to the ratio of the capacities between the cathode (positive electrode) and the anode (negative electrode). There are different ways to calculate this ratio, as there are different measures of capacity for the cathode and anode, which correspond to different values and therefore different ratios, depending upon the measures of capacity used to calculate the ratio. I address some of these differences in my analysis below.

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[3] Ex. 2020, A55.

[4] Ex. 1013 (Jacobs) at 8:65–9:3; *see also* Ex. 1011 (Miyasaka) at 1:59–60, 16:23–37 (finding $Li_{1+x}Mn_2O_4$ to be "extremely unstable and easily oxided" and charged the battery up to 4.2V); Ex. 2014 (Ozawa 1994) at Fig. 1 (charging $LiMn_2O_4$ to a maximum of 4.2V).

Around the time of the ’641 Patent, the approach to setting the capacity ratio in lithium-ion batteries varied significantly among battery designers and manufacturers. Many literature and industry guidelines available at that time provided little to no specific guidance on setting the ratio.

56. Many in the industry adopted an approach by designing batteries where the cathode capacity exceeded that of the anode.[5] This was based on the understanding that some lithium ions are lost due to side reactions and the formation of the solid electrolyte interface (SEI) on the anode during the initial charge cycles.[6] By providing the cathode with excess capacity, manufacturers aimed to compensate for these losses and maintain battery balance over time.[7]

57. Some manufacturers and researchers designed batteries with anodes and cathodes to have equal capacities. Other segments of the industry thought that it was safer to have more anode capacity relative to the cathode capacity to prevent lithium plating. Among other considerations, battery size and material utilization efficiency were factors that battery designers considered when designing battery and electrode capacity, as it was well-known that overdesigning the capacity of either

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[5] *See, e.g.*, Ex. 2023 at 3650; Ex. 1012 at 4.

[6] Ex. 1013, 1:64-2:4; 2:20-26.

[7] Ex. 1013, 2:50-53.

the anode or the cathode could, depending upon other variables in battery operation, lead to waste.

D. The ’641 Patent

58. The ’641 Patent is titled “Secondary lithium ion cell or battery, and protecting circuit, electronic device, and charging device of the same.” I have been informed that for purposes of this IPR, I should use September 28, 2001 as the priority date.

59. The ’641 Patent tackles the charge cut-off voltage and the capacity ratio in tandem, for the first time in the art, to raise the charge cut-off voltage and improve battery energy density while maintaining superior cycle life. Rather than developing new battery materials, the inventors improved utilization of existing cathode materials by adjusting the anode to cathode capacity ratio to an appropriate range such that the charge cut-off voltage could safely exceed 4.2V without substantial performance loss. The novel combination of these two battery design parameters was allowed by the patent examiner, resulting in the issuance of the ’641 Patent.

60. The patent includes two independent claims (1 & 5), of which Claim 5 is representative:

> 5. A secondary lithium ion cell or battery, characterized in that the secondary lithium ion cell or battery has a charge cut-off voltage of greater than 4.2V but less than 5.8V, and a ratio of positive electrode material to negative electrode material of the secondary lithium ion cell or battery is from

1:1.0 to 1:2.5, as calculated by a theoretic capacity with a charge cut-off voltage set at 4.2V.

61. Claim 5 includes (1) a charge cut-off voltage greater than 4.2V and less than 5.8V, and (2) a capacity ratio ranging between 1:1.0 to 1:2.5, as calculated by a theoretic capacity with a charge cut-off voltage of 4.2V. Claims 2-3 depend from claim 1 and narrow the charge cut-off voltage range to 4.3-5.2V and 4.3-4.8V, respectively. Claim 4 also depends from claim 1 and narrows the ratio range to 1:1.15 to 1:2.5. Claims 6-7 depend from claim 5 and narrow the charge cut-off voltage range to 4.3-5.2V and 4.3-4.8V, respectively; and Claim 8 depends from claim 5 and narrows the capacity ratio range to 1:1.15 and 1:2.5. Claims 9 and 10 depend from claim 5 and recite limitations relating to the battery's protection mechanisms. Claims 11-18 depend from claim 1 or 5 and require that the battery maintain certain capacity levels after 400 cycles.

E. Petitioner's Cited References

62. The Petition asserts the following ten grounds:[8]

Ground	Claims	Basis
#1	1-8	Anticipated under §102(e) by Uemura
#2	1-8	Obvious under §103(a) over Uemura
#3	11-18	Obvious under §103(a) over Uemura

[8] Ex. 1035, 7.

#4	11-18	Obvious under §103 over Uemura in view of Guyomard
#5	1-8	Anticipated under §102(b) by Abe
#6	1-8	Obviousness under §103(a) over Abe
#7	2-4, 6-8, 11-18	Obvious under §103 over Abe in view of Guyomard
#8	9	Obvious under §103 over Uemura in view of Iwaizono
#9	9-10	Obvious under §103 over Uemura in view of Iwaizono in view of Guyomard
#10	9-10	Obvious under §103 over Abe in view of Guyomard and Iwaizono

1. Uemura (Ex. 1009)

63. Uemura (US Patent Pub. No. 2002/0012830) is titled "Rechargeable Lithium Battery" and purportedly describes a lithium-ion battery that uses "Li deficient type lithium manganese oxide of a layer structure as a positive electrode material."[9] Uemura claims that by combining this kind of cathode material with "a negative electrode material having a total irreversible capacity of 45% or less of a total capacity of a positive electrode material," a "rechargeable lithium battery

[9] Ex. 1009, Abstract.

having a large capacity and high cyclic resistance at high temperature can be provided."[10]

a) Uemura is directed to a cathode material that was known to be unstable and cannot be reversibly cycled.

64. Uemura states that at that time, much research had already been carried out for $LiCoO_2$ and $LiMn_2O_4$ of spinel structure, both of which had limitations.[11] According to Uemura, cobalt (Co) is expensive and is "unstable under an environment where a battery is operated."[12] As to $LiMn_2O_4$ of spinel structure, "the cyclic resistance at high temperature is insufficient, thus causing a problem that the positive material is dissolved in an electrolyte to cause deterioration of the negative electrode in performance," and its capacity "is lower than the capacity of 140 mAh/g of the conventionally used $LiCoO_2$ based material."[13] Instead of further improving these two cathode materials, Uemura states that it is directed to improving "a $LiMnO_2$ based material of layer structure" that "has a much larger capacity than the conventional $LiCoO_2$ based material."[14]

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[10] *Id*.

[11] Ex. 1009, [0006].

[12] *Id*.

[13] *Id*. at [0008].

[14] *Id*. at [0010].

65. In the 1990s, various research groups had attempted to synthesize layered $LiMnO_2$ but failed.[15] In 1996, A. Robert Armstrong and Peter G. Bruce published an article reporting the first successful synthesis of pure layered $LiMnO_2$ in the journal Nature.[16] Armstrong 1996 is also cited in Uemura.[17] Armstrong 1996 notes that "[m]any attempts have been made to prepare layered $LiMnO_2$ mainly involving the use of aqueous solutions. The resulting products, though interesting, have stoichiometries which differ from $LiMnO_2$, contain water or protons, are of poor

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[15] *See, e.g.*, Ex. 2017, Akihisa Kajiyama et al., *Synthesis and electrochemical properties of* $Li_xCo_{0.5}Mn_{0.5}O_2$, Solid State Ionics 149 (2002) 39-45 ("Kajiyama") at 39 ("The so-called 'lithium ion battery' is widely used nowadays, and $LiCoO_2$ with layered α-$NaFeO_2$ structure is used as a cathode material in it. Cobalt is an expensive element and, hence, there have been many trials to substitute cobalt with cheaper elements, e.g., manganese or iron. However, substitution of cobalt with manganese has not resulted in the layered compound with α-$NaFeO_2$-type structure by conventional solid-state reactions").

[16] Ex. 2009, A. Robert Armstrong & Peter Bruce, *Synthesis of layered* $LiMnO_2$ *as an electrode for rechargeable lithium batteries*, 381 NATURE 499 (June 6, 1996) ("Armstrong 1996").

[17] Uemura at [0010].

crystallinity or do not maintain their structure during cycling."[18] Instead of using conventional methods, Armstrong 1996 used the ion-exchange method to obtain layered $LiMnO_2$ from layered $NaMnO_2$.[19]

66. After successfully synthesizing the layered $LiMnO_2$, Armstrong et al. built "a three-electrode cell composed of lithium metal counter and reference electrodes."[20] "The cell was subjected to charging at a current density of 10 μA cm^{-2}," a very slow charging rate.[21] The authors report the following voltage curve, and found that "up to 0.95 lithium[] per formula unit may be extracted from $LiMnO_2$ on initial charging, corresponding to a capacity of 270 mAh g^{-1}."[22] Uemura itself relies upon this disclosure.[23] As shown in Fig. 2 of Armstrong 1996 below (with my

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[18] Ex. 2009 at 499.

[19] *Id*.

[20] Ex. 2009 at 500.

[21] *Id*.

[22] *Id*.

[23] Uemura at [0010] ("The capacity of layered $LiMnO_2$ based material is about 270 mAh/g, which is more than twice the capacity of the conventional $LiMn_2O_4$ of spinel structure.").

annotation), when the voltage of $LiMnO_2$ reached approximately 4.1V relative to Li, the specific capacity (a term I will explain below) already reached 270 mAh/g.[24]

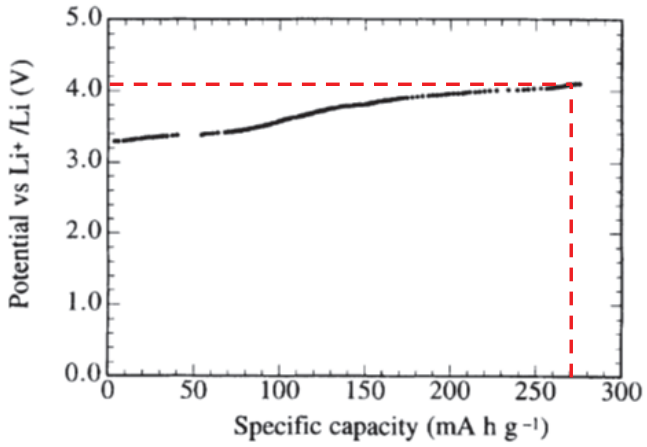

FIG. 2 Variation of electrode potential with capacity on charging $LiMnO_2$ at a current density of 10 μA cm^{-2}.

67. However, while this layered cathode structure discussed in Armstrong 1996 has a large initial charge capacity, when the battery "was cycled at a constant current density of 0.5 mA cm^{-2} between the potential limits 3.4 and 4.3 V," the capacity declined rapidly.[25] Fig. 3 of Armstrong 1996 demonstrates this significant decline clearly: as the battery was charged and discharged repeatedly, the time it took the battery to complete one charge and one discharge dropped significantly, indicating much smaller capacity. And, notably, Armstrong 1996 does not disclose

[24] Ex. 2009 at Fig. 2.

[25] Ex. 2009 at Fig. 3, 500.

a battery voltage of 4.2V, or a full-cell voltage of 4.2V, only an applied voltage of 4.3V relative to lithium metal (the distinction will be explained in more detail below).

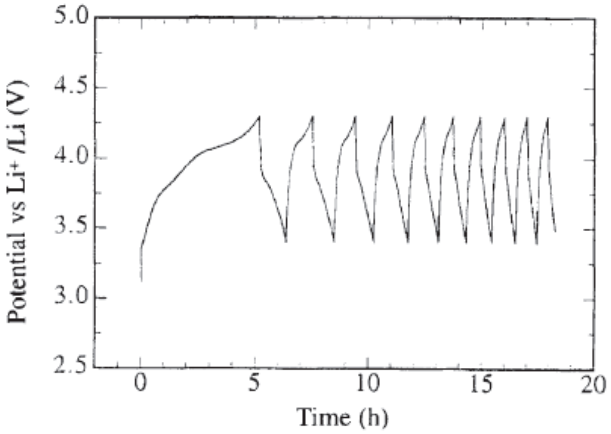

FIG. 3 Cycling of the $LiMnO_2$ electrode at a current density of 0.5 mA cm^{-2} and between voltage limits of 3.4 to 4.3 V vs Li^+/Li.

b) Uemura's purported invention attempts to reduce cathode capacity to improve stability.

68. Uemura purportedly attempts to address the cycle life issue of layered $LiMnO_2$.[26] To accomplish that, Uemura claims that "the layered lithium manganese

[26] *See* Uemura at [0012] ("An object of the present invention is to provide a rechargeable battery capable of improving the cyclic resistance, more particularly, to provide a rechargeable lithium battery structure capable of ensuring good cyclic resistance in the case of using a positive electrode material with a large capacity but unstable as described above").

complex oxide with a very large capacity but with an unstable crystalline structure" can be combined with a "negative electrode material with a larger irreversible capacity than [a] conventional one."[27] Uemura acknowledges that its method is distinct from the conventional wisdom at that time.[28] At that time and indeed still today, it is preferable to use a negative electrode material with an irreversible capacity as low as possible.

69. Uemura's purported invention involves two components. *First*, Uemura proposes to use an anode with large irreversible capacity. When the anode has a larger irreversible capacity, more lithium ions will be consumed by the anode

[27] Uemura at [0025].

[28] Uemura at [0005]; [0023]

during the first charge and discharge cycle.[29] Uemura claims that this could help stabilize the crystal structure of layered lithium manganese complex oxide.[30]

70. *Second*, Uemura purports to use a "Li deficient type layered lithium manganese complex oxide" as the cathode material, stating that "the positive electrode already has a stable structure where the Li is deficient before the charge-discharge. Therefore, the cyclic resistance can be further improved."[31]

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[29] *See* Uemura at [0025] ("For example, in the case where the layered lithium manganese complex oxide with a very large capacity but with an unstable crystalline structure and the negative electrode material with a larger irreversible capacity than the conventional one are employed in combination, the Li deficient quantity of the positive electrode material, which is caused by the charge-discharge, can be substantially increased by increasing the irreversible capacity of the negative electrode material more than that of the conventional one.").

[30] *Id*. ("For example, if the negative electrode material with a total irreversible of 10% or more, or 20% or more of a total capacity of the positive electrode material is used, the crystalline structure can be stabilized more, and the cyclic resistance of the rechargeable lithium battery can be improved.").

[31] *Id*. at [0026].

71. Uemura's approach is the opposite of the one disclosed in the '641 Patent. As discussed above, the '641 Patent aims to increase the capacity of a lithium-ion battery by increasing the charge cutoff voltage. In contrast, Uemura chooses to *reduce* the capacity of the layered $LiMnO_2$ cathode by employing an anode material with a larger irreversible capacity than conventional anode materials. Uemura purports to *further reduce* the capacity of the layered $LiMnO_2$ cathode by using a lithium deficient cathode material at the start, which explains why Uemura nowhere discusses the idea of elevating the charge cutoff voltage of the battery. Instead, a POSITA would understand that increasing the charge cutoff voltage would be counterproductive to Uemura's purported approach to stabilize the crystal structure of layered $LiMnO_2$.

2. Abe (Ex. 1005)

72. Abe (JPH10189052) is titled "Non-aqueous electrolyte-based secondary battery" and attempts to address potential safety concerns when a lithium-ion battery is being charged or discharged at a high current rate.[32]

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[32] *See* Ex. 1005 (Abe) at [0011] ("it is desirable for secondary batteries to have excellent cycle characteristics and good stability against higher loads, i.e., secondary batteries that exhibit high capacity in charging and discharging at high current

(continued…)

73. Abe's purported invention is directed at the negative electrode material. Abe describes "graphitized vapor-phase-grown carbon fiber" with particular physical characteristics, including a large specific surface area, particular "average aspect ratio," and certain average diameter. For example, by maintaining the surface area of the carbon fiber within a specific range, Abe claims that "a reduction in the electrolytic catalysis of the solvent" is achieved, thus achieving better safety.[33] These parameters are designed to reduce the reaction level of the electrolyte, thus avoiding decomposition or the production of gas when the current level is high.[34]

74. Because Abe focuses on safety, it takes the same conventional approach as prior art at that time, by charging the battery up to 4.1V. Abe explains that this is because "if the cut-off voltage at the time of charging is limited to 4.1V, a longer-lived non-aqueous electrolyte-based secondary battery can also be obtained."[35]

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values."); *see also* Abe at [0013]-[0017], [0030] ("discussing the scenario with "a large current flows due to a large load").

[33] Abe at [0022]-[0023].

[34] Abe at [0026]

[35] Abe at [0080].

Indeed, in all the examples of Abe, no matter what cathode material was used, the maximum charging voltage was 4.1V.[36]

3. Guyomard (Ex. 1008)

75. Guyomard (PCT Publication No. 93/21665) is titled "High-voltage stable electrolytes for $Li_{1+x}Mn_2O_4$/Carbon secondary batteries" and describes an electrolyte that is allegedly resistant to decomposition from high voltages.[37]

76. Guyomard states that prior art electrolyte would be oxidized when the voltage was slightly higher than 4.3V.[38] In contrast, Guyomard reports that their electrolyte could "withstand oxidation (decomposition) under recharging voltages in excess of about 4.5V."[39] They describe that their electrolytes "are obtained from a composition of about a 0.5M to 2M solution of $LiPF_6$, or $LiPF_6$ to which up to about an equal amount of $LiPF_6$ has been added, dissolved in a mixture of dimethylcarbonate (DMC) and ethylene carbonate (EC) wherein these solvent components are present in the weight percent ratio range from about 95 DMC:5 EC

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[36] Abe at [0095]; [0097]; [0104]; [0110]; [0119].

[37] Ex. 1008, Abstract.

[38] Ex. 1008, 3:9-11.

[39] Ex. 1008, 6:30-33.

to 33 DMC:67 EC. A preferred ratio of these solvents is from about 80 DMC:20 EC to 20 DMC:80 EC."[40]

77. Guyomard assembled test cells with $Li_{1+x}Mn_2O_4$ as the positive electrode.[41] The test cells also had electrolyte of 1 M $LiPF_6$ in 95 DMC:5 EC and "carbon (graphite or petroleum coke)" as the negative electrode.[42] The charge and discharge of these test cells were performed "at about 25°C and 55°C and at charging cut-off voltages of 4.9V and 4.5V, respectively."[43] Guyomard reports that "there was no significant loss of cell capacity, verifying the high voltage stability of the electrolyte. The ability of the electrolyte to extend the cycle life of the batteries was amply demonstrated by the remarkable fact that the cell capacities after 500 cycles was only about 10% less than after 5 cycles."[44]

78. I note that Guyomard reports the capacity loss compared to the fifth cycle, and does not report any data of the capacity of the first cycle, or any capacity loss data between the first cycle and the fifth cycle, as such data would be needed to

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[40] Ex. 1008, 4:30-5:1.

[41] Ex. 1008, 8:23-26.

[42] Ex. 1008, 8:32-37.

[43] *Id*.

[44] *Id*., 9:3-8.

assess the overall capacity loss of the battery under such charging and discharging conditions. Guyomard also does not disclose any detail about the performance or state of the cathode under such testing conditions. Indeed, Guyomard only discloses the "charging cut-off voltages" but does not specify the details of the charging and discharging conditions, such as the current.

4. Iwaizono (Ex. 1007)

79. Iwaizono (U.S. Patent No. 6,577,105) is titled "Circuit and device for protecting secondary battery" and describes a "protective circuit for protecting a rechargeable battery from battery breakdown caused by prolonged overcharging."[45] Iwaizono notes that "[l]ithium-based rechargeable batteries are particularly susceptible to deterioration or damage when operated at a voltage exceeding a predetermined range. It is therefore the normal practice to provide a battery protection device for protecting the battery from improper use."[46] Just like Abe, Iwaizono limits the charge voltage to at most 4.2V.[47]

F. Level of Ordinary Skill

80. The Petition and Petitioner's expert propose:

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[45] Ex. 1007, Abstract.

[46] Ex. 1007, 1:13-18.

[47] *Id.*, 15:34-40.

> The [POSA] would have had a Master's degree in material science, chemical engineering, chemistry, or similar field with four years experience designing testing, and building secondary lithium batteries. In the context of lithium-based batteries, a PHOSITA would have been aware of (1) positive electrode materials, (2) negative electrode materials, (3) separators, (4) electrolytes, (5) charge-discharge parameters, and (6) protection circuits, as well as "battery failure modes" such as plating and the formation of dendrites. More experience can substitute for less education and vice-versa.

Petition at 11–12; *see also* Ex. 1002, ¶51. I do not dispute Petitioner's level of ordinary skill for purposes of this declaration.

81. My level of qualifications as described in Section II exceeds the level of ordinary skill proposed by Petitioner.

VI. CLAIM CONSTRUCTION

82. I understand that Mr. Juzkow did not render any opinions on claim construction.[48] Instead, he "was asked to apply certain claim constructions" that RJ Technology proposed in the Apple litigation.[49] I was retained by RJ Technology in the Apple litigation as an expert to opine on the understanding of a POSITA and the appropriate constructions for certain terms, including the ones I will explain below.

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[48] Ex. 1002, ¶76.

[49] *Id*.

A. "charge cut-off voltage"

83. In the Apple litigation, I proposed that the term should be construed based on its plain and ordinary meaning, which is "the maximum voltage to which the battery is configured to be charged." I understand that the district court in the Apple litigation adopted my proposed construction. I further understand that Petitioner adopts this construction in its own district court litigation.

84. As I will explain below, a POSITA would understand that the voltage to which a battery is configured to be charged is the potential difference between a battery's two electrodes (cathode and anode) after charging is complete, which is different from the external voltage applied to a battery during charging. The post-charging voltage to which a battery is charged is also referred to as the equilibrium potential; and the maximum of that voltage to which a battery is configured to be charged is known as the maximum equilibrium potential.

85. Further, a POSITA would also understand that in the context of the '641 Patent, the term "charge cut-off voltage" refers to the full-cell voltage, i.e., the voltage difference between the cathode and anode, instead of the half-cell voltage, i.e., the difference in potential between an electrode and a reference electrode such as lithium metal.

86. When a battery is being charged, there are two distinct voltages (potentials), the applied voltage and the battery voltage, and their relationship can be expressed by the following equation:

$$V_{\text{applied}} = U + |\eta_{\text{ohmic}}| + |\eta_{\text{neg}}| + |\eta_{\text{pos}}| + |\eta_{\text{con}}|$$

V_{applied} is the applied voltage and U is the battery voltage in equilibrium. The other factors noted in the equation are polarization factors. The battery voltage in equilibrium is also called the equilibrium potential, which is defined as the voltage of the battery when it is in equilibrium, i.e., no current is flowing between the electrodes and there is no net change in electrons.

87. The battery voltage depends, among other things, on the materials of the electrodes and their chemical composition, e.g., the amount of lithium held in the electrodes. During charging, the battery voltage changes as lithium ions are extracted from the cathode and inserted into the anode. The battery voltage thus is a measure of the chemical potential of lithium in each electrode, as well as the internal chemical state of the battery, and changes with the state of charge ("SOC").[50]

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[50] The state of charge is a measure of the current amount of electrical charge a battery holds compared to its maximum capacity. A state of charge of 80% means that the battery has 80% of its full capacity.

88. The applied voltage, which is different than the battery voltage, is always greater than the battery voltage during charging. That is because to drive the charging process to force lithium ions to move from the cathode to the anode, an *external* voltage higher than the battery voltage is required. Accordingly, the applied voltage is a measure of external voltage applied to the battery during charging (e.g., by a charging device).

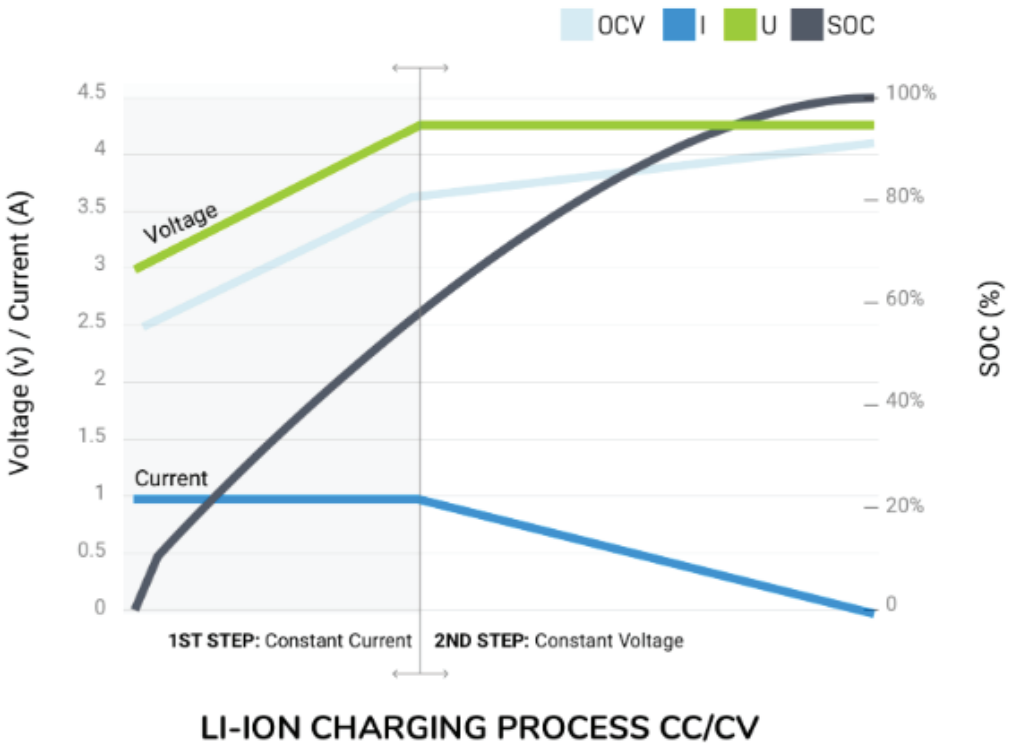
89. The extra charge above the battery voltage (frequently called overpotential) is needed to overcome various resistive forces within the battery, including ohmic resistance (resistance from the electrolyte, separator, and internal components), charge transfer resistance (resistance at the interface of the electrode and electrolyte), and mass-transfer limitations (delays in the movement of ions within the electrode or across the electrolyte). These are reflected in some of the polarization factors laid out in the equation above.

90. The charging current has a major effect on the applied voltage and the difference between the applied voltage and the battery voltage. This is because based on Ohm's Law, as the current increases, more voltage is required to overcome the various internal resistances. In contrast, the battery voltage (i.e., the equilibrium potential) is independent of the current, as the current is assumed to be zero for battery voltage.

91. Constant current/constant voltage charging ("CC/CV") has been a typical method used to charge a battery to its full capacity known to POSITAs from before the time of the invention until present. Below is a figure showing how the current, applied voltage, and the open circuit voltage ("OCV") of the battery changes as the charging progresses using constant current/constant voltage charging.[51] The OCV is the voltage across the two electrodes of a battery if the battery is not connected to any external charging source, so there is no current flowing. OCV is thus a practical measurement of the battery's voltage when no current is being drawn. Under CC/CV charging, the battery is first charged with a constant current. Once the applied voltage reaches the maximum allowed voltage, the applied voltage is kept constant and the rate of the charging current decreases gradually. The constant current stage allows the battery to be charged quickly and efficiently, and the constant voltage stage prevents the battery from being overcharged. In addition, the constant voltage phase continues to charge the battery so the battery will have a

[51] Ex. 20013, SAFT, *Charging your lithium-ion batteries: 5 expert tips for a longer lifespan* (https://www.saft.com/energizing-iot/charging-your-lithium-ion-batteries-5-expert-tips-longer-lifespan#:~:text=When%20the%20battery%20provides%20current,This%20restores%20the%20battery's%20capacity) (last accessed May 7, 2024).

higher battery voltage, which means more capacity. As the current decreases slowly, the OCV (the light blue line) increases and gradually approaches the level of the applied voltage (the green line). When the current is close to zero, there is almost no difference between the applied voltage and the OCV. The battery is considered fully charged then.



92. Charge cutoff voltage is the maximum voltage ***to*** which the battery is configured to be charged. It thus is a battery property. In contrast, the applied voltage is supplied by an external charger, variable, and dependent upon factors external to the battery, such as what current is being applied to the battery. A POSITA would understand that the applied voltage may temporarily exceed the

charge cutoff voltage during charging (indeed technically the applied voltage can be set to any level by external equipment), but this does not mean that the battery is configured for (i.e., designed and manufactured) for that higher voltage. A POSITA would understand that if the battery is designed and manufactured for that maximum voltage, charging the battery to a voltage that exceeds the charge cut-off voltage may cause structural damages or hazardous operating conditions.

93. In addition, during the Apple litigation, I understand that Apple and RJ Technology agreed that the "charge cut-off voltage" as claimed by the '641 Patent refers to the full cell voltage.[52] I understand that the court in the Apple litigation adopted this construction.

94. The difference between half-cell voltage and full-cell voltage was well-known in the art at the priority date. The half-cell voltage is the electrical potential of an electrode relative to a reference electrode (e.g., lithium). Since the potential of a single electrode cannot be measured just by itself (two electrodes are needed to complete a circuit), a POSITA measures the potential against a known reference such as lithium metal.

95. For example, Abe discusses why a half-cell is used. By building a battery with $LiCoO_2$, $LiNiO_2$, or $LiMn_2O_4$ as the cathode active material and lithium

[52] Ex. 2012 at 12.

metal as the counter electrode and the reference electrode, the charging capacity of the cathode can be determined under controlled experimental conditions.[53] Using the same process, the charging capacity of the anode material can be determined.[54] Testing an electrode material in a half-cell setup allows researchers to isolate the properties of that material without interference from the counter electrode's characteristics. It thus provides a more controlled and straightforward method to measure the specific capacity of an electrode material.

96. However, because the half-cell reaction takes place in a controlled environment and is against a reference electrode such as lithium metal, it necessarily means that the compatibility of the cathode and anode materials are not tested. In a full cell, the cathode must be paired with a specific anode material, and the interaction between these two materials can significantly influence overall performance. Moreover, the full cell voltage is the potential difference between the cathode and the anode of the battery, when they are connected in a complete circuit. Because each electrode has its own potential against the lithium metal reference electrode, it also means that the half-cell voltage of an electrode does not equate the full cell voltage of a secondary lithium-ion battery.

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[53] Ex. 1005 (Abe) at [0078].

[54] *Id*.

97. A POSITA would understand that the ’641 Patent uses “charge cutoff voltage” in reference to the full-cell voltage. The claims refer to the charge cut-off voltage of a secondary lithium-ion battery, and the specification explains that “as to lithium cobalt oxide[] that is used as positive electrode material in [] most commercial lithium ion batteries, the charge cut-off voltage is limited to below 4.2V … although many documents indicate that the charge cut-off voltage can be over 4.2V for a test cell using metallic lithium as counter electrode.”[55] The ’641 Patent thus makes clear that its innovation is directed to the full cell voltage, i.e., increasing the full-cell voltage to be higher than 4.2V, instead of the half-cell voltage, which did have voltages higher than 4.2V in the prior art.

B. “a ratio of positive electrode material to negative electrode material of the secondary lithium ion cell or battery … as calculated by a theoretic capacity with a charge cut-off voltage set at 4.2V” (claim 5) / “a ratio of positive electrode material to negative electrode material of the secondary lithium ion cell or battery … as calculated by a specific capacity with a charge voltage limited to 4.2V” (claim 1)

98. In the Apple litigation, I construed this term to mean “the ratio calculated as the product of the capacity of the cathode active material per mass unit and the amount of the cathode active material in the same mass unit divided by the product of the capacity of the anode active material per mass unit and the amount of

[55] Ex. 1001, 1:64-2:3.

the anode active material in the same mass unit, when the charge cutoff voltage is 4.2V."[56] I understand that the district court in the Apple litigation adopted my construction.

99. Further, as I stated in my declaration submitted in the Apple litigation, when calculating the claimed ratio, "a POSITA would understand that the theoretical capacity at 4.2V should be used for the calculation, instead of the theoretical maximum capacity."[57] In particular, I noted that the theoretical capacity of the cathode active material at a particular voltage is distinct from its practical specific capacity at that voltage.[58] When a battery is being charged and discharged, it can experience detrimental "side reactions," which are unintended and do not contribute to the energy storage of the battery. The practical specific capacity is an experimentally determined value that takes these side reactions into account, while the theoretical value does not.

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[56] Ex. 2022, ¶37.

[57] Ex. 2022, ¶56; *see also id.*, ¶45 ("A POSITA would understand this as the theoretical capacity of the material at the stated voltage").

[58] Ex. 2022, ¶50 ("Such specific capacity is also closer to the actually usable capacity, so it acts as a good reference point to determine how to balance the capacities of cathode and anode in a battery").

100. Accordingly, as my proposed construction makes clear, when calculating the claimed ratio, the theoretical capacity at 4.2V should be used. Further, it is the theoretical capacity of the *active* material that matters. A POSITA would understand that active material of an electrode is the material that participates in the intercalation and deintercalation of the lithium ions.[59]

101. As a threshold matter, I will discuss the different kinds of capacities that are relevant here. An electrode's capacity can be normalized over a unit measure, such as the mass of the electrode's active material, e.g., milliampere hours per gram. This is called specific capacity and it describes how much capacity can be stored per gram weight of the active material.

102. Active material of an electrode refers to the substances within the anode or cathode that participate directly in the electrochemical reactions during charging and discharging. It is the material that allows for the reversible storage and release of lithium ions and contributes positively to the battery's capacity and cycling. For example, the active material in the cathode typically includes compounds like lithium cobalt oxide, while the active material used in anodes includes graphite (a form of carbon).

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[59] *See* Ex. 1001, 8:50-55.

103. When fabricating an electrode, binder and conducting agent are typically added, but they are considered as inactive materials because they do not participate in the intercalation and de-intercalation of lithium ions during charging and discharging.

104. Turning back to capacities, relevant to this case, there are three distinct types of specific capacity for an electrode:

- **Theoretical maximum capacity**: the maximum specific capacity of an electrode active material when all lithium ions are extracted from the electrode material. This value is only dependent on the chemistry of the electrode and does not vary based on voltage.
- **Theoretical capacity at 4.2V**: the theoretical specific capacity of an electrode when the voltage is 4.2V and thus only a portion of the lithium ions are extracted. It is the theoretical maximum capacity multiplied by an extraction coefficient x, which depends on the voltage. It is the maximum specific capacity that could be obtained at 4.2V. In this case, the voltage is 4.2V—at the time of the invention seen as the conventionally accepted maximum cutoff voltage for lithium-ion batteries.
- **Practical specific capacity**: the specific capacity of an electrode material that is experimentally measured. It depends on the chemistry of the electrode and the experimental conditions.

105. I use a typical commercial lithium-ion battery as an example to illustrate the difference between these measures of capacity. In today's lithium-ion batteries, the cathode active material is usually $LiCoO_2$ and the anode active material is usually graphite (carbon). During charging, at the cathode side, the reaction can be written as:

$$LiCoO_2 \rightarrow xLi^+ + Li_{1-x}CoO_2 + xe^-$$

"x" represents the number of lithium ions extracted from $LiCoO_2$ per formula unit of $LiCoO_2$.

106. The theoretical capacity of a cathode material can be determined based on Faraday's Law of electrolysis using the equation below:

$$C=(x \times F)/M$$

C represents the amount of charge that can be released for the cathode material per unit mass of the active substance and is in Coulombs per gram (C/g); F is the Faraday's constant: about 96,485 Coulombs per mole of electrons, and represents the charge carried by one mole of electrons; and M is the molecular weight of the active substance (g/mol).

107. To convert this amount of charge C to the more commonly used unit of ampere-hours per gram (mAh/g), this result is divided by 3.6 since 1 mAh = 3.6 C.

108. When all of the lithium in the active material is extracted from the cathode active material, x=1, the capacity of $LiCoO_2$, using the equation above, is thus 274 mAh/g. This is called the theoretical maximum capacity of $LiCoO_2$.

109. Applying the same equation to $LiCoO_2$ at 4.2V, it is well-known that half of the lithium ions of that material is extracted from the cathode, x=0.5, and so the theoretical capacity at 4.2V for $LiCoO_2$ is 137 mAh/g.

110. In the '641 Patent, claim 5 explicitly states that when calculating the claimed ratio, "theoretic capacity with a charge cut-off voltage set at 4.2V" should be used.[60] A POSITA thus would understand that it is the theoretical capacity at 4.2V that should be used, instead of the theoretical maximum capacity.

111. Such a construction is also consistent with the literature. In the field, the term "theoretical capacity" sometimes is referred to as the theoretical maximum capacity, and sometimes it is referred to as the theoretical capacity at a particular voltage. A POSITA would be able to understand what the term means based on the context.

112. For example, S. Ohta et al. reported that "[t]he theoretical electrochemical capacity of LCO is 137 mAh g^{-1}, which corresponds to 0.5 Li per

[60] Ex. 1001, 17:10-11.

$LiCoO_2$."[61] In other words, the authors there did not identify the theoretical capacity of $LiCoO_2$ as the theoretical maximum specific capacity (274 mAh/g). Instead, they identified the capacity at 4.2V as the theoretical capacity. In fact, consistent with the general practice in the industry, numerous articles refer to "theoretical capacity" to mean the capacity at a particular voltage.[62]

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[61] *See* Ex. 2025, S. Ohta et al., *Electrochemical performance of an all-solid-state lithium ion battery with garnet-type oxide electrolyte*, Journal of Power Sources 202 (2012) 332-335.

[62] *See, e.g.*, Ex. 2026, Eiji Hosono et al., *Synthesis of single crystalline electro-conductive Na0.44MnO2 nanowires with high aspect ratio for the fast charge-discharge Li ion battery*, Journal of Power Sources 182 (2008) 349-352 at 350 (identifying 137 mAh/g as the "theoretical capacity" for $LiCoO_2$); Ex. 2027, Kaoru Dokko et al., *Solvate Ionic Liquid Electrolyte for Li-S Batteries*, Journal of the Electrochemical Society, 160 (8) A1304-A1310 (2013) at A1304 ("The cathode materials currently in use consist of transition metal compounds such as $LiCoO_2$ and $LiFePO_4$, which have ***theoretical capacities of 137*** and 170 mAh g^{-1}, respectively") (emphasis added); Ex. 2028, Kai Chen et al., *High capacity and cyclic performance in a three-dimensional composite electrode filled with inorganic solid electrolyte,*

(continued…)

113. Further, a POSITA would understand that theoretical capacity at 4.2V is distinct from the practical specific capacity at 4.2V. Again, the plain language of claim 5 refers to the "theoretic capacity," instead of the experimentally determined practical capacity. At the time of the '641 Patent, 4.2V was widely considered as the industry standard, so it was conventional and efficient to use the theoretical capacity at 4.2V to calculate the ratio, instead of the practical capacity. By using a theoretical value, a POSITA would not need to do an actual experiment every time she assembles a battery.

114. Accordingly, when calculating the claimed ratio in the '641 Patent, a POSITA would use the *theoretical* capacity of an electrode's *active* material at 4.2V to determine whether a battery is practicing the claimed capacity ratio ranges.

Journal of Power Sources 249 (2014) 306-310 at 307 ("A rather high specific discharge capacity of 131 mAh g-1 (or a high surface capacity of 5 mAh cm^{-2}) was achieved in a 100-µm-thick composite electrode, which is up to 96% of **the *theoretical capacity of $LiCoO_2$ (137 mAh g^{-1})***)) (emphasis added); Ex. 2029, Zhanpeng Huang et al., High-capacity and stable sodium-sulfur battery enabled by confined electrocatalytic polysulfides full conversion, Adv. Funct. Mater. 2021, 31, 2100666 (identifying 137 mAh g^{-1} as the "theoretical discharge capacity" of $LiCoO_2$).

VII. UEMURA DOES NOT TEACH OR SUGGEST EVERY LIMITATION OF CLAIMS 1-8 OF THE '641 PATENT (GROUNDS 1-2)

115. Petitioner and Mr. Juzkow argue that Uemura discloses every element of claims 1-8 of the '641 Patent. For the reasons I discuss below, I disagree. *First*, Uemura does not disclose the charge cutoff voltage limitation or the claimed ratio limitation. *Second*, Uemura does not enable the claimed invention of the '641 Patent, as a POSITA cannot practice the claimed invention without undue experimentation. Further, Uemura contains errors obvious to a POSITA such that the POSITA would disregard those disclosures.

A. Uemura does not disclose the claimed charge cutoff voltage limitation.

116. Claim 1 and claim 5 of the '641 Patent require the secondary lithium-ion cell or battery to have a charge cutoff voltage higher than 4.2V and lower than 5.8V. Claims 2 and 6 narrow the range to 4.3–5.2V, and claim 3 and claim 7 further narrow the range to 4.3–4.8V.

117. I understand that Mr. Juzkow opines that Uemura discloses a charge cutoff voltage of 4.3V, based on one sentence from Uemura:

> The charge-discharge was repeatedly performed at a constant current of 0.5 mA/cm^2 and a voltage ranging from 4.3V to 2.0V at an atmospheric temperature of 60 °C.[63]

[63] Uemura at [0081].

118. I disagree with Mr. Juzkow's opinion. As I will explain below, Mr. Juzkow misapplies the terms of the '641 Patent, properly construed. Uemura at most discloses an applied voltage of 4.3V, which is the external voltage applied to the battery. As I have discussed above, the applied voltage is always higher than the battery voltage during charging. Mr. Juzkow does not show that when the batteries disclosed in Uemura were purportedly charged according to paragraph 81, those batteries had a battery voltage higher than 4.2V. Indeed, it is reasonable to expect that their battery voltage was lower than 4.2V. Accordingly, it is my opinion that Uemura does not disclose a charge cutoff voltage higher than 4.2V.

119. All Uemura discloses is an applied voltage of 4.3V. Uemura does not disclose what the battery voltage or the open circuit voltage was when the applied voltage reached 4.3V. Instead, because the batteries in Uemura were purportedly only charged with a constant current,[64] and there was no constant voltage phase, the

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[64] Based on the limited information provided by Uemura, I was able to estimate the current rate. Uemura discloses that the cathode had a diameter of 12 mm and the anode had a diameter of 15 mm. Uemura at [0075], [0076]. Because the cathode has a smaller diameter, its diameter should be used to calculate the current. Because the current density was allegedly 0.5 mA/cm^2, the current rate is approximately 0.56

(continued…)

batteries were not fully charged when the applied voltage reached 4.3V. Instead, the charge cutoff voltage as claimed by the '641 Patent, which refers to the battery voltage or the open circuit voltage, must be lower than 4.3V. For this reason, Uemura does not disclose a charge cutoff voltage of 4.3V and cannot anticipate claims 2, 3, 6, or 7, or render them obvious.

120. Further, Uemura does not disclose a charge cutoff voltage higher than 4.2V. The overpotential—the difference between the applied voltage and the equilibrium potential—depends on a multitude of factors. While the current rate is one of the key factors, many other factors come into play, including electrode active material density, its particle size and distribution, conductivity of the electrode, the thickness of the electrode, its surface areas, the composition of the electrolyte, temperature, and electrode porosity. A POSITA, with the limited disclosure of Uemura, would not be able to determine with reasonable certainty the value of the battery voltage when the applied voltage reached 4.3V.

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mA. According to the capacity data reported in Uemura, the charging for each of the examples in Fig. 3 lasted between 3-4 hours. A POSITA would understand that generally this is a relatively medium charging current, but certainly not the kind of slow charging that could charge a battery to its full capacity using only constant current charging.

121. However, based on published data for batteries with similar cathode materials as those used in Uemura, it is reasonably certain that the charge cutoff voltage of the batteries in Uemura were lower than 4.2V when the applied voltage reached 4.3V. For example, as shown below, for a typical rechargeable lithium-ion battery with $LiCoO_2$ as the cathode, when the applied voltage reached 4.2V for the first time under the constant current charging phase, its capacity was only 60%, when the current was 1A.[65] When the constant current was 0.5A, the state of charge when the applied voltage reached 4.2V was around 80%.

K. Ozawa / Solid State Ionics 69 (1994) 212–221 217

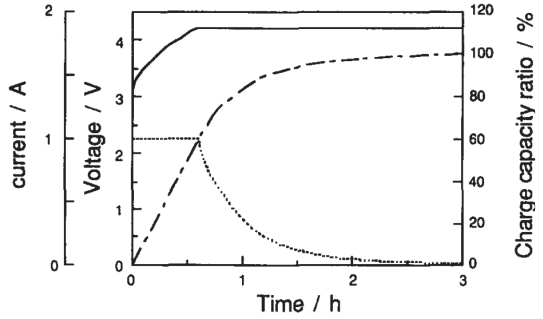

Fig. 9. Typical charge profiles of a lithium ion rechargeable battery. Charge: max. limit 4.2 V, 1 A. (——) voltage; (– – –) charge capacity; (—·—) current. Diameter; 20 mm; height: 50 mm. Electrolyte solution: PC-DEC/Li PF_6.

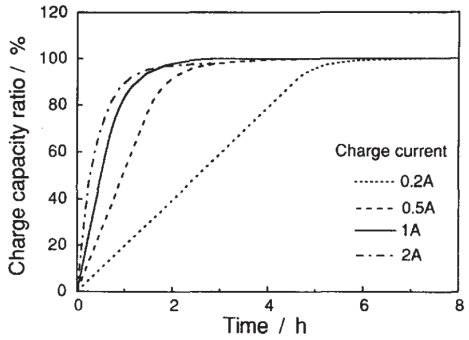

Fig. 10. Charge characteristics of a lithium ion rechargeable battery. Charge: max. limit 4.2 V.

[65] Ex. 2014, Kazunori Ozawa, *Lithium-ion rechargeable batteries with $LiCoO_2$ and carbon electrodes: the $LiCoO_2$/C system*, 69 Solid State Ionics 212 (1994) ("Ozawa 1994") at 217.

122. The state of charge is proportional to the open circuit voltage, the higher the state of charge, the higher the open circuit voltage is for the battery.[66] Based on the figure below, when the state of charge is 80%, the open circuit voltage is just above 4V. Accordingly, a POSITA would understand that Uemura's applied voltage equal to maximum 4.3V corresponds to a battery voltage equal to about 4V and, according to the published literature, in no circumstance greater than 4.2V.

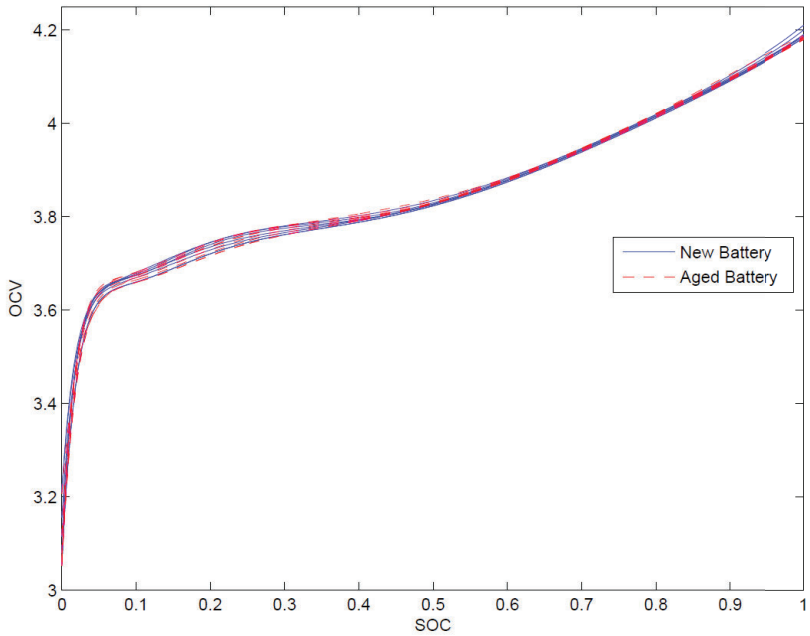

Fig. 11. OCV–SOC characterization curves of new vs. aged batteries. New battery curves are plotted in solid blue and aged battery curves are plotted in dashed red. Different curves of the same type correspond to temperatures ranging from −25 °C to 50 °C. The new and aged battery OCV curves overlap. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

[66] *See* Ex. 2015, B. Pattipati et al., *Open circuit voltage characterization of lithium-ion batteries*, 269 J. Power Sources 317 (2014) ("Pattipati 2014") at 326, Fig. 11.

123. As discussed below, Dr. Yanliang Liang tried to reproduce the alleged experimental results in Uemura. Even with the successful synthesis of Co-doped layered $LiMnO_2$, when a cell with $Li_{0.8}Mn_{0.5}Co_{0.5}O_2$ as the cathode active material (similar to the cathode active material in Example 2 of Uemura) and hard carbon as the anode active material was charged with a current density of 0.14 mA/cm^2 (an even lower current than what was allegedly used in Uemura), before the applied voltage even reached 4V, the cell had already started to degrade.[67] The results suggest that the disclosed battery in Uemura cannot be safely charged to 4.2V without causing severe damages to the battery. Accordingly, Uemura does not disclose a charge cutoff voltage higher than 4.2V and does not anticipate any claim of the '641 Patent, or render them obvious.

B. Uemura Does not Disclose the Claimed Ratio Limitation.

124. Claim 5 of the '641 Patent requires the lithium-ion battery to have "a ratio of positive electrode material to negative electrode material" between 1:1.0 and 1:2.5, "as calculated by a theoretic capacity with a charge cut-off voltage set at 4.2V." Claim 8 narrows the range of the claimed ratio to 1:1.15 to 1:2.5.

125. I understand that Mr. Juzkow's opinion is that Uemura describes this ratio range. Ex. 1002, ¶114. Mr. Juzkow relies on two portions of Uemura to support

[67] Liang Decl., ¶35.

his opinion. First, Mr. Juzkow relies upon Fig. 3 of Uemura, as copied below.[68] Mr. Juzkow claims that the "Capacity balance Pc:Nc" of Fig. 3 discloses the claimed ratio.[69]

FIG.3

	Positive electrode material						Negative electrode material			Capacity balance Pc:Nc	Ic/Pc ×100(%)	Number of cycles
	Used transition metal material	Composition of positive electrode material	X	Y	Weight (mg)	Total capacity : Pc (mAh)	Weight (mg)	Total capacity : Nc (mAh)	Total irreversible capacity : Ic			
Example 1	Cobalt(Ⅱ) nitrate	$Li_{0.67}Mn_{0.5}Co_{0.5}O_{2-\delta}$	0.033	0.5	15	1.8	6.2	2.36	0.002	(1:1.3)	0.1	300
Example 2	Cobalt(Ⅱ) nitrate	$Li_{0.83}Mn_{0.5}Co_{0.5}O_{2-\delta}$	0.17	0.5	15	2.24	6.2	3.41	0.44	(1:1.5)	20.0	330
Example 3	Cobalt(Ⅱ) nitrate	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	0.033	0.5	15	2.6	6.2	3.27	1.18	(1:1.3)	45.0	310
Example 4	Cobalt(Ⅱ) nitrate	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	0.033	0.5	15	2.6	4.9	2.6	0.94	(1:1)	36.0	350
Example 5	Cobalt(Ⅱ) nitrate	$Li_{0.75}Mn_{0.75}Co_{0.25}O_{2-\delta}$	0.25	0.25	15	2	6.2	2.36	0.002	(1:1.3)	0.1	330
Example 6	Nickel(Ⅱ) nitrate	$Li_{0.83}Mn_{0.75}Ni_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	325
Example 7	Iron(Ⅲ) nitrate	$Li_{0.83}Mn_{0.67}Fe_{0.33}O_{2-\delta}$	0.17	0.33	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	245
Example 8	Aluminium(Ⅲ) nitrate	$Li_{0.83}Mn_{0.75}Al_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	310
Example 9	Chromium(Ⅲ) nitrate	$Li_{0.83}Mn_{0.75}Cr_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	350
Example 10	Gallium(Ⅲ) nitrate	$Li_{0.83}Mn_{0.75}Ga_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	120
Example 11	Indium(Ⅲ) hydroxide	$Li_{0.83}Mn_{0.75}In_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	110
Example 12	Zirconium(Ⅳ) hydroxide	$Li_{0.83}Mn_{0.75}Zr_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	95
Example 13	Vanadium(Ⅲ) oxide	$Li_{0.83}Mn_{0.75}V_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	130
Example 14	Iron(Ⅲ) oxide	$Li_{0.75}Mn_{0.875}Fe_{0.125}O_{2-\delta}$	0.25	0.125	15	2	6.2	2.36	0.002	(1:1.3)	0.1	220
Example 15	Niobium(Ⅱ) oxide	$Li_{0.83}Mn_{0.75}Nb_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	190
Example 16	Tantalum(Ⅴ) oxide	$Li_{0.83}Mn_{0.75}Ta_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	180
Example 17	Titanium(Ⅳ) oxide	$Li_{0.83}Mn_{0.75}Ti_{0.25}O_{2-\delta}$	0.17	0.25	15	2.24	6.2	2.36	0.002	(1:1.3)	0.1	250
Comparative example		$LiMnO_{2-\delta}$	0	0	15	2.7	10	–	–	(1:1.3)	–	10

126. Second, Mr. Juzkow relies on paragraph 33 of Uemura, which provides "a capacity balance ratio B/A of the total capacity B of the negative electrode

[68] Ex. 1002, ¶115; Uemura, FIG. 3.

[69] *Id.*

material to the total capacity A of the positive electrode material is preferably fixed at a range of 1 to 1.5."[70]

127. As an initial matter, paragraph 33 of Uemura is clearly based on its Fig. 3. Fig. 3 purportedly discloses seventeen examples and one comparative example. Each of the examples purports to have a "capacity balance" of 1:1, 1:1.3, or 1:1.5, which is consistent with and falls within the range disclosed in paragraph 33 of Uemura—1 to 1.5. I therefore consider the two aspects of Uemura one and the same.

128. In addition, as Mr. Juzkow correctly points out, Fig. 3 of Uemura includes obvious errors. Indeed, Fig. 3 lists the wrong "capacity balance Pc:Nc" for fourteen out of the seventeen examples. For instance, Examples 6–13 and 15–17 all have the same cathode "total capacity" and same anode "total capacity."[71] Uemura reports that each of these examples has a cathode "total capacity" (labeled as Pc) of 2.24 mAh.[72] Uemura also reports that each of these examples has an anode "total

[70] Ex. 1002, ¶115; Uemura at [0033].

[71] Uemura, Fig. 3.

[72] *Id*.

capacity" (labeled as Nc) of 2.36 mAh.[73] The "capacity balance Pc:Nc" for each of these examples should be 1:1.05, not 1:1.3 as Uemura reports:[74]

$$\frac{2.24}{2.36} = \frac{1}{1.05}$$

129. Similarly, Examples 2 and 14 each have a cathode total capacity of 2 mAh and an anode total capacity of 2.36 mAh. Their "capacity balance Pc:Nc" should be 1:1.18, instead of 1:1.3 as Uemura reports.[75]

$$\frac{2}{2.36} = \frac{1}{1.18}$$

130. As I will discuss in more detail below, I disagree with Mr. Juzkow's opinion. When forming his opinion, Mr. Juzkow applies the construction of the ratio limitation in the wrong way. The "capacity balance" disclosed in Uemura is not the same as the claimed ratio in the '641 Patent. On the cathode side, Uemura uses the "total capacity" of the cathode material to calculate the "capacity balance,"[76] which was allegedly experimentally determined.[77] In contrast, the '641 Patent's claimed

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[73] *Id*.

[74] *See* Ex. 1002, n.107.

[75] Uemura, Fig. 3.

[76] Uemura at [0033].

[77] Uemura at [0081], [0102]; *see also* Ex. 1002, n.107.

ratio is calculated based on the *theoretical* capacity of the cathode active material when the charge cutoff voltage is 4.2V. As I discussed above, theoretical capacity of a cathode material at 4.2V is the maximum capacity that could be obtained at 4.2V.

131. On the anode side, Uemura uses the "total capacity" of the anode material to calculate the "capacity balance," which includes the capacity of the non-carbon inactive material.[78] In contrast, the '641 Patent's claimed ratio uses the theoretical capacity of the anode *active* material. Accordingly, as shown below, after converting the "capacity balance" in Uemura to the claimed ratio in the '641 Patent, all seventeen examples of Uemura have claimed ratios falling outside the claimed range in the '641 Patent.

1. Uemura uses the "total capacity" of the cathode active material instead of the theoretical capacity at 4.2V, as the '641 Patent requires.

132. The "total capacity" reported in Fig. 3 of Uemura is allegedly experimentally determined. Uemura claims that the charge and discharge of all seventeen examples and the comparative example was "repeatedly performed at a constant current of 0.5 mA/cm^2 and a voltage ranging from 4.3 V to 2.0 V at an

[78] Uemura at [0033].

atmospheric temperature of 60°C."[79] Uemura then reports the purported experimental results at Fig. 3.[80]

133. For the comparative example, Uemura reports that it has a "total capacity" of 2.7 mAh when its weight is 15 mg.[81] The specific capacity of the comparative example thus is 180 mAh/g:

$$\frac{2.7\ \text{mAh}}{0.015\ \text{g}} = 180\ \text{mAh/g}$$

134. However, this is not the value representing the theoretical capacity of layered $LiMnO_2$ at 4.2V. One common way of identifying the theoretical capacity of an electrode material is through slow charging.[82] As Armstrong 1996 shows, when the charging rate is as low as 10 $\mu A/cm^2$, the specific capacity of layered

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[79] Uemura at [0081].

[80] Uemura at [0081] ("A result thereof is shown in Table 1 together with other values"); [102]; *see also* Ex. 1002 (Juzkow Dec.), n.107.

[81] Uemura, Fig. 3.

[82] *See, e.g.*, Ex. 2020, Ramadass Premanand et al., *Studies on Capacity Fade of Spinel-Based Li-Ion Batteries*, J. Electrochem. Soc 149 A54 (2002) ("Ramadass 2002"); Ex. 2037, T.D. Tran et al., *Rate effect on lithium-ion graphite electrode performance*, J. Applied Electrochem. 26 (1996) 1161-67 ("Tran 1996").

$LiMnO_2$ reached 270 mAh/g even before the voltage reached 4.2V.[83] Because the '641 Patent requires the use of theoretical capacity at 4.2V for calculating the claimed ratio, 270 mAh/g is more appropriate to use than Uemura's 180 mAh/g.[84]

135. Turning to the seventeen examples in Fig. 3 of Uemura, each of them was purportedly prepared based on the comparative example (layered $LiMnO_2$) and has a layered structure.[85] The cathode in all seventeen examples has the same weight (15 mg), but each of them has a different chemical composition (other than Examples 3 and 4, which share the same chemical composition). I calculated the specific capacity of each of the examples based on their weight and "total capacity," which is shown in the "Uemura specific capacity (mAh/g)" column.

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[83] Ex. 2009 (Armstrong 1996) at 500.

[84] I note that based on Fig. 2 of Armstrong 1996, the theoretical capacity of layered $LiMnO_2$ at 4.2V likely exceeds 270 mAh/g, as the battery already achieved a specific capacity of 270 mAh/g at approximately 4.1V. Because the claimed ratios of all examples in Uemura are already below 1, meaning more cathode theoretical capacity at 4.2V than anode theoretical capacity, using a specific capacity higher than 270 mAh/g for the cathode would further reduce the ratios, deviating more from the claimed range.

[85] Uemura at [0035].

Example	Composition of positive electrode material	Weight (mg) as reported in Uemura	Pc: total capacity of cathode (mAh) as reported in Uemura	Specific capacity (mAh/g) calculated based on Uemura's reported data
1	$Li_{0.67}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	1.8	120
2	$Li_{0.83}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.24	149
3	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.6	173
4	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.6	173
5	$Li_{0.75}Mn_{0.75}Co_{0.25}O_{2-\delta}$	15	2	133
6	$Li_{0.83}Mn0_{.75}Ni_{0.25}O_{2-\delta}$	15	2.24	149
7	$Li_{0.83}Mn_{0.67}Fe_{0.33}O_{2-\delta}$	15	2.24	149
8	$Li_{0.83}Mn_{0.75}Al_{0.25}O_{2-\delta}$	15	2.24	149
9	$Li_{0.83}Mn_{0.75}Cr_{0.25}O_{2-\delta}$	15	2.24	149
10	$Li_{0.83}Mn_{0.75}Ga_{0.25}O_{2-\delta}$	15	2.24	149
11	$Li_{0.83}Mn_{0.75}In_{0.25}O_{2-\delta}$	15	2.24	149
12	$Li_{0.83}Mn_{0.75}Zr_{0.25}O_{2-\delta}$	15	2.24	149
13	$Li_{0.83}Mn_{0.75}V_{0.25}O_{2-\delta}$	15	2.24	149
14	$Li_{0.75}Mn_{0.875}Fe_{0.125}O_{2-\delta}$	15	2	133
15	$Li_{0.83}Mn_{0.75}Nb_{0.25}O_{2-\delta}$	15	2.24	149
16	$Li_{0.83}Mn_{0.75}Ta_{0.25}O_{2-\delta}$	15	2.24	149
17	$Li_{0.83}Mn_{0.75}Ti_{0.25}O_{2-\delta}$	15	2.24	149

Comparative Example	$LiMnO_{2-\delta}$	15	2.7	180

136. Following Uemura's approach in ascertaining the specific capacity of each of the seventeen examples,[86] I calculated the theoretical capacity at 4.2V of these cathode materials based on the equation below:

$$\text{Theoretical specific capacity at 4.2V} = 270\frac{\text{mAh}}{\text{g}} \times \text{lithium amount}$$

137. Based on the equation, the theoretical specific capacity at 4.2V for each of the examples is listed at the table below at column "Theoretical capacity at 4.2 V (mAh/g)":

[86] As I discuss in Section VII.C., it would be apparent to a POSITA that these data were not genuine experimental data because they do not have any degree of error, which is impossible in the field of electrochemistry. They are also inconsistent with what is reported in the literature. Instead, Uemura *calculates* the specific capacity of each of the seventeen examples based on the (wrong) assumption that as long as the cathode active material has the chemical formula of $LiMn_xM_yO_2$ ($x + y = 1$), even though M (i.e., the doping element) could be entirely different and x, y can also vary, when charged and discharged under the same conditions, all these countless variations of materials would have the same specific capacity as the layered $LiMnO_2$: 180 mAh/g. As I discuss below, such assumption is wrong.

Example	Composition of positive electrode material	Specific capacity (mAh/g) calculated based on Uemura's reported data	Theoretical capacity at 4.2 V (mAh/g)
1	$Li_{0.67}Mn_{0.5}Co_{0.5}O_{2-\delta}$	120	180.9
2	$Li_{0.83}Mn_{0.5}Co_{0.5}O_{2-\delta}$	149	224.1
3	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	173	261.1
4	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	173	261.1
5	$Li_{0.75}Mn_{0.75}Co_{0.25}O_{2-\delta}$	133	202.5
6	$Li_{0.83}Mn0_{.75}Ni_{0.25}O_{2-\delta}$	149	224.1
7	$Li_{0.83}Mn_{0.67}Fe_{0.33}O_{2-\delta}$	149	224.1
8	$Li_{0.83}Mn_{0.75}Al_{0.25}O_{2-\delta}$	149	224.1
9	$Li_{0.83}Mn_{0.75}Cr_{0.25}O_{2-\delta}$	149	224.1
10	$Li_{0.83}Mn_{0.75}Ga_{0.25}O_{2-\delta}$	149	224.1
11	$Li_{0.83}Mn_{0.75}In_{0.25}O_{2-\delta}$	149	224.1
12	$Li_{0.83}Mn_{0.75}Zr_{0.25}O_{2-\delta}$	149	224.1
13	$Li_{0.83}Mn_{0.75}V_{0.25}O_{2-\delta}$	149	224.1
14	$Li_{0.75}Mn_{0.875}Fe_{0.125}O_{2-\delta}$	133	202.5
15	$Li_{0.83}Mn_{0.75}Nb_{0.25}O_{2-\delta}$	149	224.1
16	$Li_{0.83}Mn_{0.75}Ta_{0.25}O_{2-\delta}$	149	224.1
17	$Li_{0.83}Mn_{0.75}Ti_{0.25}O_{2-\delta}$	149	224.1
Comparative Example	$LiMnO_{2-\delta}$	180	270

138. Because each of the examples has the same weight, their theoretical capacity can be calculated by multiplying their theoretical capacity per unit of mass (mAh/g) with their weight. I summarize the results below:

Example	Pc: total capacity of cathode (mAh) as reported in Uemura	Theoretical Capacity at 4.2V (mAh)
1	1.8	2.71
2	2.24	3.36
3	2.6	3.92
4	2.6	3.92
5	2	3.04
6	2.24	3.36
7	2.24	3.36
8	2.24	3.36
9	2.24	3.36
10	2.24	3.36
11	2.24	3.36
12	2.24	3.36
13	2.24	3.36
14	2	3.04
15	2.24	3.36
16	2.24	3.36

Example	Pc: total capacity of cathode (mAh) as reported in Uemura	Theoretical Capacity at 4.2V (mAh)
17	2.24	3.36
Comparative Example	2.7	

2. Contrary to the '641 Patent, Uemura calculates its "capacity balance" using an anode capacity that includes inactive materials.

139. The construction I proposed in the Apple litigation, which I understand is adopted by Petitioner for purposes of this IPR, makes clear that the claimed ratio must be calculated using the theoretical capacity of the anode ***active*** material when the charge cutoff voltage is 4.2V. I understand that in the Samsung litigation, Samsung also agrees that for purposes of calculating the claimed ratio, it is the capacity of the ***active*** material that should be used.

140. The "total capacity" of the anode reported in Fig. 3 of Uemura does not reflect the total capacity of the anode *active* material, because it includes capacity attributable to the non-carbon content of the anode. For example, Example 2 has 95.5% carbon content and Example 3 has only 83.5% carbon content. According to Uemura, the irreversible capacity of the anode material is directly proportional to the non-carbon content: the more impure the anode material is, the more irreversible

capacity the anode material has.[87] In other words, according to Uemura, the sole purpose of the alleged non-carbon content was to create irreversible capacity, but the non-carbon content does not participate in the reversible intercalation and de-intercalation of lithium ions in subsequent charging and discharging cycles. A POSITA would thus understand that the non-carbon content of the anode is inactive material because it does not contribute to the battery's cyclable capacity or net output.

141. Accordingly, because the claimed ratio of the '641 Patent should be calculated with the capacity of the active material, when calculating the claimed ratio, the irreversible capacity should be excluded. The yellow highlighted column includes the number that should be used to calculate the claimed ratio:

Examples	Total Anode Capacity (mAh) as reported in Uemura	Total irreversible capacity of the anode (mAh) as reported in Uemura	Total reversible capacity of the anode (mAh) based on data reported in Uemura
2	3.41	0.44	2.97
3	3.27	1.18	2.09
4	2.6	0.94	1.66

142. As shown in the table below, if the correct capacities are used to calculate the claimed ratio of the '641 Patent, all of the Examples have ratios falling

[87] Uemura at [0030]-[0031], [0022]

outside the claimed range, as shown in the yellow highlighted column. In other words, all of them have more cathode theoretical capacity at 4.2V than anode theoretical capacity.

Example	Theoretical capacity of the cathode at 4.2V (mAh)	Total capacity of the anode *active* material (mAh) based on data reported in Uemura	Capacity Balance Nc/Pc reported in Uemura	Claimed ratio of the '641 patent
1	2.71	2.358	1.3	0.87
2	3.36	2.97	1.5	0.88
3	3.92	2.09	1.3	0.53
4	3.92	1.66	1.0	0.42
5	3.04	2.358	1.2	0.78
6	3.36	2.358	1.1	0.70
7	3.36	2.358	1.1	0.70
8	3.36	2.358	1.1	0.70
9	3.36	2.358	1.1	0.70
10	3.36	2.358	1.1	0.70
11	3.36	2.358	1.1	0.70
12	3.36	2.358	1.1	0.70
13	3.36	2.358	1.1	0.70
14	3.04	2.358	1.2	0.78

Example	Theoretical capacity of the cathode at 4.2V (mAh)	Total capacity of the anode *active* material (mAh) based on data reported in Uemura	Capacity Balance Nc/Pc reported in Uemura	Claimed ratio of the ’641 patent
15	3.36	2.358	1.1	0.70
16	3.36	2.358	1.1	0.70
17	3.36	2.358	1.1	0.70

143. Accordingly, Uemura does not disclose the claimed ratio range, and does not anticipate or render obvious any claim of the ’641 Patent.

C. Uemura is not an enabling reference.

144. I understand that Dr. Liang tried to reproduce the kind of batteries described in Uemura. Despite multiple attempts and further improvements, he was unable to reproduce a secondary lithium-ion battery with the performance characteristics described by Uemura. Dr. Liang’s testing demonstrates that producing the kind of secondary lithium-ion battery on which Petitioner relies would have required undue experimentation as of the ’641 Patent’s priority date. Accordingly, Uemura does not enable its own disclosures or the claimed invention of the ’641 Patent.

145. In this section, I first describe what Dr. Liang did to try to reproduce the alleged experimental results of Uemura, and I provide my interpretation of those

experimental results. I then apply the *Wands* factors, which strongly support the conclusion that Uemura is not an enabling reference.

146. As an initial matter, I understand that Dr. Liang tried to prepare the cathode active materials in Examples 1-4, following the experimental procedure disclosed by Uemura.[88] I also understand that Dr. Liang tried to prepare a battery similar to the one described in Example 2.[89]

147. Petitioner relies upon all seventeen examples for its argument that Uemura discloses every element of claims 1-8 of the '641 Patent, or renders them obvious. The cathode active materials of Examples 1-4 are representative of the cathode active materials described by Uemura, and the batteries described in Examples 1-4 purportedly have the best cycle life among all seventeen examples.[90] Further, Example 2 is representative of all examples in Uemura as it contains both alleged innovative aspects of Uemura, namely that Example 2 purports to use a lithium deficient Co-doped $LiMnO_2$ as the cathode active material and also use an anode material with more irreversible capacity than conventional anode materials.[91]

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[88] Ex. 2031 (Liang Declaration), ¶14.

[89] *Id*.

[90] Uemura at Fig. 3.

[91] *See supra* section V.E.1; Ex. 1009, Fig. 3.

Accordingly, a POSITA would reasonably expect that when trying to reproduce the examples in Uemura, those examples (cathode materials in Examples 1-4 and Example 2 battery) should have the best chance of being reproduced.

148. Uemura discloses that all three cathode materials in Examples 1-4 were prepared according to a coprecipitation method described at paragraph 71, and Dr. Liang followed the procedure laid out there to synthesize those cathode active materials.[92]

149. Consistent with the literature of the time, which discusses the difficulties in synthesizing the cathode materials discussed in Uemura, following the experimental procedure in Uemura does not lead to successful synthesis of a layered structure of Co-doped $LiMnO_2$ cathode material. Instead, the materials synthesized likely had a rock salt structure, a spinel structure, or a mixture of the two.[93] When the cathode materials were assembled into test batteries with lithium metal as the counter electrode to measure their capacity, they exhibited very low capacity (around 5-20 mAh/g, depending on the lithium amount)[94], nowhere close to what is reported

[92] Ex. 2031, ¶¶17-19.

[93] Ex. 2031, ¶¶23-24.

[94] Ex. 2031, ¶¶25-28.

in Uemura (more than 120 mAh/g),[95] at levels that a POSITA would recognize as insufficient for a secondary rechargeable lithium-ion battery.

150. *Second*, because layered structure of cathode material is typically annealed in air, Dr. Liang modified the synthesis process and annealed the mixtures in air at 500 °C for five hours then 900 °C for 12 hours.[96] Based on the experimental results, each of the synthesized materials appeared to be of a spinel structure.[97]

151. The failed attempts by Dr. Liang are not surprising. Many attempts have been made to prepare layered structures of $LiMnO_2$ and its doped modifications by using direct synthesis such as the one described in Uemura (coprecipitation method).[98] Those attempts have consistently failed to produce layered $LiMnO_2$ with good crystallinity.[99] For example, Uyama et al. reviewed prior attempts at producing $LiCo_{1-x}Mn_xO_2$ and found that conventional direct synthesis only works when $x \leq$

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[95] Ex. 1009, Fig. 3; *see infra* section VII.C.4.

[96] Ex. 2031, ¶29.

[97] Ex. 2031, ¶¶31-32.

[98] *See* Ex. 2009 at 499; *see also* Ex. 2012, Takeshi Uyama et al., *Synthesis of Rhombohedral $LiCo_{0.64}Mn_{0.36}O_2$ using a high-pressure method*, 58 Inorg. Chem. 6684 (2019) ("Uyama 2019") at 6684.

[99] *Id*.

0.2.[100] Instead, previous successful attempts at synthesizing materials such as $Li_xMn_{0.5}Co_{0.5}O_2$ all used the ion-exchange method, which Uemura does not use. Further, even to 2019, the field still has not successfully used the ion-exchange method to prepare cathode active material similar to the one in Examples 3-4.[101]

152. Dr. Liang continued to measure the capacity of the samples annealed in air when they were assembled into a test battery (with lithium metal as the counter electrode).[102] When charged between 2.0-4.3V against lithium metal, those test batteries showed slightly improved capacity compared to the argon-annealed samples, but their capacity was still quite low, e.g., between 10-26 mAh/g.[103]

153. *Third*, aiming to see if layered $LiMnO_2$ with doping element can actually work as Uemura discloses, Dr. Liang successfully synthesized pure layered $Li_{0.8}Mn_{0.5}Co_{0.5}O_2$ based on the ion-exchange method.[104] He then tested the capacity of the synthesized cathode material at different voltages (4.3V and 5V) using lithium metal as the counter electrode, and the results were consistent with what is reported

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[100] Ex. 2016 at 6684.

[101] *See* Ex. 2017 at 42; Ex. 2016 at 6684; Ex. 2031, ¶38.

[102] Ex. 2031, ¶33.

[103] Ex. 2031, ¶34.

[104] Ex. 2031, ¶¶37-40.

in the literature.[105] When a half-cell with the synthesized $Li_{0.8}Mn_{0.5}Co_{0.5}O_2$ as the cathode active material was charged with an applied voltage between 3.5V and 4.3V, the first charge capacity was approximately 70 mAh/g, while the literature reports approximately 100 mAh/g. When the applied voltage increased to about 5V, the test cell had a first charge capacity close to 200 mAh/g, which is similar to what is reported in Kajiyama (also close to 200 mAh/g).[106]

154. Dr. Liang then built a lithium-ion battery with the layered $Li_{0.8}Mn_{0.5}Co_{0.5}O_2$ as the cathode and a hard carbon as the anode, which has about 11% irreversible capacity.[107] Contrary to the results presented in Uemura, such a battery cannot be safely charged to 4.3V.[108] Even before the charging voltage reached 4V, the battery started to degrade.[109] This suggests that detrimental side reactions were happening inside the battery. A POSITA would understand that charging the battery further to a higher voltage would cause more damages to the battery, which could lead to safety issues and even explosion. Further, this suggests

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[105] Ex. 2031, ¶¶41-44; *see* Kajiyama 2002.

[106] Ex. 2031, ¶¶41-44; *see* Kajiyama 2002.

[107] Ex. 2031, ¶¶43, 45.

[108] Ex. 2031, ¶¶45-46.

[109] *Id*.

that such a battery system is not configured to be charged above even 4V. Accordingly, a POSITA would not understand that this battery is a secondary lithium-ion battery that is configured to be charged higher than 4.2V, i.e., a secondary lithium-ion battery with a charge cutoff voltage higher than 4.2V. A POSITA would further understand that such a battery would not be able to maintain a reasonable level of capacity after successive charging and discharging cycles, let alone the level of capacity after 400 cycles as required by claim 11-18 of the '641 Patent.

155. In addition, the *Wands* factors, which counsel asked me to apply to Uemura's disclosure also in light of Dr. Liang's experiments, further demonstrate that Uemura does not enable its own disclosures or the claimed invention of the '641 Patent, and cannot render any claim of the '641 Patent anticipated or obvious:

1. Nature of the invention, state of the art, unpredictability of the art (*Wands* factors 4, 5, and 7)

156. Uemura's purported invention includes doping a highly unstable cathode material (layered $LiMnO_2$). Around 2001, many researchers in the field were focused on the development of lithium metal oxides enhanced with doping to improve both capacity and stability. However, the effects of doping on the crystal structure and electrochemical properties of the cathode materials were not straightforward. For example, each doping element could alter the lattice parameters differently, affecting the ability of the cathode to intercalate and de-intercalate

lithium ions. Predicting how these changes would impact overall battery performance was complex and required testing and refinement.

157. Further, the doped cathode materials had to be compatible with existing anode, electrolyte, and other components of the battery. The interrelationships between these disparate components further complicated the design of a secondary lithium-ion battery.

2. Absence of working examples, and absence of direction or guidance (*Wands* factors 2, 3)

158. As discussed below in section VII.C.4, due to the questionable nature of Uemura's data, a POSITA would have disregarded the data in Uemura, and would not have considered that it discloses a secondary lithium-ion battery with large capacity and excellent cyclability using doped $LiMnO_2$. Accordingly, a POSITA would not have considered any of the disclosed examples in Uemura as working.

159. Dr. Liang's testing demonstrates that Uemura's alleged examples do not work. Uemura does not disclose a working method to synthesize the cathode active material, which is essential for constructing a battery and implementing the purported invention of Uemura. Despite Dr. Liang's success in synthesizing a layered Co-doped $LiMnO_2$ similar to the one used in Example 2, when combined with a hard carbon with similar irreversible capacity as the one used in Example 2, the battery cannot be charged above 4V and simply would not be considered as secondary.

3. Quantity of experimentation, relative skill in the art (*Wands* factors 1, 6)

160. As discussed, Uemura does not provide working examples. Further, as of the priority date of the ’641 patent, the field of lithium-ion batteries was in its nascency, and the art was (and remains) very unpredictable. Accordingly, developing a battery with the properties touted in Uemura based on Uemura’s guidance would require extraordinary experimentation, with no expectation of successful replication. To successfully test the hypothesis of Uemura, a POSITA would need to develop a working method to synthesize at least the seventeen examples in Uemura, which by itself is not easy to do. Even with a successful synthesis, a POSITA would still need to find an anode material that could be compatible with the cathode active material. Despite his higher than ordinary skill level, Dr. Liang was not able to assemble a workable secondary lithium-ion battery that has a charge cutoff voltage higher than 4.2V, using the disclosed combination of cathode and anode active materials in Uemura. Even today, with much follow-up research studying the electrochemical properties of layered $LiMnO_2$, no commercial battery is using this type of material as the cathode active material.

161. In sum, the *Wands* factors demonstrate that a POSITA could not possibly have implemented Uemura’s disclosure without undue experimentation.

4. A POSITA would disregard Uemura’s disclosures because they include obvious errors.

162. Uemura's data on cathode capacity are obviously erroneous such that the disclosure would simply be disregarded by a POSITA. As discussed below, Uemura's data suggest that as long as the cathode materials are derived from layered $LiMnO_2$, they would have the same specific capacity, even though they have completely different chemical compositions. A POSITA would know this is inconsistent with lithium-ion battery operation principles and empirical data, immediately identify this error, and disregard Uemura's disclosure that contains these errors.

163. As summarized above and reproduced here for ease of reference, each of the example's specific capacity can be calculated based on the "total capacity" reported by Uemura and their reported weight:

Example	Composition of positive electrode material	Weight (mg) reported in Uemura	Pc: total capacity of cathode (mAh) as reported in Uemura	Specific capacity (mAh/g) calculated based on Uemura's reported data
1	$Li_{0.67}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	1.8	120
2	$Li_{0.83}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.24	149
3	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.6	173
4	$Li_{0.967}Mn_{0.5}Co_{0.5}O_{2-\delta}$	15	2.6	173
5	$Li_{0.75}Mn_{0.75}Co_{0.25}O_{2-\delta}$	15	2	133
6	$Li_{0.83}Mn0_{.75}Ni_{0.25}O_{2-\delta}$	15	2.24	149
7	$Li_{0.83}Mn_{0.67}Fe_{0.33}O_{2-\delta}$	15	2.24	149
8	$Li_{0.83}Mn_{0.75}Al_{0.25}O_{2-\delta}$	15	2.24	149
9	$Li_{0.83}Mn_{0.75}Cr_{0.25}O_{2-\delta}$	15	2.24	149
10	$Li_{0.83}Mn_{0.75}Ga_{0.25}O_{2-\delta}$	15	2.24	149
11	$Li_{0.83}Mn_{0.75}In_{0.25}O_{2-\delta}$	15	2.24	149
12	$Li_{0.83}Mn_{0.75}Zr_{0.25}O_{2-\delta}$	15	2.24	149
13	$Li_{0.83}Mn_{0.75}V_{0.25}O_{2-\delta}$	15	2.24	149
14	$Li_{0.75}Mn_{0.875}Fe_{0.125}O_{2-\delta}$	15	2	133
15	$Li_{0.83}Mn_{0.75}Nb_{0.25}O_{2-\delta}$	15	2.24	149
16	$Li_{0.83}Mn_{0.75}Ta_{0.25}O_{2-\delta}$	15	2.24	149
17	$Li_{0.83}Mn_{0.75}Ti_{0.25}O_{2-\delta}$	15	2.24	149

Comparative Example	$LiMnO_{2-\delta}$	15	2.7	180

164. It is apparent that these values of specific capacity are not genuine experimental data but instead derived from one simple equation:

$$\text{Specific capacity in Uemura} = 180\frac{\text{mAh}}{\text{g}} \times \text{lithium amount}$$

165. The lithium amount refers to the amount of lithium in the positive electrode material. For example, the cathode in Example 1 has a specific capacity of 120 mAh/g:

$$\frac{1.8\ \text{mAh}}{0.015\ \text{g}} = 120\ \text{mAh/g}$$

The chemical composition of Example 1's cathode is $Li_{0.67}Mn_{0.5}Co_{0.5}O_{2-\delta}$, thus it has 0.67 lithium. 180 mAh/g multiplied by 0.67 is exactly 120 mAh/g:

$$180\frac{\text{mAh}}{\text{g}} \times 0.67 = 120\frac{\text{mAh}}{\text{g}}$$

166. Similarly, the cathode in Example 2 has a specific capacity of 149 mAh/g, based on the reported "total capacity" and its weight. The cathode in Example 2 has 0.83 lithium, and 180 mAh/g multiplied by 0.83 is also 149 mAh/g. All seventeen examples follow this equation.

167. In other words, Uemura makes the unfounded assumption that if the example cathode materials in Uemura are not lithium deficient, i.e., all of them have a full lithium in their chemical composition, when they are charged and discharged

under the same conditions, they would have the same "total capacity." Put differently, Uemura assumes (incorrectly) that as long as the cathode active material has the chemical formula of $LiMn_xM_yO_2$ ($x + y = 1$), notwithstanding difference in the doping element ("M") and the stoichiometric variables x, y, charging and discharging the battery under the same conditions will result in the same amount of lithium extraction from the cathode. Thus, Uemura erroneously suggests that materially dissimilar cathode materials may be assumed to have the same specific capacity as the layered $LiMnO_2$: 180 mAh/g. As I explain below, this assumption is contrary to both data reported in the literature and contrary to well-established principles of electrochemistry.

168. As an initial matter, the theoretical maximum capacities of the example cathode active materials are different, due to their different molecular weight. Uemura claims that all examples were subjected to the same charge-discharge conditions.[110] When the cathode active materials with different theoretical maximum capacities are charged and discharged in the same manner, it is extremely unlikely that these cathode active materials would all have the same capacity.

169. For example, for the comparative example $LiMnO_2$, its molecular weight is 93.88 g/mol, and the maximum number of electrons it can transfer during

[110] Uemura at [0081].

charging is 1 (as there is one full lithium). Accordingly, its theoretical maximum capacity is about 285 mAh/g based on Faraday's law of electrolysis.

170. In Example 1 of Uemura, its chemical composition is $Li_{0.67}Mn_{0.5}Co_{0.5}O_2$ (without considering the oxygen deficient amount), and its molecular weight is 93.58 g/mol. Based on Faraday's Law of electrolysis, its theoretical maximum capacity is 192 mAh/g.

171. I calculated the theoretical maximum capacity for each of Uemura's example cathode active materials in the same way, and the results are shown below at the column "Theoretical maximum capacity."[111]

Example	Composition of positive electrode material	Molecular weight (g/mol)	Theoretical maximum capacity (mAh/g)
1	$Li_{0.67}Mn_{0.5}Co_{0.5}O_2$	93.58	192
2	$Li_{0.83}Mn_{0.5}Co_{0.5}O_2$	94.69	235
3	$Li_{0.967}Mn_{0.5}Co_{0.5}O_2$	95.64	271
4	$Li_{0.967}Mn_{0.5}Co_{0.5}O_2$	95.64	271
5	$Li_{0.75}Mn_{0.75}Co_{0.25}O_2$	93.14	216
6	$Li_{0.83}Mn0_{.75}Ni_{0.25}O_2$	93.63	238
7	$Li_{0.83}Mn_{0.67}Fe_{0.33}O_2$	93.00	239
8	$Li_{0.83}Mn_{0.75}Al_{0.25}O_2$	85.71	260

[111] I calculated the molecular weight of each of the examples based on the assumption that the oxygen deficient amount is 0, as that value is typically very small.

Example	Composition of positive electrode material	Molecular weight (g/mol)	Theoretical maximum capacity (mAh/g)
9	$Li_{0.83}Mn_{0.75}Cr_{0.25}O_2$	91.96	242
10	$Li_{0.83}Mn_{0.75}Ga_{0.25}O_2$	96.40	231
11	$Li_{0.83}Mn_{0.75}In_{0.25}O_2$	107.67	207
12	$Li_{0.83}Mn_{0.75}Zr_{0.25}O_2$	101.77	218
13	$Li_{0.83}Mn_{0.75}V_{0.25}O_2$	91.70	242
14	$Li_{0.75}Mn_{0.875}Fe_{0.125}O_2$	92.26	218
15	$Li_{0.83}Mn_{0.75}Nb_{0.25}O_2$	102.19	218
16	$Li_{0.83}Mn_{0.75}Ta_{0.25}O_2$	124.2	179
17	$Li_{0.83}Mn_{0.75}Ti_{0.25}O_2$	90.93	245
Comparative Example	$LiMnO_{2-\delta}$	93.88	285

172. As can be seen above, each of the different cathode active materials has a different theoretical maximum capacity. While some of them are similar, others are quite different. For example, Example 16 has a theoretical maximum capacity as low as 179 mAh/g, while Example 8's theoretical maximum capacity is as high as 260 mAh/g—45% higher than that of Example 8. Uemura claims that all 17 examples and the comparative example were charged and discharged under the same conditions,[112] and despite their differences in theoretical maximum capacities, examples 2, 6-13, and 15-17 all have the same capacity, and examples 5 and 14 also

[112] Uemura at [0081].

share the same capacity. A POSITA would find such results highly improbable (indeed impossible) and would question whether the data were genuine experimental data.

173. To illustrate this in a different way, as discussed above, Uemura's unfounded assumption is that as long as the cathode active material has the chemical formula of $LiMn_xM_yO_2$ ($x + y = 1$) (notwithstanding differences in the variables M, x, and y in this formula) when charged and discharged under the same condition, all materials that observe this formula have the same specific capacity as the layered $LiMnO_2$: 180 mAh/g. But as shown below, when x, y, or M is different, the theoretical maximum capacity of the cathode active material (when lithium amount is 1) changes. Depending on the exact composition, the theoretical maximum capacity can be as low as 214 mAh/g, and can be as high as 308 mAh/g. Uemura ignores this and teaches that when the cathode was charged and discharged according to paragraph 81, different materials that should have different specific capacities actually all have the same specific capacity. As I stated above, this is highly improbable.

Example	Composition of positive electrode material	Molecular weight (g/mol)	Theoretical maximum capacity (mAh/g)	Specific capacity (Uemura's data)
1	$LiMn_{0.5}Co_{0.5}O_2$	95.88	280	180
2	$LiMn_{0.5}Co_{0.5}O_2$	95.88	280	180

Example	Composition of positive electrode material	Molecular weight (g/mol)	Theoretical maximum capacity (mAh/g)	Specific capacity (Uemura's data)
3	$LiMn_{0.5}Co_{0.5}O_2$	95.88	280	180
4	$LiMn_{0.5}Co_{0.5}O_2$	95.88	280	180
5	$LiMn_{0.75}Co_{0.25}O_2$	94.88	282	180
6	$LiMn0_{.75}Ni_{0.25}O_2$	94.82	283	180
7	$LiMn_{0.67}Fe_{0.33}O_2$	94.18	285	180
8	$LiMn_{0.75}Al_{0.25}O_2$	86.89	308	180
9	$LiMn_{0.75}Cr_{0.25}O_2$	93.14	288	180
10	$LiMn_{0.75}Ga_{0.25}O_2$	97.58	275	180
11	$LiMn_{0.75}In_{0.25}O_2$	108.85	246	180
12	$LiMn_{0.75}Zr_{0.25}O_2$	102.95	260	180
13	$LiMn_{0.75}V_{0.25}O_2$	92.88	289	180
14	$LiMn_{0.875}Fe_{0.125}O_2$	93.99	285	180
15	$LiMn_{0.75}Nb_{0.25}O_2$	103.37	259	180
16	$LiMn_{0.75}Ta_{0.25}O_2$	125.38	214	180
17	$LiMn_{0.75}Ti_{0.25}O_2$	92.11	291	180
Comparative Example	$LiMnO_2$	93.88	285	180

174. In addition to different theoretical maximum capacities, a POSITA would also understand that a doping element could significantly change the electrochemical properties of an electrode. Accordingly, even if those cathode active materials are charged and discharged under the same conditions, different amounts of lithium would be extracted from these cathodes. That is because each metal has its own unique set of properties, including size, electron configuration, and its ability to form bonds. When these doping elements are introduced into the $LiMnO_2$ structure, they can change how tightly or loosely lithium ions are held

within the electrode material. For example, if the doping element has a different size from manganese, it can cause strain or distortions in the crystal structure of the cathode material. This can affect how easily lithium ions move in and out during charging and discharging process.

175. Similarly, because different elements have different number of valence electrons, changing the doping elements also changes the balance of charges within the structure, which in turn affects the electrical characteristics of the material. For example, in a study, R. Prasad and colleagues examined how different doping elements could affect the stability of the crystal structure of doped layered $LiMnO_2$, including the ones in Uemura, such as Example 5 ($LiMn_{0.75}Co_{0.25}O_2$), Example 6 ($LiMn_{0.75}Ni_{0.25}O_2$), Example 8 ($LiMn_{0.75}Al_{0.25}O_2$), Example 9 ($LiMn_{0.75}Cr_{0.25}O_2$), Example 13 ($LiMn_{0.75}V_{0.25}O_2$), Example 14 ($LiMn_{0.875}Fe_{0.125}O_2$), and Example 17 ($LiMn_{0.75}Ti_{0.25}O_2$).[113] They found that some doping elements are effective in stabilizing the crystal structure, while some are not.[114] Prasad et al. found that "Al, Sc, and Cr are least effective in stabilizing the rhombohedral structure," while the

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[113] Ex. 2038, R. Prasad et al., *Dopant-induced stabilization of rhombohedral $LiMnO_2$ against Jahn-Teller distortion*, 71 Physical Review B 134111 (2005) ("Prasad 2005") at Table I, Table II.

[114] *Id*. at 134111-8.

unique character of Fe "enhances its ability to stabilize that structure."[115] It is worth noting that Uemura's data were contrary to the findings of Prasad 2005. In Fig. 3, Examples 8 (Al doped) and 9 (Cr doped) allegedly have much better cycle life than Example 14 (Fe doped).[116]

176. As another example, a study conducted by Z.P. Guo and colleagues demonstrates that different doping elements led to quite different capacities and cycling behaviors.[117] When testing the cycle life of doped $LiMnO_2$ in a cell with lithium metal as the anode material, Guo et al. found that the discharge capacity of those doped materials, compared to pure $LiMnO_2$, "is smaller, but the cyclability of electrodes has been improved."[118] Guo et al. report that pristine $LiMnO_2$ loses capacity at a rate of "about 0.3% per cycle after 20 cycles," while Mo doped, Cr doped, Zn doped, and V doped cathode materials "show a lower capacity loss rate

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[115] *Id*.

[116] Uemura at Fig. 3.

[117] Ex. 2039, Z.P. Guo et al., *Structure and electrochemical characteristics of* $LiMn_{0.7}M_{0.3}O_2$ *(M=Ti, V, Zn, Mo, Co, Mg, Cr)*, 348 J. Alloys and Compounds 231 (2003) ("Guo 2003).

[118] *Id*. at 233.

(0.17, 0.11, 0.23, and 0.19% per cycle, respectively)."[119] The findings by Guo et al. are distinctly contrary to the data in Uemura, which shows no decrease in capacity with doping elements and show the same capacity across different doped cathode active materials.

177. Even putting aside these significant inherent differences in chemical compositions, no matter how controlled an experiment is, there will always be some degree of error and variability. For example, minor fluctuations in experimental conditions, such as temperature or pressure, could influence the results. The electrochemical reactions involved in battery operation are also complex and sensitive to factors that cannot be realistically controlled. In addition, all measuring instruments have a degree of error. However, the only recognizable variability in Uemura's data can be attributable to rounding errors. This is simply not possible, and a POSITA would recognize this as a red flag as to the accuracy of Uemura's data.

178. Similarly, fourteen out of the seventeen examples in Uemura allegedly have the same amount of "total capacity" and "total irreversible capacity" for the anode.[120] All of them had a "total capacity" of 2.36 mAh and "total irreversible

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[119] *Id*.

[120] Uemura at Fig. 3.

capacity" of 0.002 mAh.[121] The level of precision indicated by 0.002 mAh suggests that the measurement was precise to within ±0.0005 mAh. This means that when Uemura was preparing the anode, they were able to consistently obtain identical results with this level of precision across fourteen samples. A POSITA would understand that such uniform results are highly improbable and do not reflect the reality of experimental studies, which inherently have a degree of error.

179. For the reasons explained above, a POSITA would immediately find obvious errors in Fig. 3 of Uemura and would disregard the disclosure. Because the numbers of cycles reported in Uemura are predicated upon the cathode and anode capacity data, a POSITA would likewise question the reliability and authenticity of the cycle life data and would mentally disregard the disclosure. In any event, Uemura's capacity balance data are plagued by serious errors that put in question their reliability, and a POSITA would thus disregard them.

VIII. CLAIMS 9-18 ARE NOT OBVIOUS OVER UEMURA ALONE OR IN VIEW OF GUYOMARD AND/OR IWAIZONO (GROUNDS 3-4, 8-9)

180. Claims 9 and 10 depend from claim 5 and recite additional limitations regarding the secondary lithium-ion battery's protection mechanisms. They recite two additional voltages: the overcharging protection voltage and overcharging protection release voltage.

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[121] *Id.*

181. When an overcharging event is detected by the battery's protection mechanism, the protection mechanism will be triggered to prevent the battery from being charged to a higher voltage. Once that protection mechanism is triggered, the charging will stop and the voltage will drop. The overcharging protection release voltage is the voltage level at which the battery's protection mechanism disengages or resets.

182. As to claims 11-18, each of them requires the battery to maintain a certain level of percentage of capacity after 400 cycles.

183. Mr. Juzkow argues that Uemura alone or in view of Guyomard renders claims 11-18 obvious (Grounds 3 and 4). Mr. Juzkow also argues that Uemura in view of Iwaizono renders claim 9 obvious (Ground 8). Finally, Mr. Juzkow argues that Uemura in view of Iwaizono in view of Guyomard renders both claims 9 and 10 obvious (Ground 9). I disagree.

184. *First*, none of the combinations teaches or suggests every element of claims 9-18 of the '641 Patent. As discussed above, Uemura does not disclose the charge cutoff voltage limitation or the ratio limitation. Neither Guyomard nor Iwaizono could remedy those deficiencies. Iwaizono does not disclose any charge cutoff voltage higher than 4.2V.

185. As to Guyomard, it does not teach anything about the capacity ratio. As to the charge cutoff voltage limitation, neither Petitioner nor Mr. Juzkow argues

that a POSITA would have been motivated to modify Uemura to have a charge cutoff voltage of 4.3V or higher.[122] Instead, Petitioner relies solely upon Uemura for the charge cutoff voltage limitation. Because Uemura does not disclose a charge cutoff voltage higher than 4.2V, Uemura in combination of Guyomard and/or Iwaizono does not teach or suggest every element of claims 9-18.

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[122] To the extent that Petitioner argues that a POSITA would have been motivated to modify Uemura in light of Guyomard to increase the charge cutoff voltage to be higher than 4.2V, Petitioner is wrong. As discussed, a POSITA would find it counterproductive to increase the charge cutoff voltage given Uemura's goal is to decrease the utilization of lithium in the layered $LiMnO_2$ to improve its stability. *See supra* section V.E.1. Further, Uemura's purported invention focuses on doped layered $LiMnO_2$. Guyomard's purported innovation is not directed to layered $LiMnO_2$, but to a cathode active material that Uemura explicitly teaches away (spinel $LiMn_2O_4$). Uemura at [0009]. A POSITA would understand that a voltage that may work for one cathode material would not necessarily work for another cathode material. A POSITA in possession of Uemura would not have been motivated to increase the charge cutoff voltage of doped layered $LiMnO_2$, and certainly would not have had any reasonable expectation of success in obtaining a secondary lithium-ion battery with layered $LiMnO_2$ as the cathode active material.

186. Further, none of the combinations, as a whole, would enable a POSITA to practice the claimed invention of the ’641 Patent without undue experimentation. Neither Guyomard nor Iwaizono teaches anything about layered $LiMnO_2$. A POSITA, even with the two references at hand, would still have to undertake undue experimentation to practice the claimed invention of the ’641 Patent. Accordingly, none of the combinations of references render claims 9-18 obvious.

IX. ABE DOES NOT TEACH OR SUGGEST EVERY LIMITATION OF CLAIMS 1-8 OF THE ’641 PATENT (GROUNDS 5-6)

187. Petitioner asserts that Abe discloses every element of claims 1-8 of the ’641 Patent. As discussed below, Abe fails to disclose the claimed charge cutoff voltage or the ratio limitation, accordingly Abe does not anticipate claims 1-8 or render them obvious.

A. Abe does not disclose the claimed charge cutoff voltage.

188. Petitioner claims that Abe discloses a charge cutoff voltage of 4.2-4.3V, based on disclosure of Abe at paragraph 78. Paragraph 78 states:

> The design capacity is determined, for example, from the initial charge capacity per unit weight of the active material in a predetermined charging voltage range and the amount of active material coated on the current collector. The charging capacity can be obtained, for example, by continuously recording a voltage that changes over time by applying a constant current using ***a three-electrode cell in which both the counter and the reference pole are made of metal lithium. In the triode cell***, the starting voltage when using a vapor-phase-grown carbon fiber negative electrode as the working electrode is 3 V, and the

> charge (applying current from the working electrode to the counter electrode) proceeds and decreases toward 0 V. When a positive electrode is used for the working electrode, ***the voltage at the start is the potential difference between the metal lithium and the positive electrode material***, and the voltage rises with charging (applying current from the counter electrode to the working electrode) .... and at the positive electrode, the voltage is set to a range in which no electrolyte decomposition occurs, and no irreversible structural breakdown of the positive electrode active material occurs. For example, $LiMn_2O_4$ is 4.2-4.3 V, preferably 4.2 V, and $LiCoO_2$ and $LiNiO_2$ are 4.1-4.2 V, preferably 4.1 V.[123]

189. Contrary to Mr. Juzkow's conclusion, the 4.2-4.3V disclosed in Abe is the voltage difference between the cathode and lithium metal. This is the half-cell voltage of the cathode and does not reflect the voltage of the battery when it is in practical use, i.e., in a complete battery.

190. In contrast, the charge cutoff voltage as claimed by the '641 Patent is the full cell voltage, which is the voltage between the cathode and the anode. Because the '641 Patent's charge cutoff voltage refers to the full cell voltage and the battery claimed by the '641 Patent does not use lithium metal as the anode,[124] the disclosure of 4.2-4.3V of a half-cell voltage is not a disclosure of a charge cutoff voltage of 4.2-4.3V. Instead, a POSITA would understand that a disclosure of a

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[123] Abe at [0078] (emphasis added).

[124] '641 Patent (Ex. 1001) at 8:56–9:7.

half-cell voltage of 4.2-4.3V means a charge cutoff voltage of 4.0-4.2V. Accordingly, Abe does not disclose a charge cutoff voltage higher than 4.2V.

191. *First*, the claims of the '641 Patent is directed to a secondary ***lithium-ion*** battery.[125] A secondary lithium-ion battery does not use lithium metal as the anode. A secondary battery that uses lithium metal as the anode is called secondary lithium ***metal*** battery. The voltage range (4.2-4.3V) as disclosed in paragraph 78 of Uemura is between a cathode and a lithium metal counter electrode. It is thus not a voltage range of a secondary *lithium-ion* battery, as that test cell uses lithium metal as the anode.

192. *Second*, as discussed in section VI.B., a POSITA would understand that the claimed charge cutoff voltage refers to the full-cell voltage, not to the half-cell voltage. Abe discloses using the half-cell configuration, e.g., a test cell with $LiMn_2O_4$ as the cathode and lithium metal as the anode, a POSITA would be able to determine the charge capacity of that cathode active material.[126] Abe thus discloses a half-cell voltage between 4.2V and 4.3V for $LiMn_2O_4$ as the cathode active material.

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[125] Ex. 1001, 17:5-11.

[126] Abe at [0078].

193. *Third*, when graphite is used as the anode material, it typically has a half-cell voltage of about 0.1-0.2V, so the full cell voltage of a battery with graphite as the anode is lower than the half-cell voltage of the cathode, typically by 0.1-0.2V. The anode material used in Abe is "graphitized vapor-phase-grown carbon," which mimics the property of graphite.[127] Accordingly, when Abe discloses a half-cell voltage between 4.2V and 4.3V for $LiMn_2O_4$, Abe discloses a full-cell voltage of at most 4.2V.

194. Jaephil Cho and colleagues confirmed that when the cell has a carbon material as the anode, the half-cell voltage of the cathode is 0.1V higher than the charge cutoff voltage of the cell (i.e., the full cell voltage):

> In an effort to improve energy density of Li-ion cells, $LiNiO_2$ has been studied extensively as a cathode material by many investigators because its specific capacity is higher than that of $LiCoO_2$, which is presently used in most commercially available Li-ion cells. $LiNiCo_2$ shows a specific capacity up to 203 mAh/g (cf. 160 mAh/g for $LiCoO_2$) when cycled between 2.75 and 4.3 V *vs*. Li metal. ***This potential (4.3V vs. Li metal) corresponds approximately to a 4.2V charging voltage for a practical Li-ion cell***, because the potential of an incompletely charged carbon anode in the cell at the end of charge is approximately 0.1 V *vs*. Li.
>
> Commercially available Li-ion cells containing $LiCoO_2$ as the cathode material are typically charged to ***two different***

[127] *See, e.g.*, Ex. 1005, ¶¶99, 102.

> ***cutoff voltages, i.e., 4.1 and 4.2V, which corresponds to approximately 4.2 and 4.3 V vs. Li, respectively***.[128]

195. Similarly, Guyomard states that "the voltage of a Li_xC_6 negative electrode is always greater than that of a pure lithium negative electrode."[129]

196. Indeed, embodiments in Abe show that when the half-cell voltage is at most 4.3V, the full-cell voltage is lower. All embodiments in Abe were charged and discharged up to the same maximum charging voltage: 4.1V:

> Charge and discharge tests were carried out at current values of 800 mA, 1,600 mA, 2,400 mA, and 3,200 mA in the range of charge and discharge voltages of 2.5 to 4.1 V for each current value.[130]

197. The 4.1V maximum voltage in Abe applies to all three lithium metal oxides, including $LiMn_2O_4$. The 4.1V maximum charging voltage is consistent with the fact that graphite has a 0.1-0.2V voltage against lithium metal, so a half-cell voltage of $LiMn_2O_4$ in the range of 4.2-4.3V corresponds to a full-cell voltage no higher than 4.2V. Further, because the embodiments in Abe were charged and

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[128] Ex. 2018, Jaephil Cho et al., *Electrochemical properties and thermal stability of $Li_aNi_{1-x}Co_xO_2$ cathode materials*, 147 Journal of the Electrochemical Society (1) 15-20 (2000) ("Cho 2000") at 15 (emphasis added).

[129] Ex. 1008 (Guyomard) at 2:8–10.

[130] Abe at [0097]; [0104]; [0110]; [0119].

discharged with a constant current until the applied voltage reached 4.1V, the charge cutoff voltage for those batteries would be lower than 4.1V.

198. Abe's disclosure is also consistent with the literature, which consistently reports that for spinel $LiMn_2O_4$, the charge cutoff voltage should be limited to below 4.2V. For example, Ramadass Premanand et al. studied the capacity fade of spinel-based Li-ion batteries.[131] They found that when using CC/CV charging, to "prevent oxidation of the electrolyte and the spinel," the battery should be charged at no more than 4.2V.[132] As another example, another reference describes charging lithium manganese oxide "by applying 4.2 volts" as "conventional."[133]

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[131] Ex. 2020 at A54.

[132] *Id*. at A55 ("Since, no difference in capacity is seen between charging at 4.17V and 4.3V, in subsequent studies the cell was charged to 4.17V. This was done primarily to prevent oxidation of the electrolyte and the spinel. According to Aurbach *et al*., cycling spinel in the potential range 3.5–4.2V caused no Mn dissolution.").

[133] Ex. 1013 (Jacobs) at 8:65–9:3; *see also* Ex. 1011 (Miyasaka) at 1:59–60, 16:23–37 (finding $Li_{1+x}Mn_2O_4$ to be "extremely unstable and easily oxidized" and charged

(continued…)

B. Abe does not disclose the claimed ratio limitation.

199. I understand that Mr. Juzkow opines that Abe discloses the claimed ratio of the ’641 Patent. I disagree.

200. Mr. Juzkow points to three places that allegedly disclose the claimed ratio.[134] *First*, Mr. Juzkow points to paragraph 78 of Abe, which states that “[i]n a non-aqueous electrolyte-based secondary battery according to the present invention, the design capacity of the negative electrode is adjusted so that the design capacity of the negative electrode is greater than the design capacity of the cathode.”[135] *Second*, Mr. Juzkow points to paragraph 18 of Abe, which discloses a ratio of “more than 1 and less than or equal to 1.6” for the design capacity of the negative electrode to the design capacity of the positive electrode.[136] *Third*, Mr. Juzkow points to Embodiment 2 of Abe, which discloses a $LiMn_2O_4$ cell with a “design capacity” of 1:1.1 (positive electrode to negative electrode).[137]

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the battery up to 4.2V); Ex. 2014 (Ozawa 1994) at Fig. 1 (charging $LiMn_2O_4$ to a maximum of 4.2V).

[134] Ex. 1002, ¶163.

[135] Abe at [0078].

[136] Abe at [0018].

[137] Abe at [0103].

201. Mr. Juzkow then claims that the "design capacity" described in Abe is determined at a charge cutoff voltage between 4.2V and 4.3V.[138] I disagree. As I note above, Abe only discloses a half-cell voltage for $LiMn_2O_4$ between 4.2V and 4.3V – not the full-cell voltage. The embodiments in Abe further demonstrate that the highest charge cutoff voltage Abe discloses is up to 4.1V.[139] Because Abe focuses on the safety of a secondary lithium-ion battery and warns about the danger of overcharging, a POSITA would understand that the "design capacity" is determined with a charge cutoff voltage of at most 4.1V, consistent with the embodiments of Abe.

202. Because Abe's "design capacity" is determined at a lower voltage than the voltage used to determine the theoretical capacity of the cathode, depending on the cathode material, Abe's design capacity is likely lower than the theoretical capacity of that cathode material at 4.2V.

203. Further, there is no suggestion that the "design capacity" as described in Abe for the cathode active material is the same as the theoretical capacity of the cathode active material at 4.2V, as the '641 Patent requires. Instead, Abe merely states that "the design capacity is determined, for example, from the initial charge

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[138] Ex. 1002 at [0166].

[139] Abe at [0097]; [0104]; [0110]; [0119].

capacity per unit weight of the active material in a predetermined charging voltage range and the amount of active material coated on the current collector," thus suggesting that the "design capacity" could be a measure of practical specific capacity.[140] Because the theoretical capacity of a cathode material at a particular voltage is the maximum amount of capacity the cathode active material could achieve at that voltage, Abe's "design capacity" is likely lower than the theoretical capacity at 4.2V.

204. Accordingly, because it is not clear from Abe how its "design capacity" compares with the theoretical capacity at 4.2V for the cathode material, and indeed, the design capacity probably is lower than the theoretical capacity at 4.2V, Abe's disclosures of the "design capacity" ratios in Embodiment 2 and paragraph 18 do not expressly disclose a claimed ratio of the '641 Patent between 1:1 and 1:2.5.

X. CLAIMS 2-4, 6-8, AND 11-18 ARE NOT OBVIOUS OVER ABE IN VIEW OF GUYOMARD (GROUND 7)

205. Claims 2 and 6 of the '641 Patent narrow the independent claims and require the secondary lithium-ion battery to have a charge cutoff voltage within the range of 4.3-5.2V. Claims 3 and 7 narrow the range further to 4.3-4.8V. Claims 4 and 8 narrow the ratio limitation to a range of 1:1.15 to 1:2.5. As discussed above,

[140] Abe at [0078].

claims 11-18 require the secondary lithium-ion battery to maintain a certain percentage of capacity after 400 cycles.

206. Mr. Juzkow argues that a POSITA "would have been motivated to combine the teachings of Abe with Guyomard"[141] and a POSITA "would have readily expected to succeed in making the combination of Guyomard (and specifically Guyomard's electrolyte) with Abe's lithium-ion batteries."[142] I disagree. A POSITA would not have been motivated to increase the charge cutoff voltage of spinel $LiMn_2O_4$ to 4.5V, as Mr. Juzkow and Petitioner suggest, based on Abe in view of Guyomard. The POSITA would not have had a reasonable expectation of success either. This is because the charge cutoff voltage limit of $LiMn_2O_4$ is due to its own chemical stability; beyond this voltage limit, the structure of $LiMn_2O_4$ can start to break down.[143] Considering the risk of cathode dissolution, a POSITA would not have had the motivation to increase the charge cutoff voltage beyond 4.2V.

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[141] Ex. 1002, ¶182.

[142] Ex. 1002, ¶188.

[143] Ex. 1005 (Abe) at [0078] (describing the voltage at which "electrolyte decomposition occurs" and "irreversible structural breakdown of the positive electrode active material occurs" is between 4.2-4.3V).

207. A POSITA in possession of Abe would be focused on developing a lithium-ion battery that is safe. That is the objective of Abe.[144] Abe warns about the danger of overcharging, i.e., charging the battery to a voltage above which it is configured for, stating that overcharging may lead to ignition and explosion.[145] Even though by the time of Abe, certain battery manufacturers already sold batteries with a charge cutoff voltage of 4.2V, Abe still limited its batteries to at most 4.1V.[146]

208. Abe notes that for spinel $LiMn_2O_4$, the half-cell voltage (the potential difference between spinel $LiMn_2O_4$ as the cathode and lithium metal as the counter electrode) should be set where "no electrolyte decomposition occurs and no irreversible structural breakdown of the positive electrode active material occurs."[147] For spinel $LiMn_2O_4$, that voltage is between 4.2V and 4.3V, "preferably 4.2V."[148] Accordingly, Abe teaches that between 4.2V and 4.3V, for spinel $LiMn_2O_4$,

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[144] Ex. 1005 at [0013]-[0017].

[145] Ex. 1005 at [0009].

[146] Ex. 2024; Ex. 1005, ¶80.

[147] Ex. 1005 at [0078].

[148] *Id*.

electrolyte decomposition and irreversible structural breakdown of the cathode may occur.[149]

209. Abe's teaching is consistent with the literature. It was common knowledge in the art that $Li_{1+x}Mn_2O_4$ is "extremely unstable and easily oxidized."[150] Indeed, another reference relied upon by Petitioner, Uemura, states that "[t]hough $LiMn_2O_4$ of spinel structure is good in cyclic resistance in comparison with the conventional $LiCoO_2$, the cyclic resistance at high temperature is insufficient, thus causing a problem that the positive material is dissolved in an electrolyte to cause deterioration of the negative electrode in performance."[151] Similarly, Ramadass et al. reports that "to prevent oxidation of the electrolyte and the spinel," the authors limited the voltage to 4.17V for spinel $LiMn_2O_4$.[152]

210. A POSITA in possession of Abe thus would understand that the issue associated with spinel $LiMn_2O_4$ is connected with both the oxidation of the electrolyte and the structural breakdown of the spinel structure at voltages between 4.2V and 4.3V. Even with Guyomard at hand, whose purported innovation is

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[149] *Id*.

[150] Ex. 1011, 1:59-60.

[151] Ex. 1009 (Uemura) at [0007].

[152] Ex. 2020 at A55.

exclusively focused on electrolyte, a POSITA would not understand that the issue with regard to the structural stability of the cathode was also solved by Guyomard. Guyomard was published in 1993, but years after its publication, the field still considered 4.2V as the limit for spinel $LiMn_2O_4$.[153] For example, Arora et al. studied the capacity fading mechanisms and side reactions for a $LiMn_2O_4$ cell using computational models in 1998—five years after Guyomard's publication.[154] It also reviewed the electrolyte reported in the literature at that time, including the one noted in Guyomard.[155]

Table I. Electrolyte oxidation potential of various electrolytes on different substrates.

Electrolyte	E_{ox} (V vs. Li/Li^+)	Substrate	Ref.
$LiClO_4$ + PC/DME (1:1)	4.6	LiV_3O_8	68
1 M $LiClO_4$ + PC	4.5	Ni	66
1 M $LiClO_4$ + PC	5.75	Al	66
1 M $LiClO_4$ + PC	5.2	Pt	66
1 M $LiClO_4$ + PC	5.5	Au	66
1 M $LiClO_4$ + EC/DEE (1:1)	4.55	$LiMn_2O_4$ + 10% carbon black	64
1 M $LiClO_4$ + EC/DMC (1:1)	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiN(CF_3SO_2)_2$ + EC/DEE (1:1)	4.4	$LiMn_2O_4$ + 10% carbon black	64
$LiN(CF_3SO_2)_2$ + EC/DME (1:1)	4.35	$LiMn_2O_4$ + 10% carbon black	64
$LiCF_3SO_3$ + EC/DEE (1:1)	4.1	$LiMn_2O_4$ + 10% carbon black	64
$LiCF_3SO_3$ + EC/DMC (1:1)	3.2	$LiMn_2O_4$ + 10% carbon black	64
$LiBF_4$ + EC/DEE (1:1)	3.4	$LiMn_2O_4$ + 10% carbon black	64
$LiBF_4$ + EC/DMC (1:1)	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiAsF_6$ + PC/DME (1:1)	4.7	LiV_3O_8	68
$LiAsF_6$ + PC	5.6	Pt	67
$LiAsF_6$ + PC/DME (1:1)	4.7	Pt	67
$LiAsF_6$ + EC/DMC (1:1)	4.7	$LiMn_2O_4$ + 10% carbon black	64
$LiAsF_6$ + EC/DEE (1:1)	3.9	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + EC/DEE (1:1)	3.8	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + EC/DMC (1:1)	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + PC	5.0	Ni	66, 67
$LiPF_6$ + PC	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + PC/EC (1:1)	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + DMC	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + DEC	3.8	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + PC/DMC (1:1)	>5.1	$LiMn_2O_4$ + 10% carbon black	64
$LiPF_6$ + EC/DEC (1:1)	>4.8	$LiMn_2O_4$ + 10% carbon black	64

[153] Ex. 1011; Ex. 1013; Ex. 2020; Ex. 2014.

[154] Ex. 2023 at 3649.

[155] *Id*. at 3652-3654.

211. Despite the existence of such electrolyte, Arora et al. still limited the half-cell voltage of $LiMn_2O_4$ to 4.2V.[156] Similarly, Abe, which is dated years after Guyomard, still limited the charge cutoff voltage at most to 4.1V.

212. Accordingly, even if a POSITA would have been motivated to increase the charge cutoff voltage of $LiMn_2O_4$ (they would not given the concern of cathode dissolution and the lack of capacity increase by the increase of charge cutoff voltage), they would not have had a reasonable expectation of success in obtaining a battery with excellent cycle life.

XI. CLAIMS 9-10 ARE NOT OBVIOUS OVER ABE IN VIEW OF GUYOMARD AND IWAIZONO (GROUND 10)

213. Petitioner asserts that claims 9-10 are obvious over Abe in view of both Guyomard and Iwaizono. For the same reasons as discussed above, because a POSITA would not have been motivated to combine Abe with Guyomard with a reasonable expectation of success, adding Iwaizono would not cure the deficiencies. Accordingly, claims 9-10 are not obvious over Abe in view of Guyomard and Iwaizono.

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[156] *Id*. at 3649, Fig. 3.

XII. DECLARATION

214. I hereby declare that all statements made herein of my own knowledge are true and all statements made herein on information and belief were and are believed by me to be true, and that all statements herein were and are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that any such willful false statements may jeopardize the validity of the application or any patents issued thereon. If called to testify as to the truth of the matters stated herein, I could and would testify competently.

215. I declare under penalty of perjury that the foregoing is true and correct.

Respectfully submitted,

Dr. Yan Yao

Dated: May 15, 2024