

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Kim et al.
U.S. Patent No.: 9,457,541 Attorney Docket No. 57533-0005IP1
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Appl. Serial No.: 13/722,585
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Title: COPPER FOIL FOR CURRENT COLLECTOR OF LITHIUM
SECONDARY BATTERY WITH IMPROVED WRINKLE
CHARACTERISTICS

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DECLARATION OF DR. JACK JOSEFOWICZ

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I, Dr. Jack Josefowicz, of Westlake Village, California, declare that

1. I have been retained by Solus Advanced Materials Co., Ltd. (“Petitioner”) in connection with the above-captioned petition for Inter Partes Review (“IPR”) of U.S. Patent No. 9,457,541 to Seung Min Kim, et al. (“the ’541 Patent”). I understand the ’541 Patent is currently assigned to SK Nexilis Co., Ltd. (“Patent Owner”). I have been asked to provide my independent analysis of the ’541 Patent based on the prior art publications cited in this declaration.

2. I have been asked by Petitioner to offer opinions regarding the ’541 Patent, including the unpatentability of claims 1-4 (which I may refer to subsequently as the “Challenged Claims”) in view of certain prior art. This declaration sets forth the opinions I have reached to date regarding these matters.

3. I am being compensated by Petitioner at my standard hourly consulting rate for my time spent on this matter. My compensation is not contingent on the outcome of the IPR or on the substance of my opinions.

4. I have no financial interest in Petitioner or Patent Owner.

I. QUALIFICATIONS AND BACKGROUND INFORMATION

5. I have provided my full background in my attached curriculum vitae (“CV”). (Appendix A). As indicated in my CV, I received a B.Sc. in Mathematics and Physics from Concordia University, Montreal, in Montreal, Quebec, Canada, in

1969. In 1975, I earned my Ph.D. in Physics from the University of Waterloo, in Waterloo, Ontario, Canada. In 1975, I secured the position of Research Associate at Harvard University in Cambridge, Massachusetts.

6. In my tenure as senior scientist at Hughes Research Laboratories (1984-1996), I designed and innovated new thin film deposition methods and techniques used in semi-conductor device fabrication. I have extensive experience in thin film coating methods (atomic and molecular layer by layer deposition processes; quantum well structures; epitaxial growth and lattice matching) including electron beam deposition of metals, semi-conductors, optical coatings, and insulators. I designed equipment that performed the multi-target sputtering of metals and semi-conductors, thermal evaporation depositions of metals and insulators and semi-conductors, radio frequency (RF) plasma deposition of metals, semi-conductors, and insulators, as well as spin coating techniques in photolithography and electron beam lithography. I have hands on experience in measuring the mechanical properties of thin films and foils to determine stress and strain properties with the intension of minimizing the compressive and tensile stress in the materials.

7. I also have extensive experience in surface science of thin film properties, including optical and electronic applications for light emitting diode (LED) device design, LED light fixture design and optimization, LED Light Engine printed circuit boards (PCB), advanced electronics for LED power supply drivers

and controllers, electronic system prediction analysis for reliability, semiconductor materials and design for high reliability of design in p-n junctions such as LED devices, and lithium-ion battery development for space satellites.

8. During my tenure at Tyco Electronics as Director of Technology and R&D (1996-2008), I headed engineering divisions in 13 manufacturing facilities around the world. My work involved oversight of engineering and development groups working on advanced and high reliability design of PCBs, including metal core heat sink PCBs used as LED light engines and power supply drivers. My technical programs included PCB thin film surface mount finishes, design for solder joint reliability, process manufacturing optimization, design for manufacturability, and automation of complex process manufacturing in facilities at nine Tyco Electronics manufacturing factories, including “best practice,” statistical process control (SPC), and reliability testing.

9. I also was responsible for collaborative engineering development that improved PCB assembly and improved the reliability and strength in solder joints formed during reflow in automated assembly lines. I also served as an active member of IPC PCB surface finishes committees and participated in writing acceptance standards and specifications for surface finishes such as hot air solder level, immersion silver, electroless Ni immersion Au, and organic solderable protective coatings. I was also active in IPC committees that worked on copper electrochemical

plating for planar and through-hole plating applications.

10. In 2008, I helped found LED Roadway Lighting (LRL) Limited. As Executive VP of Technology, I led a team of physicists and engineers, including electrical and mechanical engineers, in the invention and development of new globally acclaimed high efficiency and high reliability LED streetlights, including electronics power supply driver, LED control systems including dimming and on/off controls, optics design, and fixture housing design for optimized thermal management. I also directed the qualification of suppliers for all the components that included electronic devices and components, PCB suppliers, die cast and mould design. I led a team in lean manufacturing, as well as design for manufacturing, parts, and system integration in the manufacturing of the new LED lights.

11. I am currently an independent consultant, working in the fields of PCB fabrication processes and design for manufacturability, LED device design, LED lighting, Li-Ion battery design and performance, and aerospace electronic systems. I have served as an expert technologist in finding the root cause for solder joint fractures on PCB surface mount pads. I also have extensive experience in semiconductor electronics, optical materials, electronic micro-devices, and electronic systems design. I have also served as expert witness in cases involving electronic system failures and root cause determination.

12. I have broad experience in designing, engineering, and developing

specifications for LED surface mounting, including layout of discrete LEDs, selection, and design of printed circuit material for LED light engines (including metal core PCBs) and design for surface mounting, the selection and specification of surface-mount pad materials and surface coating. I am a listed inventor of 22 patents, including LED related technology, and am an author of over 50 refereed academic science journal articles, commercial publications, and presentations.

13. I have been retained on behalf of Solus Advanced Materials Co., Ltd. to offer technical opinions relating to the '541 Patent and prior art references relating to its subject matter. I have reviewed the '541 Patent, and relevant excerpts of the prosecution history of the '541 Patent. I have also reviewed the following references:

SOLUS-1001	U.S. Patent No. 9,457,541 (“the '541 Patent”)
SOLUS-1002	U.S. Patent No. 9,457,541 File History
SOLUS-1004	Barclay, William R. et al., <i>Electroplating</i> —A Treatise on the Electro-Deposition of Metals with a Chapter on Metal-Colouring and Bronzing, London-Edward-Arnold, 1912
SOLUS-1005	Swantson, Howard and Tatge, Eleanor, <i>Standard X-ray Diffraction Powder Patterns</i> , National Bureau of Standards, Circular 539, Vol. 1, June 15, 1953.
SOLUS-1006	Reserved
SOLUS-1007	U.S. Patent Application Publication No. 2009/0061326 (“Hirose”)

SOLUS-1008	Japanese Patent Application Publication No. JP 2003051340 (“Hara”)
SOLUS-1009	Translation of SOLUS-1008
SOLUS-1010	U.S. Patent Application Publication No. 2004/0029006 (“Otsuka”)
SOLUS-1011	U.S. Patent Application Publication No. 2010/0136464 (“Hanafusa”)
SOLUS-1012	U.S. Patent Application Publication No. 2010/0038115 (“Matsuda”) (now US Patent 8,722,199 from Japanese Patent Application Publications No. JP2006-009321 and JP2005-104540)
SOLUS-1013	Ye, Xingpu, et al. 1992 “Role of Overpotential on Texture, Morphology and Ductility of Electrodeposited Copper Foils for Printed Circuit board Applications”, <i>J. Electrochem. Soc.</i> , Vol. 139, No. 6, 1592 (June 1992) (“Ye”)
SOLUS-1014	Chiang, S.K. DiFranco, D.F. and Pucci, D.G. (1995), “High Strength, Low Profile Copper Foil for High Performance PCBs,” <i>Circuit World</i> Vol. 21 No. 3, pp. 56-59. (“Chiang”)
SOLUS-1015	Reserved
SOLUS-1016	Chinese Patent Publication CN1710737A (“Zhang”), published 2005-12-21
SOLUS-1017	Translation of SOLUS-1016
SOLUS-1018	Kim, Jongsoo and Kim, Heesan, <i>Corrosion Science and Technology</i> , Vol. 6, No. 4, pp. 154-158 (2007). (“Kim”)
SOLUS-1019	U.S. Patent No. 4,695,348 (“Battey”)
SOLUS-1020	U.S. Patent No. 6,451,441 (“Nishimoto”)

SOLUS-1021	U.S. Patent Application Publication No. 2004/0149583 ("Kumagai")
SOLUS-1022	U.S. Patent Pub. No. 2009/0047539 ("Dobashi")
SOLUS-1023	U.S. Patent Pub. No. 2006/0191798 ("Sano")
SOLUS-1024	Reserved
SOLUS-1025	Frederick A. Lowenheim, <i>Modern Electroplating</i> , John Wiley & Sons, 1974 ("Lowenheim")
SOLUS-1026	Reserved
SOLUS-1027	Japanese Patent Pub. No. JP 2007/217787 ("Matsuda-787")
SOLUS-1028	Translation of SOLUS-1027
SOLUS-1029	<i>Surface roughness – Definitions and designation</i> , Japanese Industrial Standard (JIS) B 0601-1994 ("JIS Standard 1994")
SOLUS-1030	<i>Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters</i> ("JIS Standard 2001")
SOLUS-1031	<i>Operating Instructions MarSurf M 300 + RD 18</i> , Mahr GmbH, 2008 ("MarSurf M300 instruction manual")
SOLUS-1032	<i>Surface Roughness Measurement-Parameters</i> , Olympus, https://www.olympus-ims.com/en/metrology/surface-roughness-measurement-portal/parameters/ ("Olympus")

II. OVERVIEW OF CONCLUSIONS FORMED

14. This declaration explains the conclusions that I have formed based on my analysis. To summarize those conclusions, based upon my knowledge and experience and my review of the prior art publications listed above, I believe that:

- Claims 1-4 are obvious over Kim in view of Hara and Otsuka;
- Claims 1-4 are obvious over Ye in view of Hara and Otsuka;
- Claims 1-4 are obvious over Hirose in view of Hara and Otsuka or Matsuda;

III. DESCRIPTION OF THE RELEVANT TIMEFRAME AND LEVEL OF ORDINARY SKILL IN THE ART

15. I understand that the '541 Patent claims a priority date of July 15, 2010, which I will also refer to as the "Priority Date." For the purposes of my analysis, and in the absence of any information to the contrary, I have used the July 15, 2010 date as the relevant date for my analysis of the prior art.

16. In my opinion, a person of ordinary skill in the art ("POSITA") relating to the subject matter of the '541 Patent would have had at least an undergraduate degree in materials science, chemical engineering, electrical engineering, or related field, or equivalent knowledge, training, or experience, with at least two years of experience working on the development of materials or components for electronic devices such as batteries. Additional education, such as a graduate degree, could

compensate for less work experience, and additional work experience could compensate for less formal education.

IV. SUMMARY OF THE '541 PATENT

A. Brief Description

17. I have reviewed and will now summarize the '541 Patent. The '541 Patent purports to describe a “copper foil for a current collector of a lithium secondary battery.” SOLUS-1001, Abstract. As discussed in the '541 Patent's Background, copper foils are commonly used as the anode current collector in lithium secondary batteries. *Id.*, 1:38-40. However, according to the '541 Patent, “In case a wrinkle exists on a surface of a copper foil ... active material is not uniformly coated due to the irregularity of the surface shape, which may cause a short-circuit or separate the active material from the copper foil during a charging or discharging process.” *Id.*, 1:58-62.

18. “Battery characteristics of a lithium secondary battery are greatly changed in accordance with a surface state of a copper foil used as a current collector, so it is very important to improve surface characteristics such as wrinkle characteristics in order to improve a yield.” *Id.*, 1: 53-57.

19. Thus, the '541 Patent's goals are 1) to improve yield, 2) prevent a short circuit, and 3) keep active material on the copper foil during battery operation. The means to achieving these goals are to produce copper foil with certain material

characteristics which also produce a wrinkle-free surface of the copper foil.

20. The '541 Patent purports to provide copper foils “with a crystalline structure capable of decreasing the generation of wrinkles at a surface of the copper foil.” *Id.*, 2:2-4. In this regard, the '541 Patent highlights several features of the copper foils that allegedly provide a decrease in the generation of wrinkles.

21. First, the '541 Patent outlines four specific ratios of texture coefficients, derived from X-ray diffraction measurements, that must fall within defined ranges to ensure proper adhesion of the active material to the copper foil surface. *Id.*, 3:52-4:3. Details of the X-ray diffraction and texture coefficients will be presented below when discussing the claims.

22. Second, the '541 Patent states that the copper foil must have several physical parameters (weight deviation and tensile strength for the independent claims and surface roughness, elongation, and foil thickness for the dependent claims) within certain ranges.

23. “The weight deviation of the copper foil should be 3% or less. If the weight deviation exceeds 3%, property deviations occur at the surface of the copper foil, which may increase the number of wrinkles and make properties of the current collector irregular.” *Id.*, 4: 26-30.

24. The '541 Patent states “the copper foil should satisfy the following conditions: a tensile strength of 30 to 40 kgf/mm², an elongation of 3 to 20%, and a

thickness of 1 to 35 μm . Out of the above ranges, the properties of the copper foil are deviated to increase the number of wrinkles, and the properties of the current collector become irregular.” *Id.*, 4: 40-45.

25. In addition, the ’541 Patent describes “Surface roughness (R_z) of the copper foil should be 2 μm or less, based on JIS (Japanese Industrial Standards). In case the surface roughness (R_z) exceeds 2 μm , the surface is irregular, so a short circuit may occur during a charging or discharging process. In addition, the coating state of the anode active material becomes irregular.” *Id.*, 4:20-25.

26. As I discuss below, each and every element set forth in the claims were well-known in the art. Importantly, while the claims recite specific ranges of values for these characteristics, the ’541 Patent fails to demonstrate, or even suggest, that these ranges are critical to enhancing an electrolytic copper foil with “high adhesiveness to a negative electrode material and a low electrical resistance” that “can be provided by controlling the surface properties of the electrolytic copper foil surface.” SOLUS-1001, Abstract.

27. I have reviewed relevant portions of the file history of the ’541 Patent (SOLUS-1002). The ’541 Patent issued from U.S. Patent App. No. 13/722,585. Prosecution of the ’541 patent, across several Office Actions, cited the following references:

US Patent Publication 2004/0149583 to Kumagai et al., SOLUS-1021

US Patent Publication 2009/0061326 to Hirose et al., SOLUS-1007

US Patent 6,451,441 to Nishimoto et al., SOLUS-1020

US Patent 4,695,348 to Battey et al., SOLUS-1019

US Patent Publication 2010/0038115 to Matsuda et al., SOLUS-1012

28. The application was subsequently allowed after several rounds of minor amendments and a Terminal Disclaimer. As to the reason for allowance, the Notice of Allowance stated that “The prior art of record does not teach or suggest a copper foil having the claimed texture coefficients so as to prevent wrinkle generation.” (SOLUS-1002, 21)

29. The reasons for allowance suggest that the Examiner’s consideration of the prior art was incomplete, however. Indeed, the file history contains no indication that the Examiner had been presented with or considered Kim (SOLUS-1018), Hara (SOLUS-1008), Otsuka (SOLUS-1010), or Ye (SOLUS-1013)—i.e., the references presented in Grounds 1-3 of this Petition—during original examination of the ’541 Patent. If these references had been fully considered, the Challenged Claims should not have been allowed and the ’541 Patent should not have issued.

V. TECHNICAL BACKGROUND

A. Historical Perspective of Copper Electroplating and Additives

30. The manufacture of electrolytic copper foil as well as the process

involved were mature technology long before the Priority Date. Although an exact date for the first application of electroplating to metals is uncertain, it is Giovanni Beccaria who was acknowledged as the father of electroplating and who did the first experiment, depositing metal by discharging a Leyden bottle and using the spark to decompose metal salts in 1772. Next came Luigi Brugnatelli, who in 1803 successfully electroplated a thin layer of gold onto a silver coin. After these accomplishments, electroplating development languished until the beginning of the 20th century when the physics and engineering understanding of electricity allowed for the development of electricity generators that would support scale up of electrochemical plating for technological applications such as batteries, automotive, aircraft and aerospace, home appliances and many other products that benefited from electroplating of metals on large and small surfaces.

31. In the year of 1912, Barclay and Hainsworth co-wrote a book entitled, **“Electroplating.”** SOLUS-1004, cover page. Even though it was early in the 20th century, in chapter 11 on the electroplating of copper, the authors wrote:

“Many years ago Sir J. W. Swan drew attention to the fact that exceedingly minute additions of glue or gelatine to some copper depositing solutions exercised an important modifying influence on both the conductivity of the solutions and the character of the deposit. In the case of solutions of copper nitrate, for example, which under ordinary circumstances do not give at all a satisfactory deposit of copper, the addition of a very small proportion of glue made it possible to obtain a beautifully

smooth, reguline, and coherent deposit of copper at a fairly high rate of deposition.”

“Since that time many operators have made use, to a greater or lesser extent, of what are now generally known as "addition agents " not merely to copper solutions but to those of other metals, as has already been indicated. In this connection, however, electrolytes of copper have been more extensively experimented with than have other metals, as indeed is natural in view of the extensive applications of copper depositing.”

SOLUS-1004, 248.

32. As such, the efficacy of additives to achieve desirable characteristics of surface roughness, structural features, and strength for metal foils was known as early as 1912. In 1912, it was already clear to Barclay and Hainsworth, as well as other practicing electrochemists, that additive agents have a significant beneficial influence on the resulting deposit of a metal film or foil as it related to surface roughness, structural features and strength. SOLUS-1004, 168, 208, 248, 249, 250, 251, 259, 307, 313, 320, 327, 333, 336.

33. By 2007, the use of organic additives was revealed as a means of controlling metal foil characteristics. For example, Jongsoo Kim and Heesan Kim published a scientific paper in 2007 in which the use of organic additive agents was shown to control characteristics in metal foils related to surface roughness, surface

morphology, internal stress, and texture coefficient. SOLUS-1018, 1-5¹.

34. In their paper, Jongsoo Kim and Heesan Kim use a host of organic additives for copper plating that function as inhibitors, levelers and accelerators. For example, in their introduction, it is stated:

“As inhibitors with 100~100,000 molecular weight, polymers including oxygen suppress charge transfer on the electrode surface during plating.1),2) There are polyethylene glycol (PEG), polyethylene oxide (PEO), polypropylene glycol (PPG), gelatin, and so on. The inhibiting action is explained by adsorption of inhibitor-Cl complex with chloride ion1),3)-6) behaving as uniform barrier to suppress charge transfer.1),7) As levelers, organic compounds including nitrogen such as benzotriazole (BTA), janus green B (JGB), and so on also suppress charge transfer on the electrode surface during plating. However, levelers effecting transport in electrolyte are preferentially adsorbed on the sites such as protrusions and corners to prevent formation of protrusion.5),8)-10) As accelerators, the following organic compounds including sulfur promote charge transfer on the electrode surface: 3-mercapto-1-propane sulfonic acid (MPSA), Bis-(3-sodiumsulfopropyl) disulfide (SPS), 3- N,N-dimethylaminodithiocarbamoyl-1-propanesulphonic acid (DPS), etc.”

SOLUS-1018, 1.

35. The paper shows that through use of different organic additives from the list in the above paragraph, both the surface roughness and the texture coefficient

¹ Hereinafter, unless otherwise noted, I will be referring to the page number of the PDF document.

would be changed in the electroplated copper films in a controlled manner. For example, using different additives can achieve desired surface roughness characteristics such as Ra and Rz. As clearly shown in Fig. 2 below, the surface roughness would be controlled between about 10 nm and 50 nm in a controllable way using different additives at different concentrations. SOLUS-1018, 3.

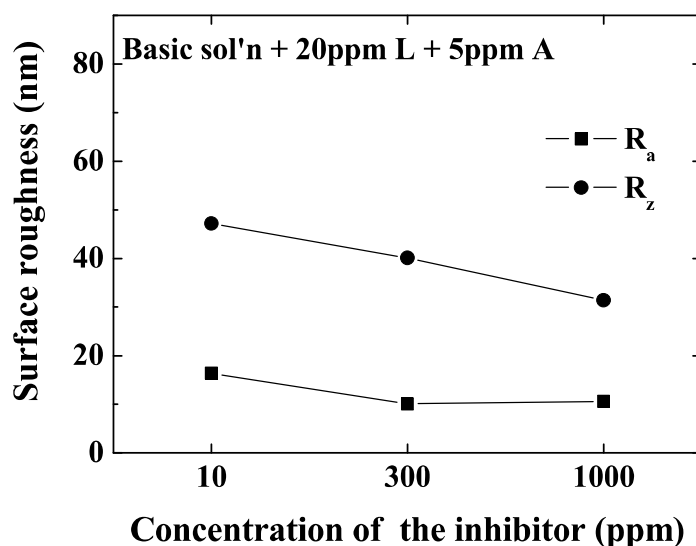


Fig. 2. Surface roughness with the concentration of the inhibitor (I: inhibitor, L: leveler, A: accelerator).

SOLUS-1018, FIG. 2

36. Additionally, the 2007 paper Kim (SOLUS-1018) shows that texture coefficient may be controlled through use of additives. Table 1 from the publication, shown below, divulges that the addition of accelerator in the plating bath caused the preferred plane to be changed from (220) to (200) as well as decreasing the residual stress. On page 155 of the paper, the definition of texture coefficient is shown below,

which is precisely the same definition as used in the '541 Patent:

The texture coefficient, TC of the (hkl) plane is defined by equation (3).

$$TC(hkl) = n \frac{I(hkl)/I_o(hkl)}{\sum I(hkl)/I_o(hkl)} \quad (3)$$

where $I(hkl)$ and $I_o(hkl)$ are the integrated intensities of (hkl) reflections measured for the copper plated film and a standard copper powder sample, respectively and n is the total number of reflection planes.

SOLUS-1018, 2.

37. Further, Table 1 below shows that, by using different organic additives, significant changes to the texture coefficient and the residual stress can be made:

Table 1. Relation between residual stress and preferred plane formed during plating (I: inhibitor, L: leveler, A: accelerator).

Electrolyte	Texture coefficient			Residual stress (MPa)	Preferred plane
	(111)	(200)	(220)		
300ppm I + 20ppm L	0.23	0.30	2.47	6.92	(220)
300ppm I + 20ppm L + 5ppm A	0.88	1.15	0.97	0	(200)

SOLUS-1018, Table 1.

38. All the discussion above relates to advancements and knowledge gained in the field of electrochemical deposition of copper before the Priority Date. A POSITA would have been familiar with such published results, which demonstrate that all the claims in the '514 Patent that are referred to as inventions already were not novel and fully disclosed in the published domain. A POSITA would have had knowledge that the characteristics, such as texture coefficient, surface roughness, and mechanical properties would be controlled by selecting from organic additive

agents as well as inorganic additives when electroplating copper.

VI. CLAIM INTERPRETATION

39. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning.” In determining the ordinary and custom meaning, the words of a claim are first given their plain meaning that those words would have had to a POSITA. I understand that the structure of the claims, the specification, and the file history also may be used to better construe a claim insofar as the plain meaning of the claims cannot be understood. I have followed this approach in my analysis.

40. I also understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by a POSITA. I further understand that the words of the claims should be given their plain meaning unless that meaning is inconsistent with the patent specification or the patent’s history of examination before the Patent Office. I also understand that the words of the claims should be interpreted as they would have been interpreted by a POSITA at the time of the invention was made.

VII. PRIOR ART ANALYSIS

A. [GROUND 1] — Claims 1-4 are Obvious over the Kim-Hara-Otsuka Combination

41. It is my opinion that a POSITA would have found claims 1-4 to be

obvious over the combination of Kim, Hara, and Otsuka, as I discuss in the following sections.

1. Overview of Kim

42. Kim analyzes the effects of organic additives (e.g., inhibitors, levelers, and accelerators) on the surface smoothness and internal stress of electroplated copper foils used in flexible printed circuit board (PCB). SOLUS-1018, Abstract.

43. As an initial matter, Kim explains that among such organic additives, *inhibitors* and *levelers* slow down the overall copper deposition, and lead to a copper foil having a *smoother surface but an increased internal stress* of the copper layer. *Id.*, 1 (“As inhibitors with 100~100,000 molecular weight, polymers including oxygen suppress charge transfer on the electrode surface during plating . . . The inhibiting action is explained by adsorption of inhibitor-Cl complex with chloride ion behaving as uniform barrier to suppress charge transfer,” and “As levelers, organic compounds including nitrogen such as benzotriazole (BTA), janus green B (JGB), and so on also suppress charge transfer on the electrode surface during plating. However, levelers effecting transport in electrolyte are preferentially adsorbed on the sites such as protrusions and corners to prevent formation of protrusion.”), Abstract (“The inhibitors and the leveler increased residual stress, whereas the accelerator decreased it”).

44. Moreover, Kim explains that among such organic additives,

accelerators, when used in controlled amounts, enhance copper deposition in the lower areas or valleys, and lead to a copper foil having a *smoother surface and reduced internal stress reduced internal stress*. *Id.*, Abstract (“The accelerator plays a role in accelerating the electroplating in valley parts . . . The inhibitors and the leveler increased residual stress, whereas the accelerator decreased it”).

45. Kim also discloses the *texture coefficient (TC)*, which provides insight into the dominant crystal planes within the electroplated copper. *Id.*, 2, Equation 3 (reproduced below, annotated). Kim found that the *accelerator shifts the preferred crystal orientation from the (220) plane to the (200) plane*, which is *associated with lower internal stress*. *Id.*, 4 (“Table 1 shows that that the accelerator caused preferred plane to be changed from (220) to (200) as well as decreased the residual stress. Based on the results, the organic additive can be thought to determine the preferred plane and thereby to decide the residual stress”).

46. Kim’s findings highlight the *accelerator’s* beneficial effect in *reducing internal stress* while *improving surface properties*. These are reflected in below Table 1 (annotated) and Figure 4 (annotated), which illustrate how the use of the accelerator produces a crystal orientation with [1] reduced internal stress and [2] a smoothened surface, exhibiting corresponding TC ratios and Rz values that fall within the claimed ranges of the '541 patent, as will be further described below. *Id.*, Table 1 and FIG. 4 (reproduced below, annotated).

Table 1. Relation between residual stress and preferred plane formed during plating (I: inhibitor, L: leveler, A: accelerator).

Electrolyte	Texture coefficient			Residual stress (MPa)	Preferred plane
	(111)	(200)	(220)		
300ppm I + 20ppm L	0.23	0.30	2.47	6.92	(220)
300ppm I + 20ppm L + 5ppm A	0.88	1.15	0.97	0	(200)

SOLUS-1018, Table 1 (annotated)

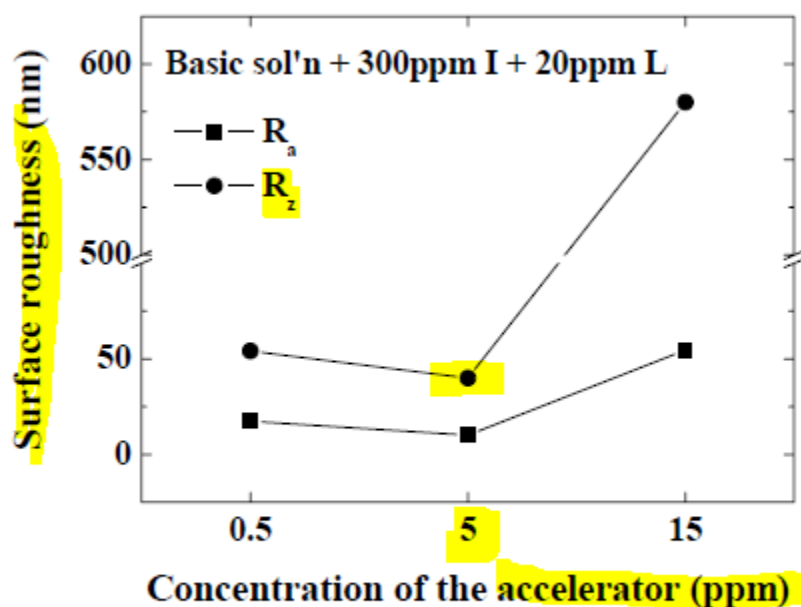


Fig. 4. Surface roughness with the concentration of the accelerator (I: inhibitor, L: leveler, A: accelerator).

SOLUS-1018, FIG. 4 (annotated)

47. Last, but not least, as described above with respect to “Historical Perspective of Copper Electroplating and Additives” section, Kim further shows that by using different additives at varying concentration in the plating solution, copper foil properties can predictably be adjusted including, TC, surface roughness and residual stress in electroplated foils of similar thickness. A POSITA would have

been intimately familiar with the role additives play in electroplating of foils and would have understood how to change the physical properties that are presented as invention in patent 541. *See* ¶¶ 33-38.

2. Overview of Hara

48. Hara describes copper foils used as negative electrodes for lithium secondary batteries. More specifically, Hara seeks to provide “lithium secondary batteries with *small variations in battery capacity* and *long life*.” SOLUS-1009, Abstract.

49. In this regard, as it is disclosed in patent 541 claim 1 where weight deviation is stated as 3% or less, and an elongation in claim 3, of 3 to 20%, Hara discloses an electrolytic copper foil that is “used for the negative electrode current collector with *a variation in weight per unit area of 2% or less* and *an elongation rate of 5% or less*.” *Id.*, Abstract, [0012]. According to Hara, “since an electrolytic copper foil with a weight variation per unit area of 2% or less is used for the negative electrode current collector, *the variation in thickness of the negative electrode current collector can be suppressed and the electrode reaction can be made uniform*” and “since an electrolytic copper foil with an elongation of 5% or less . . . the distortion when pressed to a predetermined bulk density is small, *preventing the occurrence of spontaneous short circuits*, and *a battery with small variation in*

battery capacity and long life can be obtained.” Id., [0012], [0063]. Further, in such cases, Hara describes that “it is preferable that the negative electrode current collector has a *thickness of 7 μm to 25 μm and a surface roughness R_z of 2.0 μm or less.” Id.*, [0013]. This compares with the ’541 patent’s claims 2 and 4 that disclose a surface roughness R_z of 2 μm or less and a thickness of 1 to 35 μm , respectively.

50. Hara also recognizes that “[i]f the negative electrode stretches too much, it will undulate in the width direction, causing problems such as *wrinkles during the winding process* and misalignment of the opposing positive and negative electrodes.” Id., [0008].

3. Overview of Otsuka

51. Otsuka describes “*An electrodeposited copper foil* having an extremely smooth surface roughness at the deposition surface, *having an extremely fine crystal structure*, and yet not having too high an ordinary temperature *tensile strength*, superior in *elongation*, maintaining a stable strength without softening by heat even after heat treatment, and having a *high elongation rate* even in a high temperature atmosphere. The electrodeposited copper foil has a *surface roughness R_z at a deposition surface at ordinary temperature smaller than 2.5 μm in terms of 10-point average roughness R_z* , has a minimum distance between peaks of a base foil peak of at least 5 μm , has an ordinary temperature *tensile strength of not more than 40*

kg[f]/mm²,² and has a drop in ordinary temperature tensile strength after heat treatment at 130 °C for 15 hours of less than 15%. ***Also, copper foil for a secondary battery collector using that foil.***” SOLUS-1010, Abstract.

4. The Kim-Hara-Otsuka combination

52. In my view, it would have been obvious to a POSITA to combine the teachings of Kim, Hara, and Otsuka, the combination of which would render obvious the claimed copper foil of the '541 patent.

53. Although I discuss a modification to a copper foil, I do not believe that any modifications to Kim would actually be necessary in order to obtain the copper foils recited in claims 1-4. Kim discloses electrolytic copper films having [1] TC ratios, [2] thickness values, and [3] Rz values that fall within the claimed ranges of the '541 Patent. While Kim does not mention specific [1] weight deviation, [2] tensile strength values, and [3] elongation values, Hara provides ***teachings of such weight deviation values*** and ***elongation values***, and Otsuka provides teachings of

² Here, Otsuka used 'kg/mm²' when 'kgf/mm²' was intended. A POSITA would have understood that the actual measure of tensile strength is in kgf/mm² (kilogram-force per square millimeter), not kg/mm² (kilogram per square millimeter).

tensile strength values and *elongation values*, which fall within the claimed range of the '541 Patent. As such, the combination of Kim with Hara and Otsuka discussed with respect to claims 1-4 should not be taken to indicate any substantive difference between Kim's copper foil and that recited in the '541 Patent. Rather, the combination accounts for claim 1's recitation of specific material properties that do not appear to have been measured together in any single identified reference or were not mentioned together in any single reference.

54. At least for the following reasons, it is my opinion that it would have been obvious to a POSITA to have combined Kim with Hara and with Otsuka, because there are sufficient motivation and guidance for modifying Kim's copper foil to obtain the desired ratios of the texture coefficients while taking advantage of Hara's disclosed weight deviation of $\leq 2\%$ and elongation $\leq 5\%$ and Otsuka's disclosed tensile strength $\leq 40 \text{ kgf/mm}^2$.

55. Kim discloses copper foil for use in PCB, which is also compatible for use with secondary batteries. Such use compatibility of electrolytic copper foil between PCBs and the secondary batteries was well-known at the time. Accordingly, a POSITA would have easily recognized such use compatibility of electrolytic copper foil, which is also evidenced by prior art. SOLUS-1022, [0107]; SOLUS-1023, [0001], [0005], [0012], [0066]; SOLUS-1012, [0011], [0012], [0052].

56. A POSITA seeking to utilize or optimize Kim's electroplated copper foil (e.g., electrolytic copper foil) for use in secondary batteries would have looked at other references, including Hara and Otsuka, and would have recognized that factors such as weight deviation, elongation, and tensile strength are important for further optimizing Kim's copper foil for use in secondary batteries.

57. Specifically, for example, Hara describes that an electrolytic copper foil having "*weight variation per unit area of 2% or less*" and "*elongation of 5% or less*" prevent "the occurrence of spontaneous short circuits" and helps obtaining "a battery with small variation in battery capacity." SOLUS-1009, [0012], [0063]. Further, for example, Hara describes that "by using electrolytic copper foil with a *weight variation of 2% or less*, a thickness of 10 μm , and a surface roughness of Rz of 2.0 μm or less in the negative electrode current collector, a battery with *excellent cycle life characteristics can be realized*." *Id.*, [0013], [0051].

58. Furthermore, Otsuka describes that an electrolytic copper foil with a *tensile strength* of "*not more than 40 kg[f]/mm²*" maintains or enhances adhesion between a current collector and an active material of the battery, which results in superior "charge/discharge cycle life and productivity" of secondary batteries. SOLUS-1010, Abstract, [0020], [0029], [0033], [0030]-[0031] ("Further, to obtain sufficient battery characteristics, it is important to make the distance between active material particles and between the active material and collector smaller and to have

the collector deform in shape accordance with the shape of the active material surface. If the charge collector deforms in accordance with the active material surface, the contact between the active material and collector becomes better, the electroconductivity becomes further greater, and the charge/discharge cycle life is improved. . . Therefore, the ordinary temperature tensile strength must not be more than 40 kgf/mm². If the ordinary temperature tensile strength is more than 40 kgf/mm², the softness of the copper foil itself is insufficient and the deformation of the copper foil along the active material surface in the processing for rolling or other press flattening performed after coating the active material does not sufficiently occur, so the contact with the active material becomes poor, the capacity deteriorates, and the charge discharge cycle life drops and these are not preferable.”)

59. Henceforth, at least for the reasons set forth above, it is my opinion that a POSITA would have been motivated to optimize Kim’s electrolytic copper foil for use in secondary batteries by incorporating the teachings of Hara and Otsuka to optimize weight deviation, elongation, and tensile strength values.

60. Further, it is my opinion that a POSITA would have expected success at least for the following reasons.

61. Since both Hara and Otsuka focus on providing electrolytic copper foils for use in lithium-ion secondary batteries and the use compatibility of electrolytic copper foils between the PCB and secondary batteries was well known, a POSITA

would have expected success in incorporating the teachings of weight deviation, elongation, and tensile strength values of Hara and Otsuka.

62. The fact that electrolytic copper foils with weight deviation were generally and commercially available indicates that a POSITA would have recognized the ease of applying such teachings and that copper foils were being produced in the industry with the desired range of different weight deviation characteristics. For example, as described above, Hara describes in one of their examples that such an electrolytic copper foil with the desired weight deviation of 2% or less is obtained from commercially available suppliers such as “Furukawa Circuit Foil Co., Ltd.” SOLUS-1009, [0027]. It is my opinion that, in regard to use of copper foil for a current collector of a negative electrode of secondary battery, it would have been obvious to a POSITA to use an electrolytic copper foil with minimal weight variance across the foil, but this may have gone unnoticed due to the pedestrian nature of this observation.

63. Furthermore, in addition to or as part of my explanation above in the “Historical Perspective of Copper Electroplating and Additives” section, the optimization of weight deviation, elongation, and tensile strength values in copper foil would have involved a mere routine optimization of electrodeposition conditions, such as varying concentrations of additives (e.g., organic additives), electrolysis solution chemistry, which includes copper sulfate and sulfuric acid,

treatment time, and/or current density and other plating parameters such as solution agitation and temperature. *See ¶¶30-38.* For example, it was conventional to vary the electrolyte concentration, electrolysis plating parameters, temperature, and the use of organic and inorganic additives, in order to obtain a copper foil with tensile strength and elongation values falling within the claimed ranges as these ranges were well known, at least since 1974, as illustrated below.

Outstanding Characteristic	Tensile Strength, kg/mm ²	Elongation, % (5cm)	Internal Stress, ^c kg/mm ²	Hardness (VHN ₂₀₀), kg/mm ²	Electrical Resistivity, microhm-cm
High strength	45-63.5	4-18	-4.2 or 3.6 to 5.5	131-159	1.75-2.02
Hardness	3.5-55.5	0-10	-4.2 or 3.0	193-350	1.96-4.60
Low electrical resistivity	18.5-27	15-41	-0.5 to -1.6	48-64	1.70-1.73
Near zero stress	14-16	8-24	-0.08-0.06	56-57	1.71-1.72
Good leveling	36-36.5	14-19	2.0	128-137	1.82
Thermal stability ^b	22.5-30	26-39	0.5-2.9	55-106	1.73-1.76

^aNegative values indicate a compressive stress.
^bDeposits that changed less than 0.02% in length after heating to 400°C.

SOLUS-1025, 18

64. Thus, it is my opinion that a POSITA would have been motivated to apply or optimize weight variation, tensile strength, and elongation features on Kim's electrolytic copper foil and expected success.

5. Analysis

(i) Claim 1

[1pre] A copper foil for a current collector of a lithium secondary battery:

65. As I demonstrate below, Kim renders obvious [1pre]. For example, Kim discloses an electroplated copper foil (e.g., electrolytic copper foil) for use in PCBs, which is also compatible for use in the current collector of a lithium-ion secondary battery. Such use compatibility of electrolytic copper foil between the PCB and the secondary batteries was well-known. SOLUS-1022, [0107]; SOLUS-1023, [0001], [0005], [0012], [0066]; SOLUS-1012, [0011], [0012], [0052]. Henceforth, in the combination, Kim discloses a copper foil for a current collector of a lithium-ion secondary battery.

[1a] wherein, in a crystalline structure, a ratio of a sum of texture coefficients of a (111) surface and a (200) surface to a total sum of texture coefficients of the (111) surface, the (200) surface and a (220) surface is 60 to 85%,

a ratio of a texture coefficient of the (111) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 18 to 38%,

a ratio of the texture coefficient of the (200) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 28 to 62%,

and a ratio of the texture coefficient of the (220) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 15 to 40%,

[1b] wherein the texture coefficient satisfies the following equation:

$$TC(hkl) \geq \frac{\frac{I(hkl)}{I_0(hkl)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

wherein $I(hkl)$ represents a measured diffraction intensity with respect to a (hkl) surface, and $I_0(hkl)$ represents a standard diffraction intensity of ASTM (American Society of Testing Materials) standard powder-shaped diffraction data,

66. As I demonstrate below, a disclosure of the foregoing values within the claimed range renders obvious [1a]-[1b].

67. The texture coefficient is a measure of the prominence of the x-ray diffraction (XRD) peak of a given plane, relative to other planes.

Table 1. Relation between residual stress and preferred plane formed during plating (I: inhibitor, L: leveler, A: accelerator).

Electrolyte	Texture coefficient			Residual stress (MPa)	Preferred plane
	(111)	(200)	(220)		
300ppm I + 20ppm L	0.23	0.30	2.47	6.92	(220)
300ppm I + 20ppm L + 5ppm A	0.88	1.15	0.97	0	(200)

SOLUS-1018, Table 1 (annotated)

68. Kim's Table 1 above shows texture coefficients for two of Kim's copper foils. SOLUS-1018, Table 1 (annotated, reproduced above). As described above in the "Overview of Kim" section, Kim describes how the use of accelerator produces a crystal orientation with [1] reduced internal stress and [2] a smoothened surface, exhibiting corresponding TC ratios that fall within the claimed range of the '541 patent. The copper foil data showing the TC ratios that fall within the claimed range is presented in the row labelled "300ppm I + 20ppm L + 5ppm A" in Table 1. SOLUS-1018, 5, Table 1. This copper foil data in Table 1 of Kim has been used to calculate four TC ratios recited in [1a]-[1b], as outlined in Tables 1 and 2 below. Here, Table 1 provides a simplified visualization of the data (second sample copper foil) labelled "300ppm I + 20ppm L + 5ppm A" in Table 1 of Kim. Further, Table 2 presents the TC ratio calculations, which fall within the claimed ranges.

69. Table 1. Kim texture coefficients

Peak	TC(hkl)
(111)	0.88
(200)	1.15
(220)	0.97

70. Table 2. Kim ratio check

Ratio	Claimed Lower Limit	Ratio Value	Claimed Upper Limit
1 st ratio = (111) + (200)	60%	67.7%	85%
2 nd ratio = (111)	18%	29.3%	38%
3 rd ratio = (200)	28%	38.3%	62%
4 th ratio = (222)	15%	32.3%	40%

71. As shown, the example of Kim shown in Table 3 falls within the ratio ranges for all four ratios. Thus, in the combination, Kim discloses copper foils within the limits of the ratios of the texture coefficients as recited by the '541 patent, rendering obvious [1a]-[1b].

72. Additionally, the electrodeposition process described by the '541 patent represents no great departure from that described in Kim. Both references describe deposition at similar temperatures, using similar current densities, in solutions composed primarily of similar amounts of copper ions and sulfuric acid. This would highly likely have yielded the claimed TC values, either with additives chosen from a broad range of those already used in electrochemistry that were analyzed for their effect on copper foil structure and mechanical properties, as discussed in the introduction or potentially without the inclusion of the additives mentioned by the '541 patent.

73. Regarding the X-ray diffraction normalization standards, to my knowledge, the most relevant one used for copper is the ICDD 04-0836 standard

which is also known by its former name JCPDS 04-0836. This standard is based, ultimately on Standard X-ray Diffraction Powder Patterns from the National Bureau of Standards Circular 539 (see below). The standard normalization peaks I_0 for the (111), (200), and (220) planes of copper are 100, 46, and 20. SOLUS-1005, 20, Table 5 (reproduced below, annotated).

NBS Circular
#539, Vol. 1
Standard X-
ray Diffraction
Powder
Patterns
UNITED
STATES
DEPARTMENT
OF
COMMERCE
NATIONAL
BUREAU OF
STANDARDS
Pp. 16

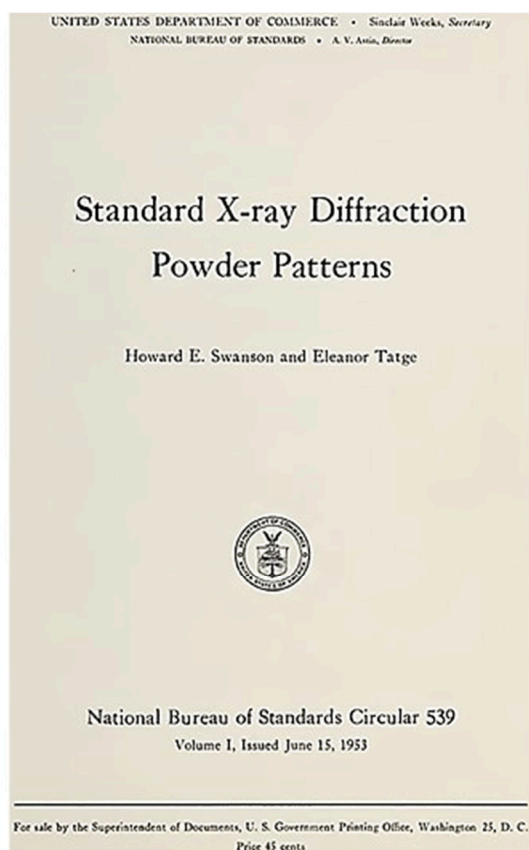


TABLE 5. Copper (cubic)

hkl	1953 Swanson and Tatge Cu. 1.5405 Å, 26° C		
	d	I	a
111	2.088	100	3.617
200	1.808	46	3.6154
220	1.278	20	3.6150
311	1.0900	17	3.6151
222	1.0436	5	3.6151
400	0.9038	3	3.6152
331	.8293	9	3.6148
420	.8083	8	3.6148
422	-----	-----	-----
Average for 1 lines.	-----	-----	3.6150

*As lines of
*Average of three lines of

SOLUS-1005, Table 5 (annotated)

74. Kim does not explicitly mention specific X-ray diffraction peak intensities nor a specific normalization standard, but does recite the exact same equation for the texture coefficient (SOLUS-1018, 2) as recited by the '541 Patent.

Even if an alternative standard for normalizing the peak intensities was used, other than the JCPDS 04-0836 standard cited in the Information Disclosure Statement filed with the application, the values of the standard intensity peaks do not vary much from one update to another. SOLUS-1001, 1; SOLUS-1002, 571. A previous standard, the JCPDS 98-062-7113, recited normalization values which differed from those of the JCPDS 04-0836 standard by at most 12%. Even applying this largest percentage shift in a normalized peak intensity to all three of the peaks involved, the variations would still not sufficient to change the outcome that Kim's second film of Kim's Table 1 has X-ray diffraction texture coefficients which are within the claimed ranges.

[1c] wherein the copper foil has a weight deviation of 3% or less,

75. As I demonstrate below, in the Kim-Hara-Otsuka combination, Hara renders obvious [1c].

76. As an initial matter, weight variation in Hara equates to weight deviation in [1c]. For example, according to the '541 Patent, "the weight deviation is obtained by cutting a copper foil by an area of 5 cm×5 cm to make a test piece, *measuring weight of the test piece and converting the weight into a weight of the copper foil per a unit area*, cutting the test piece along a width direction of the copper foil, *repeating the above processes to measure weights of copper foils of*

every test piece, and then calculating a standard deviation.” SOLUS-1001, 4:30-

39. As such, the '541 Patent's determination of "weight deviation" first measures the weight of a standard area and "converting the weight into a weight of the copper foil per a unit area," in which the "weight deviation" is the equivalent of Hara's "weight variation per unit area."

77. In line with this, Hara teaches using an electrolytic copper foil for the negative electrode current collector "with a variation in weight per unit area of 2% or less" and provides specific examples such as 1.0% and 2.0% in Examples 1 and 2. SOLUS-1009, Abstract, [0011], [0012], [0015], [0027], [0029], [0048].

78. Moreover, Hara explains that advantages of using an electrolytic copper foil with a weight variation per unit area of 2% or less include [1] suppression of the variation in thickness of the negative electrode current collector, [2] uniformity of the electrode reaction, and [3] realization of excellent cycle life characteristics of batteries. *Id.*, [0012], [0048], [0050], [0051].

79. Additionally, as described above with respect to discussion in "The Kim-Hara-Otsuka combination" section, it is my opinion that there was sufficient motivation for a POSITA to apply Hara's teachings of weight variation to Kim's electrolytic copper foil and a POSITA would have expected success.

80. Therefore, in the Kim-Hara-Otsuka combination, these specific weight deviation values (2% or less) taught by Hara and applied to Kim's copper foil in the

combination fall within the recited range of weight deviation values. Thus, Kim-Hara-Otsuka combination renders obvious the electrolytic copper foil having a weight deviation of 3% or less.

[1d] and wherein the copper foil has a tensile strength of 30 to 40 kgf/mm²,

81. As I demonstrate below, in the combination, Otsuka renders obvious [1d]. For example, Otsuka teaches an electrolytic copper foil having a **tensile strength** of “*not more than 40 kg[f]/mm²*” and lists examples of tensile strengths such as 32, 36, and 38 kgf/mm² in Table 1, which fall within the teachings of the ’541 patent’s claimed tensile strength range of 30 to 40 kgf/mm². SOLUS-1010, [0020], [0046], Table 1. Additionally, Otsuka describes that the electrolytic copper foil having such tensile strength maintains or enhances adhesion between current collector and active material of the battery, which results in superior “charge/discharge cycle life and productivity” of secondary batteries. *Id.*, Abstract, [0020], [0029], [0030], [0031], [0033].

82. Therefore, as described above with respect to the discussion of “Combination of Kim, Hara, and Otsuka,” there was sufficient motivation for a POSITA to apply Otsuka’s teachings of tensile strength to Kim’s electrolytic copper foil and a POSITA would have expected success.

83. As such, in the Kim-Hara-Otsuka combination, tensile strength of “not more than 40 kg[f]/mm²” and examples of tensile strengths such as 32, 36, and 38

kgf/mm² described above fall within the claimed tensile strength range of 30 to 40 kgf/mm². Based on these specific tensile strength values disclosed by Otsuka, the Kim-Hara-Otsuka combination renders obvious [1d].

84. Alternatively/additionally, the range of tensile strength (“not more than 40 kg[f]/mm²) for the copper foil of the Kim-Hara-Otsuka combination overlaps with the recited range of tensile strength (30 to 40 kgf/mm²). Upon my review, the ’541 Patent provides no indication of criticality or unexpected results associated with the claimed range of tensile strength. Thus, the overlapping range of tensile strength values of the Kim-Hara-Otsuka combination also renders obvious [1d].

85. Further, tensile strength of *30 to 40 kgf/mm²* indicates a wide range and it was conventional to produce or obtain electrolytic copper foils that fall within, or overlap with, this tensile strength range. SOLUS-1023, Table 2 (listing tensile strength of 14 examples of electrolytic copper foil ranging from 335MPa (34.2 kgf/mm²) to 390 MPa (~40.0 kgf/mm²); SOLUS-1028, Table 2 (listing tensile strength of electrolytic copper foil ranging from 33.6 kgf/mm² to 37.2 kgf/mm²); SOLUS-1028, claim 5, [0018], [0050], [0051] (“As for the mechanical properties of the electrolytic copper foil incorporated into the present invention, the tensile strength under normal conditions is 33 kgf/mm² or more”), [0051] (“by optimizing the manufacturing conditions, it is possible to have superior mechanical properties such as a normal tensile strength of 38 kgf/mm² or more and a tensile strength of 33

kgf/mm² or more after heating (180°C × 60 minutes, atmosphere)'). Further, it was conventional to vary the electrolyte concentration, electrolysis plating parameters, temperature, the use of organic and inorganic additives, in order to obtain a copper foil with a tensile strength falling within the claimed tensile strength range as this range was well known, at least since 1974, as illustrated below. SOLUS-1025, 18, Table 2 (reproduced below).

Table 2. PROPERTIES OF COPPER ELECTRODEPOSITS USEFUL FOR DIVERSE APPLICATIONS					
Outstanding Characteristic	Tensile Strength, kg/mm ²	Elongation, % (5cm)	Internal Stress, ^c kg/mm ²	Hardness (VHN ₂₀₀), kg/mm ²	Electrical Resistivity, microhm-cm
High strength	45-63.5	4-18	-4.2 or 3.6 to 5.5	131-159	1.75-2.02
Hardness	3.5-55.5	0-10	-4.2 or 3.0	193-350	1.96-4.60
Low electrical resistivity	18.5-27	15-41	-0.5 to -1.6	48-64	1.70-1.73
Near zero stress	14-16	8-24	-0.08-0.06	56-57	1.71-1.72
Good leveling	36-36.5	14-19	2.0	128-137	1.82
Thermal stability ^b	22.5-30	26-39	0.5-2.9	55-106	1.73-1.76

^aNegative values indicate a compressive stress.
^bDeposits that changed less than 0.02% in length after heating to 400°C.

SOLUS-1025, 18, Table 2

[1e] so as to prevent the generation of wrinkles at a surface of the copper foil.

86. I believe this phrase recited in [1e] should carry no patentable weight because it seems to merely state the desired outcome or intended use. However, to the extent that wrinkle prevention purpose is deemed limiting, the Kim-Hara-Otsuka combination renders obvious [1e]. For example, if the material parameters (the limitations recited earlier in the claim) are met, then, by the Patentee's own

explanation, this material is prevented from having wrinkles.

87. For instance, during the prosecution stage of the '541 Patent, I undersatnd the Patentee asserted that “referring to Table 1 of this application, all Examples 1-7 satisfy the numerical ranges of all conditions, defined in Claim 1 of this application, thereby preventing wrinkles.” SOLUS-1002, 35 (emphasis in original). The Patentee also asserted “In Examples 1 to 7 of Table 1, the texture coefficient ratio, the tensile strength and the weight deviation are entirely satisfied so that the number of generated wrinkles is 0 (zero).” SOLUS-1002, 37. In parallel, as described above, the Kim-Hara-Otsuka combination satisfies “all conditions [or claimed ranges]” of the texture coefficient ratio, the tensile strength and the weight deviation ranges. Therefore, the Kim-Hara-Otsuka combination renders obvious [1e].

88. Alternatively/additionally, in the combination, it is my opinion that Kim and Hara further render obvious this feature.

89. First, a POSITA would have understood that Kim relates how the proper concentrations of different additives—an inhibitor, a leveler, and an accelerator— during electroplating produce films which are so smooth it is difficult to measure the surface roughness. FIG. 5(b) of Kim illustrates a very smooth surface and the correspondingly measured surface roughness (R_z) is at or below $0.050\ \mu\text{m}$ (50 nm). Such a smooth surface is not possible if there are wrinkles on the surface.

90. Second, Hara confirms that the copper foil with an elongation of 5% or less, addresses the wrinkle formation issues to at least some extent. For instance, Hara aims to ensure controlled elongation of Cu foil, which helps prevent the *formation of wrinkles during the winding process* and by using Cu foil with minimal weight variability and controlled elongation, the risk of undulation and misalignment, which lead to wrinkles, can be reduced. SOLUS-1009, [0008] (“*If the negative electrode stretches too much*, it will undulate in the width direction, *causing problems such as wrinkles during the winding process* and misalignment of the opposing positive and negative electrodes”). In this regard, Hara focuses on controlling (1) elongation and (2) weight variation, and Hara’s teachings are applied to the combination.

91. Third, as evidenced by prior art, tensile strength would have affected both the handleability of copper foil as well as the **formation of wrinkles** and other surface defects. For example, “[t]he implication of the increase in tensile strength. . . is the significant improvement of its handleability and resistance to plastic deformation under low to medium load conditions. *Indeed, fewer wrinkles* and other surface defects *are being reported by several users of the foil.*” SOLUS-1014, 2.

92. Thus, the Kim-Hara-Otsuka combination renders obvious [1e].

(ii) Claim 2

[2] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a surface roughness (Rz - JIS) of 2 μm or less.

93. As I demonstrate below, in the Kim-Hara-Otsuka combination, Kim renders obvious [2].

94. Surface roughness parameters such as Rz correspond to measurements of surface roughness obtained through profilometric analysis of a sample. In a typical profilometry measurement, a contacting probe is scanned across the surface of the sample, and the vertical deflection of the probe indicates the underlying topography.

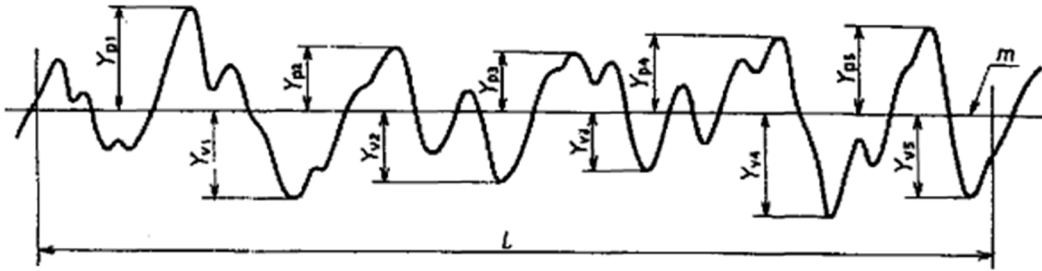
95. Here, Rz measures vertical characteristics (e.g., surface roughness) of the copper foil surface. For example, according to one or more of JIS standards, “Rz” or “Rzjis” corresponds to the 10-point average surface roughness represented as the average of value of the five maximum peak-to-valley heights (e.g., sum of absolute values of the five highest peaks and the absolute values of the five lowest valleys, divided by 5). SOLUS-1029, 13, FIG. 4; SOLUS-1030, 24-25. Further, many different standards share the same or similar definition of “Rz.” SOLUS-1031, 36; SOLUS-1032.

$$R_z = \frac{|Y_{p1} + Y_{p2} + Y_{p3} + Y_{p4} + Y_{p5}| + |Y_{v1} + Y_{v2} + Y_{v3} + Y_{v4} + Y_{v5}|}{5}$$

where, $Y_{p1}, Y_{p2}, Y_{p3}, Y_{p4}, Y_{p5}$: altitudes of the heights of five highest profile peaks of the sampled portion corresponding to the reference length l

$Y_{v1}, Y_{v2}, Y_{v3}, Y_{v4}, Y_{v5}$: altitudes of the depths of five deepest profile valleys of the sampled portion corresponding to the reference length l

Fig. 4. Determination of R_z



SOLUS-1029, FIG. 4

96. Kim describes that the copper foil has a surface roughness $R_z \approx 0.050$ μm . SOLUS-1018, FIGS. 2-4. For example, as described in FIG. 4 below with annotations, surface roughness R_z at accelerator concentration of 5 ppm, is approximately 50 nm, which is equivalent to 0.050 μm . Thus, R_z of 0.050 μm in Kim, as applied to the combination, renders obvious [2].

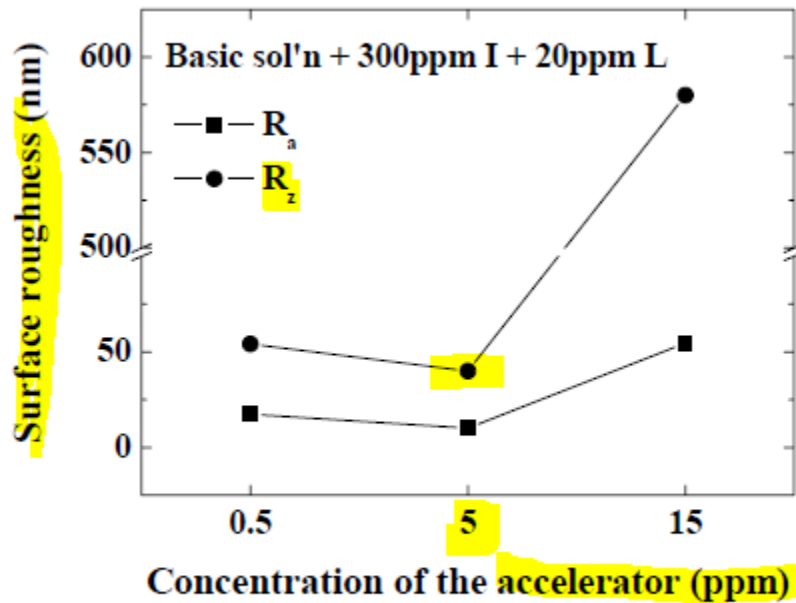


Fig. 4. Surface roughness with the concentration of the accelerator (I: inhibitor, L: leveler, A: accelerator).

SOLUS-1018, FIG. 4 (annotated)

97. Alternatively/additionally, it is my opinion that in the combination, a POSITA would have applied Hara's teachings of R_z values to Kim's copper foil to supplant Kim's R_z values, which also renders obvious [2]. For example, Hara describes R_z values that fall within the claimed range, along with associated advantages that would have motivated a POSITA to apply Hara's teachings to the Kim's copper foil. More specifically, Hara explains that that "it is preferable that the negative electrode current collector has . . . *a surface roughness R_z of 2.0 μm or less*" and that "by using electrolytic copper foil with . . . *a surface roughness of R_z of 2.0 μm or less* in the negative electrode current collector, a battery with *excellent*

cycle life characteristics can be realized.” SOLUS-1009, [0013], [0051]. Moreover, Hara discloses examples such as “*surface roughness R_z (a ten-point average surface roughness) = 1.5 μm* ” and cites to a JIS standard. SOLUS-1009, [0031], [0035].

98. Alternatively/additionally, it is my opinion that a POSITA would have applied Otsuka’s teachings of R_z values to Kim’s copper foil to supplant Kim’s R_z values, which also renders obvious [2]. Specifically, Otsuka describes or suggests these features in [2] along with associated advantages. For example, Otsuka describes that “[t]he electrodeposited copper foil has a surface roughness **R_z at a deposition surface at ordinary temperature smaller than 2.5 μm in terms of 10-point average roughness R_z** .” SOLUS-1010, Abstract; *see also* claim 1, [0014], [0020], [0025], [0026], Table 1. The 10-point average roughness R_z is Otsuka is explained by Otsuka as the value measured by a surface roughness meter based on JIS-B-0601. SOLUS-1010, [0014], [0036].

99. Alternatively/additionally, it was indeed common and perhaps conventional knowledge to a POSITA that copper foil with a “surface roughness (R_z - JIS) of 2 μm or less” would be effective for adhesion between the current collector and the active material. For instance, this is evidenced by numerous prior art references that teach R_z values of copper foil, which anticipate, or overlap with, the claimed range of “2.0 μm or less,” specifically for use in current collectors of

secondary batteries. SOLUS-1011, [0012], [0029]; SOLUS-1017, Abstract, 4, 5; SOLUS-1022, [0018], [0057], [0107]; SOLUS-1023, Abstract, [0012].

(iii) Claim 3

[3] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has an elongation of 3 to 20%.

100. As I demonstrate below, in the Kim-Hara-Otsuka combination, Hara renders obvious [3]. For example, Hara teaches an elongation rate of 5% or less and provides examples such as 4.8%, describing advantages of such elongation rate including realization of excellent cycle life characteristics of a battery. SOLUS-1009, [0031], [0050].

101. Therefore, the elongation values of Hara applied to Kim's copper foil in the combination fall within the claimed range of 3 to 20%.

(iv) Claim 4

[4] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a thickness of 1 to 35 μm .

102. As I demonstrate below, in the combination, Kim renders obvious [4]. For example, Kim describes that the copper foil used in the study is "**8 μm thick.**" SOLUS-1018, Abstract ("In the paper, the effects of surface roughness and residual stress of electroplated *copper as thick as 8 μm were studied*"), 2 ("[e]lectroplating was carried out in a stagnant solution under the constant current of 13 mA/cm² *until the copper film approached to 8 μm thick*").

103. Therefore, in the Kim-Hara-Otsuka combination, Kim's copper foil having a thickness of 8 μm falls within the claimed range and thus renders obvious [4].

104. Alternatively/additionally, Hara describes thickness values that fall within the claimed range, along with associated advantages that would have motivated a POSITA to apply Hara's teachings to Kim's copper foil. More specifically, Hara describes that "it is preferable that the negative electrode current collector has *a thickness of 7 μm to 25 μm* and a surface roughness Rz of 2.0 μm or less." SOLUS-1009, [0013]. Further, for example, Hara describes that "in Examples 4-7, batteries were fabricated in the same manner as in Example 3, except that *electrolytic copper foils with thicknesses of 10, 15, 20, and 25 μm , respectively*, and elongations of 3.5, 2.5, 2.2, and 2.0%, respectively, *were used for the negative electrode current collector.*" *Id.*, [0033]. Hara also describes advantages of such thickness values including realization of excellent cycle life characteristics of a battery. *Id.*, [0051]. Thus, it is my opinion that a POSITA would have applied Hara's teachings of thickness values to Kim's copper foil to supplant Kim's thickness values, which also renders obvious [4].

B. [GROUND 2] — Claims 1-4 are Obvious over the Ye-Hara-Otsuka Combination

105. It is my opinion that a POSITA would have found claims 1-4 to be obvious over the combination of Ye, Hara, and Otsuka, as I discuss in the following sections.

1. Overview of Ye

106. Ye describes the electrodeposition of copper foils and the correlation of various electropdeposition parameters with the resulting copper foils' materials parameters including texture, roughness, and ductility.

107. “A study was made to correlate different electrodeposition parameters, like, e.g., cathodic overpotential, bath composition, and bath ageing, with characteristics as crystallographic texture and roughness, and the ductility of electrolytic copper foils.” SOLUS-1013, Abstract. Put differently, Ye’s study focuses on understanding how different factors affect the quality of electrolytic copper foils and how the “overpotential” (the extra voltage applied between electrodes during copper deposition) and other parameters such as the bath chemical composition, pH, current density, and substrate influence the texture, surface roughness, and flexibility (e.g., ductility) of the copper foils. SOLUS-1013, Abstract.

108. For example, Ye describes that “cracks in printed circuit boards (PCB) are commonly attributed to the low ductility [e.g., elongation] of copper” and that

the plating conditions (e.g., mV cathodic overpotential) affect the ductility [e.g., elongation] of copper foil. *Id.*, Abstract. Further, for example, Ye describes that the “cathodic overpotential seems to be the most important controlling parameter” in controlling the crystallographic texture. (“the crystallographic texture and the morphology of copper electrocoatings depend on the electrodeposition parameters such as plating bath composition, pH, overpotential, current density, substrate, etc . . . Among them the cathodic overpotential seems to be the most important controlling parameter”) *Id.*, 2.

109. Moreover, Ye describes, for example, that a chloride additive “smoothens the copper coatings,” where its effect “can be seen that most specimens with a roughness factor $\alpha \geq 0.040$ were deposited from solutions containing less than 5 ppm Cl-.” *Id.*, 8. Here the roughness factor is “defined as the ratio of the roughness average over the foil thickness.” *Id.*, 2. Ye’s roughness measure is R_a and not R_z recited in a claim of the ’541 patent and by some of the other references.

2. Overview of Hara

110. Hara describes electrolytic copper foils and was discussed above in Section VII.A.2.

3. Overview of Otsuka

111. Otsuka describes electrolytic copper foils and was discussed above in Section VII.A.3

4. Combination of Ye, Hara, and Otsuka

112. As I demonstrate below, it would have been obvious to a POSITA to combine the teachings of Ye, Hara, and Otsuka, the combination of which would render obvious the claimed copper foil of the '541 patent.

113. Although I discuss a modification to a copper foil, I do not believe that any modifications to Ye would actually be necessary in order to obtain the copper foils recited in claims 1-4. Ye discloses electrolytic copper foil surface having [1] TC ratios and [2] thickness values that fall within the claimed range of the '541 Patent. Ye's mention of surface roughness is R_a which is not correlated with R_z , the surface roughness recited by the claims. While Ye does not mention values for [1] weight deviations, [2] tensile strengths, [3] surface roughnesses (R_z), or [4] elongations, Hara provides teachings of weight deviation values, surface roughness (R_z) values, and elongation values and Otsuka provides teachings of tensile strength values, elongation values, and R_z values, which fall within the claimed range of the '541 Patent. As such, the combination of Ye, Hara, and Otsuka discussed with respect to claims 1-4 is not substantively different from Ye's copper foil and that

recited in the '541 Patent. Rather, the combination accounts for claim 1's recitation of specific material properties that do not appear to have been measured together in any single identified reference or were not mentioned together in any single reference.

114. At least for the following reasons, it is my opinion that it would have been obvious to a POSITA to have combined Ye with Hara and Otsuka, especially as the prior art provides sufficient motivation and guidance for modifying Ye's copper foil to obtain the desired texture coefficients while taking advantage of Hara's disclosed weight deviation of $\leq 2\%$, surface roughness $R_Z \leq 2 \mu\text{m}$, and elongation $\leq 5\%$ and Otsuka's disclosed tensile strength $\leq 40 \text{ kgf/mm}^2$.

115. Ye discloses copper foils for use in printed circuit boards (PCBs), which are also compatible for use with secondary batteries. Such use compatibility of electrolytic copper foil between PCBs and the secondary batteries was well-known at the time. SOLUS-1022, [0107]; SOLUS-1023, [0001], [0005], [0012], [0066]; SOLUS-1012, [0011], [0012], [0052].

116. A POSITA seeking to utilize or optimize Ye's electrolytic copper foil for use in secondary batteries would have looked at other references, including Hara and Otsuka, and would have recognized that factors such as weight deviation, elongation, tensile strength, and R_Z values are important for further optimizing Ye's electrolytic copper foil for use in secondary batteries.

117. Specifically, for example, Hara describes that an electrolytic copper foil having “weight variation per unit area of 2% or less” and “elongation of 5% or less” prevent “the occurrence of spontaneous short circuits” which help create “a battery with small variation in battery capacity.” SOLUS-1009, [0012], [0063]. Further, for example, Hara describes that “it is preferable that the negative electrode current collector has a thickness of 7 μm to 25 μm and a surface roughness R_Z of 2.0 μm or less” and that “by using electrolytic copper foil with a weight variation of 2% or less, a thickness of 10 μm , and a surface roughness of R_Z of 2.0 μm or less in the negative electrode current collector, a battery with excellent cycle life characteristics can be realized.” Id., [0013], [0051].

118. Furthermore, Otsuka, for example, describes that an electrolytic copper foil with *tensile strength* of “*not more than 40 kg/mm²*” maintains or enhances adhesion between current collector and active material of the battery, which results in superior “charge/discharge cycle life and productivity” of secondary batteries. SOLUS-1010, Abstract, [0020], [0029], [0030], [0031], [0033].

119. Therefore, at least for the reasons set forth above, a POSITA would have been motivated to optimize Ye’s electrolytic copper foil for use in secondary batteries by incorporating the teachings of Hara and Otsuka to optimize weight deviation, elongation, tensile strength, and R_Z values.

120. Further, it is my opinion that a POSITA would have expected success

for at least the reasons given below.

121. As described above, both Hara and Otsuka focus on providing electrolytic copper foil for use in lithium-ion secondary batteries and the use compatibility of electrolytic copper foil between the PCB and secondary batteries was well known. A POSITA would have expected success in incorporating the teachings of weight deviation, elongation, tensile strength, and R_z values of Hara and Otsuka.

122. In addition, because electrolytic copper foils with a weight deviation less than 2% were commercially available a POSITA would have recognized the ease of applying such teachings or otherwise would have been familiar with the recipes or methods to produce copper foils with the desired weight deviation characteristics. For example, as described above, Hara describes in one of their examples that such electrolytic copper foil with the desired weight deviation of 2% or less is obtained from commercially available suppliers such as “Furukawa Circuit Foil Co., Ltd.” Id., [0027]. It is my opinion that, in regard to use of copper foil for a current collector of a negative electrode of secondary battery, it would have been obvious to a POSITA to use an electrolytic copper foil with minimal weight variance across the foil, but this may have gone unnoticed due to the pedestrian nature of this observation.

123. Moreover, in addition to or as part of my explanation above in the

“Historical Perspective of Copper Electroplating and Additives” section, the optimization of weight deviation, elongation, tensile strength, and R_Z values in copper foil would have involved a mere routine optimization of electrodeposition conditions, such as varying concentrations of additives (e.g., organic additives), electrolysis solution chemistry, which includes copper sulfate and sulfuric acid, treatment time, and/or current density and other plating parameters such as overpotential, solution agitation and temperature. *See ¶¶30-38.* For example, it was conventional to vary the electrolyte concentration, electrolysis conditions, and/or the deposition conditions to obtain a copper foil with tensile strength and elongation values falling within the claimed ranges as these ranges were well known, at least since 1974, as illustrated below. SOLUS-1025, 18, Table 2(reproduced below).

Outstanding Characteristic	Tensile Strength, kg/mm ²	Elongation, % (5cm)	Internal Stress, ^c kg/mm ²	Hardness (VHN ₂₀₀), kg/mm ²	Electrical Resistivity, microhm-cm
High strength	45-63.5	4-18	-4.2 or 3.6 to 5.5	131-159	1.75-2.02
Hardness	3.5-55.5	0-10	-4.2 or 3.0	193-350	1.96-4.60
Low electrical resistivity	18.5-27	15-41	-0.5 to -1.6	48-64	1.70-1.73
Near zero stress	14-16	8-24	-0.08-0.06	56-57	1.71-1.72
Good leveling	36-36.5	14-19	2.0	128-137	1.82
Thermal stability ^b	22.5-30	26-39	0.5-2.9	55-106	1.73-1.76

^aNegative values indicate a compressive stress.
^bDeposits that changed less than 0.02% in length after heating to 400°C.

SOLUS-1025, 18

124. Therefore, it is my opinion that a POSITA would have been motivated

to apply or optimize weight variation, tensile strength, R_z , and elongation features on the Ye's electrolytic copper foil and expected success.

5. Analysis

(i) Claim 1

[1pre] A copper foil for a current collector of a lithium secondary battery:

125. As I demonstrate, Ye renders obvious [1pre]. For example, Ye discloses an electrodeposited copper foil (e.g., electrolytic copper foil) for use in PCB, which is also compatible for use in the current collector of a lithium-ion secondary battery. SOLUS-1013, Abstract. Such use compatibility of electrolytic copper foil between the PCB and the secondary batteries was well-known. SOLUS-1022, [0107]; SOLUS-1023, [0001], [0005], [0012], [0066]; SOLUS-1012, [0011], [0012], [0052]. Therefore, in the combination, Ye discloses a copper foil for a current collector of a lithium secondary battery.

[1a] wherein, in a crystalline structure, a ratio of a sum of texture coefficients of a (111) surface and a (200) surface to a total sum of texture coefficients of the (111) surface, the (200) surface and a (220) surface is 60 to 85%,

a ratio of a texture coefficient of the (111) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 18 to 38%,

a ratio of the texture coefficient of the (200) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 28 to 62%,

and a ratio of the texture coefficient of the (220) surface to the total sum of

texture coefficients of the (111) surface, the (200) surface and the (220) surface is 15 to 40%,

[1b] wherein the texture coefficient satisfies the following equation:

$$TC(hkl) \geq \frac{\frac{I(hkl)}{I_0(hkl)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

wherein I(hkl) represents a measured diffraction intensity with respect to a (hkl) surface, and I₀(hkl) represents a standard diffraction intensity of ASTM (American Society of Testing Materials) standard powder-shaped diffraction data,

126. As I demonstrate below, in the combination, Ye renders obvious [1a]-[1b]. For example, Ye teaches electrodeposition of copper foils with results of XRD provided in Ye's Table II, reproduced below.

Table II. Relative peak intensity, corresponding NPI and stress ratio (ρ^*) for specimens tested.

No.	(111) Measured	(200) Measured	(220) Measured	(111) Normalized	(200) Normalized	(220) Normalized	ρ^*
Random	100.0	49.5	12.0	33.3	33.3	33.3	
1	100.0	44.4	86.7	11.0	9.8	79.2	
2	100.0	31.6	16.5	33.2	21.2	45.5	
3	100.0	45.5	69.7	12.9	11.9	75.2	
4	100.0	28.8	16.4	33.9	19.7	46.4	
5	100.0	35.9	53.8	16.1	11.7	72.2	
6	100.0	34.0	28.3	24.7	17.0	58.3	
7	100.0	33.7	15.4	33.8	23.0	43.3	
8	100.0	23.6	27.0	26.9	12.8	60.3	
9	100.0	31.0	71.4	13.2	8.3	78.6	
10	100.0	22.2	22.2	30.3	13.6	56.1	
11	100.0	29.4	88.2	11.2	6.6	82.2	
12	100.0	24.1	53.4	16.8	8.2	75.0	
13	100.0	33.3	18.5	31.1	20.9	48.0	
14	100.0	46.3	10.4	35.7	33.4	30.9	
15	100.0	52.6	21.1	26.2	27.9	46.0	
16	100.0	25.5	30.0	24.9	12.8	62.3	
17	100.0	41.0	43.6	18.3	15.2	66.5	
18	98.1	50.0	100.0	9.5	9.8	80.7	
19	100.0	29.2	18.5	32.0	18.9	49.2	
20	100.0	31.3	31.3	23.6	14.9	61.5	
21	81.5	48.1	100.0	8.1	9.6	82.3	
22	100.0	32.7	34.6	22.0	14.5	63.5	
23	67.5	32.5	100.0	7.0	6.8	86.2	
24	70.6	41.2	100.0	7.2	8.4	84.4	
25	100.0	40.5	94.6	10.3	8.4	81.3	
26	100.0	13.8	13.8	41.1	11.5	47.4	
27	100.0	28.9	75.6	12.7	7.4	79.9	
28	100.0	26.6	18.1	32.8	17.6	49.5	
29	100.0	27.5	75.0	12.8	7.1	80.1	
30	100.0	26.4	18.4	32.6	17.4	50.0	
31	84.6	34.6	100.0	8.6	7.1	84.4	
32	100.0	30.0	15.0	35.0	21.2	43.8	
33	100.0	25.5	12.7	38.8	20.0	41.2	
34	100.0	24.6	11.4	40.9	20.3	38.8	
35	9.4	4.7	100.0	1.1	1.1	97.8	1.047
36	29.2	8.3	100.0	3.3	1.9	94.8	1.053
37	100.0	25.7	42.9	19.6	10.2	70.2	
38	100.0	25.0	83.3	11.8	6.0	82.2	1.072
39	16.4	5.5	100.0	1.9	1.3	96.8	
40	4.1	2.1	100.0	0.5	0.5	99.0	1.033
41	100.0	21.7	10.0	44.0	19.3	36.7	1.089
42	100.0	28.7	20.4	30.5	17.7	51.8	
43	100.0	32.6	16.3	33.2	21.8	45.0	
44	5.5	2.7	100.0	0.6	0.7	98.7	

SOLUS-1013, Table II (annotated)

127. As shown in above Table II, sample No. 15, Ye discloses measured peak intensity values (“I”) for electrolytic copper foils in the context of a study to correlate certain electrodeposition parameters with characteristics such as “crystallographic texture and roughness, and the ductility” of those electrolytic copper foils. SOLUS-1013, Abstract, 1.

128. By normalizing the measured peak intensity values of Ye using the JCPDS 04-0836 cited in the '541 Patent, the TC values can be calculated for each of the three peaks. The '541 Patent prosecution history discloses in the Information Disclosure Statement (IDS) that “JCPDS (Joint Committee for Powder Diffraction Studies) card for standard powder specimens (04-0836) of copper (Cu) [was] used in the subject invention.” SOLUS-1002, 571; *see also* SOLUS-1001, Other Publications and SOLUS-1005, 20. As such, when calculating TC values using Ye’s copper foil data, the JCPDS 04-0836 data were used for each $I_0(hkl)$ value, which “represents a standard diffraction intensity of ASTM (American Society of Testing Materials) standard powder-shaped diffraction data,” as recited in [1b].

129. Table 3 Ye TC calculation

Peak	I(hkl)	$I_0(hkl)$	I/I_0	TC(hkl)
(111)	100	100	1	0.94
(200)	52.6	46	1.14	1.07
(220)	21.1	20	1.06	<u>0.99</u>
				3.00

130. Table 4 Ye TC ratio check

Ratio	Claimed Lower Limit	Value	Claimed Upper Limit
1 st ratio = (111) + (200)	60%	67.0%	85%
2 nd ratio = (111)	18%	31.3%	38%
3 rd ratio = (200)	28%	35.8%	62%
4 th ratio = (220)	15%	33.0%	40%

131. As shown, the TC and TC ratios regarding sample No. 15 in Ye’s Table 1 are shown in Tables 3 and 4. The example of Ye shown in Table 4 discloses TC

ratios that fall within the claimed ranges for all four TC ratios.

132. Thus, in the combination, Ye discloses copper foils within the limits of the ratios of the texture coefficients as recited by the '541 patent, rendering obvious [1a]-[1b].

[1c] wherein the copper foil has a weight deviation of 3% or less,

133. As I demonstrate below, in the Ye-Hara-Otsuka combination, Hara renders obvious [1c]. For example, Hara teaches using an electrolytic copper foil for the negative electrode current collector “with a variation in weight per unit area of 2% or less” and provides specific examples such as 1.0% and 2.0% in Examples 1 and 2. SOLUS-1009, Abstract, [0011], [0012], [0015], [0027], [0029], [0048].

134. Further, Hara explains that advantages of using an electrolytic copper foil with a weight variation per unit area of 2% or less include [1] suppression of the variation in thickness of the negative electrode current collector, [2] uniformity of the electrode reaction, and [3] realization of excellent cycle life characteristics of batteries. SOLUS-1009, [0012], [0048], [0050], [0051].

135. Additionally, as described above with respect to discussion of “Combination of Ye, Hara, and Otsuka” there was sufficient motivation for a POSITA to apply Hara’s teachings of weight variation to the Ye’s electrolytic copper foil and a POSITA would have expected success.

136. Accordingly, in the Ye-Hara-Otsuka combination, these specific

weight deviation values (2% or less) taught by Hara and applied to Ye's copper foil in the combination fall within the recited range of weight deviation values. Thus, Ye-Hara-Otsuka combination renders obvious the electrolytic copper foil having a weight deviation of 3% or less.

[1d] and wherein the copper foil has a tensile strength of 30 to 40 kgf/mm²,

137. As I demonstrate below, in the combination, Otsuka renders obvious [1d].

138. For example, Otsuka teaches an electrolytic copper foil having a tensile strength of "not more than 40 kg[f]/mm²" and lists examples of tensile strengths such as 32, 36, and 38 kgf/mm² in Table 1, which fall within the teachings of the '541 patent's claimed tensile strength range of 30 to 40 kgf/mm². SOLUS-1010, [0020], [0046], Table 1. Additionally, Otsuka describes that the electrolytic copper foil having such tensile strength maintains or enhances adhesion between current collector and active material of the battery, which results in superior "charge/discharge cycle life and productivity" of secondary batteries. SOLUS-1010, Abstract, [0020], [0029], [0030], [0031], [0033].

139. Therefore, as described above with respect to discussion of "Combination of Ye, Hara, and Otsuka," there was sufficient motivation for a POSITA to apply Otsuka's teachings of tensile strength to Ye's copper foil and a

POSITA would have expected success.

140. Accordingly, in the Ye-Hara-Otsuka combination, tensile strength of “not more than 40 kgf/mm²” and examples of tensile strengths such as 32, 36, and 38 kgf/mm² described above fall within the claimed tensile strength range of 30 to 40 kgf/mm². Based on these specific tensile strength values disclosed by Otsuka, the Ye-Hara-Otsuka combination renders obvious [1d].

141. Further, tensile strength of *30 to 40 kgf/mm²* indicates a wide range and it was conventional to produce or obtain electrolytic copper foils that fall within, or overlap with, this tensile strength range. SOLUS-1023, Table 2 (listing tensile strength of 14 examples of electrolytic copper foil ranging from 335MPa (34.2 kgf/mm²) to 390 MPa (~40.0 kgf/mm²); SOLUS-1028, Table 2 (listing tensile strength of electrolytic copper foil ranging from 33.6 kgf/mm² to 37.2 kgf/mm²); SOLUS-1028, claim 5, [0018], [0050], [0051] (“As for the mechanical properties of the electrolytic copper foil incorporated into the present invention, the tensile strength under normal conditions is 33 kgf/mm² or more”), [0051] (“by optimizing the manufacturing conditions, it is possible to have superior mechanical properties such as a normal tensile strength of 38 kgf/mm² or more and a tensile strength of 33 kgf/mm² or more after heating (180°C × 60 minutes, atmosphere)”). Furthermore, it was conventional to vary the electrolyte concentration, electrolysis plating parameters, temperature, the use of organic and inorganic additives, in order to

obtain a copper foil with tensile strength falling within the claimed tensile strength range as this range was well known, at least since 1974, as illustrated below.

Table 2. PROPERTIES OF COPPER ELECTRODEPOSITS USEFUL FOR DIVERSE APPLICATIONS

Outstanding Characteristic	Tensile Strength, kg/mm ²	Elongation, % (5cm)	Internal Stress, ^c kg/mm ²	Hardness (VHN ₂₀₀), kg/mm ²	Electrical Resistivity, microhm-cm
High strength	45-63.5	4-18	-4.2 or 3.6 to 5.5	131-159	1.75-2.02
Hardness	3.5-55.5	0-10	-4.2 or 3.0	193-350	1.96-4.60
Low electrical resistivity	18.5-27	15-41	-0.5 to -1.6	48-64	1.70-1.73
Near zero stress	14-16	8-24	-0.08-0.06	56-57	1.71-1.72
Good leveling	36-36.5	14-19	2.0	128-137	1.82
Thermal stability ^b	22.5-30	26-39	0.5-2.9	55-106	1.73-1.76

^aNegative values indicate a compressive stress.
^bDeposits that changed less than 0.02% in length after heating to 400°C.

SOLUS-1025, 18, Table 2

[1e] so as to prevent the generation of wrinkles at a surface of the copper foil.

142. I believe this phrase recited in [1e] should carry no patentable weight because it seems to merely state the desired outcome or intended use. However, to the extent that wrinkle prevention purpose is deemed limiting, the Ye-Hara-Otsuka combination renders obvious [1e]. For example, if the material parameters (the limitations recited earlier in the claim) are met, then, by the Patentee's own explanation, this material is prevented from having wrinkles.

143. Indeed, during the prosecution stage of the '541 Patent, I understand the Patentee asserted that "referring to Table 1 of this application, all Examples 1-7 satisfy the numerical ranges of all conditions, defined in Claim 1 of this application,

thereby preventing wrinkles.” SOLUS-1002, 35 (emphasis in original). In parallel, as described above, the Ye-Hara-Otsuka combination satisfies “all conditions [or claimed ranges]” of the texture coefficient ratio, the tensile strength and the weight deviation ranges. Therefore, the Ye-Hara-Otsuka combination renders obvious [1e].

144. Alternatively, to the extent that wrinkle prevention purpose is limiting, in the combination, Ye-Hara-Otsuka further renders obvious this feature.

145. First, a POSITA would have understood that Ye describes how the electrodeposition parameters of forming the copper foil are relevant to its texture and ductility and thus also to the likelihood of forming wrinkles.

146. Second, Hara confirms that the copper foil with an elongation of 5% or less, addresses the wrinkle formation issues to at least some extent. For instance, Hara aims to ensure controlled elongation of Cu foil, which helps prevent the formation of wrinkles during the winding process and by using Cu foil with minimal weight variability and controlled elongation, the risk of undulation and misalignment, which lead to wrinkles, can be reduced. SOLUS-1009, [0008] (“If the negative electrode stretches too much, it will undulate in the width direction, causing problems such as wrinkles during the winding process and misalignment of the opposing positive and negative electrodes”). In this regard, Hara focuses on controlling (1) elongation and (2) weight variation, and Hara’s teachings are applied to the combination.

147. Third, as evidenced by prior art, tensile strength would have affected both the handleability of copper foil as well as the **formation of wrinkles** and other surface defects. For example, “[t]he implication of the increase in tensile strength. . . is the significant improvement of its handleability and resistance to plastic deformation under low to medium load conditions. *Indeed, fewer wrinkles* and other surface defects *are being reported by several users of the foil.*” SOLUS-1014, 2.

148. Accordingly, the Ye-Hara-Otsuka combination renders obvious [1e].

(ii) Claim 2

[2] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a surface roughness (R_Z - JIS) of 2 μm or less.

149. As I demonstrate below, In the Ye-Hara-Otsuka combination, Hara renders obvious [2]. For example, Hara describes R_Z values that fall within the claimed range, along with associated advantages that would have motivated a POSITA to apply Hara’s teachings to Ye’s copper foil. More specifically, Hara explains that that “it is preferable that the negative electrode current collector has . . . a surface roughness R_Z of 2.0 μm or less” and that “by using electrolytic copper foil with . . . a surface roughness of R_Z of 2.0 μm or less in the negative electrode current collector, a battery with excellent cycle life characteristics can be realized.” SOLUS-1009, [0013], [0051]. Moreover, Hara discloses examples such as “surface

roughness R_z (a ten-point average surface roughness) = $1.5\ \mu\text{m}$ ” and cites to a JIS standard. SOLUS-1009, [0031], [0035].

150. Thus, as described above with respect to discussion of “Combination of Ye, Hara, and Otsuka,” there was sufficient motivation for a POSITA to apply Hara’s teachings of R_z values to Ye’s copper foil and a POSITA would have expected success.

151. Accordingly, based on Hara’s teachings regarding “a surface roughness R_z of $2.0\ \mu\text{m}$ or less,” which equates to the claimed range of “ $2\ \mu\text{m}$ or less,” the Ye-Hara-Otsuka combination renders obvious [2].

152. Alternatively/additionally, it is my opinion that a POSITA would have applied Otsuka’s teachings of R_z values to Ye’s copper foil in supplant of Hara’s R_z values, which also renders obvious [2]. In particular, Otsuka describes or suggests these features along with associated advantages. For example, Otsuka describes that “[t]he electrodeposited copper foil has a surface roughness R_z at a deposition surface at ordinary temperature smaller than $2.5\ \mu\text{m}$ in terms of 10-point average roughness R_z .” SOLUS-1010, Abstract; see also claim 1, [0014], [0020], [0025], [0026]. I note that the 10-point average roughness R_z is the value measured by a surface roughness meter based on JIS-B-0601. SOLUS-1010, [0014].

153. Alternatively/additionally, it was indeed common and perhaps conventional knowledge to a POSITA that copper foil with a “surface roughness (R_z

- JIS) of 2 μm or less” would be effective for adhesion between the current collector and the active material. Numerous prior art references teach R_z values of copper foil that anticipate the claimed range of “2.0 μm or less,” specifically for use in current collectors of secondary batteries. SOLUS-1011, [0012], [0029]; SOLUS-1017, Abstract, 3, 4; SOLUS-1022, [0018], [0057], [0107]; SOLUS-2023, Abstract, [0012]).

(iii) Claim 3

[3] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has an elongation of 3 to 20%.

154. As I demonstrate, in the Ye-Hara-Otsuka combination, Hara renders obvious [3]. For example, Hara teaches an elongation rate of 5% or less and provides examples such as 4.8%, describing advantages of such elongation rate including realization of excellent cycle life characteristics of a battery. SOLUS-1009, [0031], [0050].

155. Therefore, the elongation values of Hara applied to Ye’s copper foil in the combination fall within the claimed ranges of 3 to 20%.

(iv) Claim 4

[4] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a thickness of 1 to 35 μm .

156. As I demonstrate, in the combination, Ye renders obvious [4]. For example, Ye’s table I, reproduced below illustrates electrodeposited copper foils

with thicknesses between 17.7 and 22.3 μm and including sample No. 15 with a thickness of 20.5 μm . SOLUS-1013, 3, Table I (reproduced below, annotated).

Table I. Electrodeposition conditions, ductility, roughness, thickness, and morphology type for specimens tested.

No.	η (mV)	Current density (A/dm ²)	Cl ⁻ (ppm)	Pretreatment	Morphology	t	Penetration depth (mm)	h_0 (μm)	R_a (μm)	α
1	87	0.47	5	yes	b	S	1.07	19.7	0.36	0.019
2	87	0.44	5	yes	b	L	0.96	19.4	0.60	0.031
3	87	0.44	5	yes	b	S	0.99	18.5	0.50	0.027
4	87	0.45	5	yes	b	S	1.02	19.7	0.63	0.032
5	87	0.47	5	yes	b	S	1.04	20.9	0.55	0.026
6	87	0.47	25	yes	b	S	0.97	20.4	0.51	0.025
7	113	0.80	5	yes	d	L	0.87	17.7	0.75	0.042
8	113	0.66	5	yes	b	L	1.02	20.3	0.48	0.022
9	113	0.60	5	yes	b	S	1.03	20.4	0.68	0.033
10	113	0.60	5	yes	b	L	1.01	20.6	0.65	0.032
11	113	0.66	5	yes	b	S	1.01	20.1	0.79	0.039
12	113	1.10	5	yes	b	S	0.93	20.4	0.70	0.034
13	113	0.90	5	yes	b	L	0.82	22.3	1.85	0.083
14	113	0.70	10	yes	b	L	0.95	19.8	0.84	0.042
15	113	0.80	15	yes	b	L	0.93	20.5	0.68	0.033
16	113	0.90	0	no	b	S	0.92	20.1	0.81	0.040
17	113	0.70	5	no	b	S	1.06	21.1	0.58	0.027
18	113	0.90	10	no	b	S	1.09	21.0	0.38	0.018
19	120	1.10	0	no	b	L	0.97	21.4	0.60	0.028
20	120	1.10	0	no	b	S	0.93	21.7	0.59	0.027
21	120	0.70	5	no	b	S	1.06	19.9	0.42	0.021
22	120	0.70	10	no	b	L	1.02	20.9	0.38	0.018
23	120	0.85	20	no	b	S	0.90	19.4	0.37	0.019
24	120	0.81	20	no	b	S	0.93	19.7	0.60	0.031
25	158	1.00	5	yes	b	S	1.00	20.5	0.57	0.028
26	158	1.46	5	yes	d	L	0.81	21.3	1.73	0.081
27	158	1.18	5	yes	b	S	0.95	20.1	0.36	0.018
28	158	0.90	5	yes	b	L	0.95	21.9	1.31	0.060
29	200	1.27	5	yes	b	S	0.97	19.8	0.42	0.021
30	200	1.93	5	yes	b	L	0.96	20.1	0.87	0.043
31	200	1.70	20	no	a	S	0.90	21.8	0.48	0.022
32	250	3.30	0	no	c	L	0.84	20.7	0.62	0.030
33	250	3.20	0	no	c	L	0.83	19.1	0.36	0.019
34	250	3.20	0	no	c	S	0.72	20.8	0.91	0.044
35	250	2.90	5	no	a	S	0.63	19.0	0.41	0.021
36	250	3.10	10	no	a	S	0.61	19.8	0.58	0.029
37	250	3.30	20	no	a	L	0.76	19.8	0.48	0.024
38	250	3.20	20	no	a	L	0.72	21.1	0.78	0.037
39	250	2.90	20	no	a	S	0.60	20.2	0.38	0.019
40	250	3.30	40	no	a	S	0.53	19.7	0.39	0.020
41	250	3.30	5	yes	c	S	0.74	21.5	1.16	0.054
42	250	3.10	10	yes	a	S	0.70	21.0	0.93	0.044
43	250	3.10	15	yes	a	S	0.70	22.1	1.43	0.065
44	250	3.00	25	yes	a	L	0.53	19.2	0.42	0.022

Note: η , overpotential, t, ageing time of solution, (L for a long time and S for a short time); h_0 , thickness; R_a , average roughness; α , roughness factor.

SOLUS-1013, Table I (annotated)

157. In addition, Hara describes thickness values that fall within the claimed range, along with associated advantages that would have motivated a POSITA to apply Hara's teachings to the Ye's copper foil. More specifically, Hara describes that "it is preferable that the negative electrode current collector has a thickness of 7

μm to 25 μm and a surface roughness Rz of 2.0 μm or less.” SOLUS-1009, [0013]. Further, for example, Hara describes that “in Examples 4-7, batteries were fabricated in the same manner as in Example 3, except that electrolytic copper foils with thicknesses of 10, 15, 20, and 25 μm, respectively, and elongations of 3.5, 2.5, 2.2, and 2.0%, respectively, were used for the negative electrode current collector.” SOLUS-1009, [0033]. Hara also describes advantages of such thickness values including realization of excellent cycle life characteristics of a battery. *Id.*, [0051]. Therefore, a POSITA would have applied Hara’s teachings of thickness values to Ye’s copper foil in supplant of Ye’s thickness values, which also renders obvious [4].

C. [GROUND 3] — Claim 3 is Obvious over the Hirose-Hara-Otsuka/Matsuda Combination

158. It is my opinion that a POSITA would have found claims 1-4 to be obvious over the combination of Hirose, Hara, and Otsuka or Matsuda, as I discuss in the following sections.

1. Overview of Hirose

159. Hirose describes copper foils for use as an anode of a battery. For example, Hirose “The present invention relates to a current collector containing copper, and an anode and a battery using it.” SOLUS-1007, [0003].

160. Hirose's motivation is that "in the invention, it is desirable to provide a current collector, an anode, and a battery capable of improving the cycle characteristics." SOLUS-1007, [0011].

161. Three ways in which Hirose improves battery cycle characteristics are (1) improving the contact characteristics of the current collector to the active material, (2) maintaining a high discharge capacity retention ratio, and (3) preventing a short circuit between the anode and the cathode. See SOLUS-1007 at least at [0101], [0116], [0119], and [0153].

162. In regard to wrinkle formation, Hirose, for example, describes that "[i]n the case that the extension coefficient is larger than 10%, a wrinkle may be generated in the anode current collector 1 when the anode active material layer 2 is expanded and shrunk." SOLUS-1007, [0049].

2. Overview of Hara

163. Hara describes electrolytic copper foils and was discussed above in Section VII.A.2.

3. Overview of Otsuka

164. Otsuka describes electrolytic copper foils and was discussed above in Section VII.A.3

4. Overview of Matsuda

165. Matsuda describes "an electrodeposited copper foil which has a lower

profile and a higher gloss than low-profile electrodeposited copper foil conventionally supplied in markets.” SOLUS-1012, Abstract. “Particularly, the present invention relates to an electrodeposited copper foil of which the bonding surface to an insulating layer-forming material has a low profile and a high gloss.” *Id.*, [0001].

166. In addition, Matsuda is seeking to use “copper foils as negative electrode current collectors for lithium ion batteries, the copper foils having the smooth surface are preferably used.” *Id.*, [0012].

167. Matsuda uses several variations of the chemical concentrations and other process parameters (e.g., bath temperature and current density) to achieve the desired surface and materials characteristics of the copper foils. *See generally id.*

5. Combination of Hirose, Hara, and Otsuka or Matsuda

168. It would have been obvious to a POSITA to combine the teachings of Hirose, Hara, and Otsuka or Matsuda, the combination of which would render obvious the claimed copper foil of the '541 patent.

169. Although I discuss a modification to a copper foil, I do not believe that any modifications to Hirose would actually be necessary in order to obtain the copper foils recited in claims 1-4. Hirose discloses electrolytic copper foil surface having

[1] TC ratios, [2] Rz values, and [3] thickness values that fall within the claimed ranges of the '541 Patent. While Hirose does not mention [1] weight deviation values, [2] tensile strength values, and [3] elongation values, Hara provides teachings of weight deviation values and elongation values and Otsuka or Matsuda provides teachings of tensile strength values, which fall within the claimed ranges of the '541 Patent. As such, the combination of Hirose, Hara, and Otsuka or Matsuda discussed with respect to claims 1-4 should not be taken to indicate any substantive difference between the Hirose's copper foil and that recited in the '541 Patent. Rather, the combination accounts for claim 1's recitation of specific material properties that do not appear to have been measured (or simply not mentioned) together in any single identified reference.

170. At least for the following reasons, it would have been obvious to a POSITA to have combined Hirose with Hara and Otsuka (or Matsuda), especially as the prior art provides sufficient motivation and guidance for modifying Hirose's copper foil to obtain the desired the texture coefficients while taking advantage of Hara's disclosed weight deviation of $\leq 2\%$, $R_z \leq 2 \mu\text{m}$, and elongation $\leq 5\%$ and Otsuka's disclosed tensile strength $\leq 40 \text{ kgf/mm}^2$ or Matsuda's disclosed tensile strength of $\geq 33 \text{ kgf/mm}^2$.

171. First, all four references focus on enhancing battery durability and performance by mitigating mechanical stresses and improving adhesion properties

of the electrode of a secondary lithium-ion battery. SOLUS-1009, Abstract, [0011], [0012]; SOLUS-1010, [0002], [0003], [0011]-[0018]; SOLUS-1007, [0101], [0116], [0119], [0153]; SOLUS-1012, [0012].

172. Second, it is my opinion that a POSITA seeking to utilize or optimize Hirose's electrolytic copper foil for use in secondary batteries would have looked at other references, including Hara and Otsuka (or Matsuda), and would have recognized that factors such as weight deviation, elongation, and tensile strength are important for further optimizing Hirose's electrolytic copper foil for use toward current collectors of secondary batteries.

173. Specifically, Hara describes that an electrolytic copper foil having "weight variation per unit area of 2% or less" and "elongation of 5% or less" prevent "the occurrence of spontaneous short circuits" and helps obtaining "a battery with small variation in battery capacity." SOLUS-1009, [0012], [0063]. Further, for example, Hara describes that "it is preferable that the negative electrode current collector has . . . and a surface roughness R_z of 2.0 μm or less" and that "by using electrolytic copper foil with a weight variation of 2% or less, a thickness of 10 μm , and a surface roughness of R_z of 2.0 μm or less in the negative electrode current collector, a battery with excellent cycle life characteristics can be realized." *Id.*, [0013], [0051].

174. Moreover, Otsuka describes that an electrolytic copper foil with tensile

strength of “not more than 40 kg[f]/mm²” maintains or enhances adhesion between current collector and active material of the battery, which results in superior “charge/discharge cycle life and productivity” of secondary batteries. SOLUS-1010, Abstract, [0020], [0029], [0030], [0031], [0033].

175. Further, Matsuda, for example, describes that in order to prevent breakage of current collector upon repeated expansion/contraction, “mechanical properties of copper foil as current collecting material, for bearing the repeated expansion/contraction behavior, are required to have a favorable balance between the tensile strength and elongation” and presents “tensile strength of not less than 33 kgf/mm² and an elongation of not less than 5%.” SOLUS-1012, [0012], [0019], [0020].

176. Therefore, at least for the reasons set forth above, a POSITA would have been motivated to optimize Hirose’s electrolytic copper foil for use in secondary batteries by incorporating the teachings of Hara and Otsuka (or Matsuda) to optimize weight deviation, elongation, and tensile strength.

177. Further, it is my opinion that a POSITA would have expected success at least for the following reasons.

178. First, since all of the above-noted references focus on providing electrolytic copper foil for use in lithium-ion secondary batteries, a POSITA would have expected success in incorporating the teachings of weight deviation,

elongation, and tensile strength values of Hara and Otsuka (or Matsuda).

179. Second, the fact that electrolytic copper foils with weight deviation were commercially available indicates that a POSITA would have recognized the ease of applying such teachings or otherwise would have been familiar with the recipes or methods to produce copper foils with the desired weight deviation characteristics. For example, as described above, Hara describes in one of their examples that such electrolytic copper foil with the desired weight deviation of 2% or less is obtained from commercially available suppliers such as “Furukawa Circuit Foil Co., Ltd.” *Id.*, [0027]. Further, it is my opinion that it would have been obvious to a POSITA to use an electrolytic copper foil with minimal weight variance across the foil, but this may have gone unnoticed due to the obviousness of the fact.

180. Third, the optimization of weight deviation, elongation, tensile strength, and R_z values in copper foil would have involved a mere routine optimization of electrodeposition conditions, such as varying concentrations of additives (e.g., organic additives), electrolysis solution chemistry, which includes copper sulfate and sulfuric acid, treatment time, and/or current density and other plating parameters such as solution agitation and temperature. For example, it was conventional to vary the electrolyte concentration, electrolysis conditions, and/or the deposition conditions to obtain a copper foil with tensile strength and elongation values falling within the claimed ranges as these ranges were well known, at least

since 1974, as illustrated below. SOLUS-1025, 18, Table 2 (reproduced below). Furthermore, for example, a POSITA would have known to optimize weight deviation, elongation, tensile strength, R_z and TC ratios. In an example, Hirose Table 1, along with numerous other data from Hirose, discloses that intensity values (and thus TC ratios) can be varied while keeping surface roughness characteristics and thickness of copper foil constant. SOLUS-1007, [0150]–[0153]. This was achieved, for instance, by varying the annealing temperatures or through controlled heating of the copper current collector. *Id.*

Outstanding Characteristic	Tensile Strength, kg/mm ²	Elongation, % (5cm)	Internal Stress, ^c kg/mm ²	Hardness (VHN ₂₀₀), kg/mm ²	Electrical Resistivity, microhm-cm
High strength	45–63.5	4–18	–4.2 or 3.6 to 5.5	131–159	1.75–2.02
Hardness	3.5–55.5	0–10	–4.2 or 3.0	193–350	1.96–4.60
Low electrical resistivity	18.5–27	15–41	–0.5 to –1.6	48–64	1.70–1.73
Near zero stress	14–16	8–24	–0.08–0.06	56–57	1.71–1.72
Good leveling	36–36.5	14–19	2.0	128–137	1.82
Thermal stability ^b	22.5–30	26–39	0.5–2.9	55–106	1.73–1.76

^aNegative values indicate a compressive stress.
^bDeposits that changed less than 0.02% in length after heating to 400°C.

SOLUS-1025, 18, Table 2

181. Therefore, a POSITA would have been motivated to apply or optimize weight variation, tensile strength, and elongation features on the Hirose's electrolytic copper foil and expected success.

6. Analysis

(i) Claim 1

[1pre] A copper foil for a current collector of a lithium secondary battery:

182. As I demonstrate below, Hirose describes copper foil, such as “electrolytic copper foil” for a current collector of a battery. SOLUS-1007, [0010], [0052], [0010], [0085], [0090], [0145].

[1a] wherein, in a crystalline structure, a ratio of a sum of texture coefficients of a (111) surface and a (200) surface to a total sum of texture coefficients of the (111) surface, the (200) surface and a (220) surface is 60 to 85%,

a ratio of a texture coefficient of the (111) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 18 to 38%,

a ratio of the texture coefficient of the (200) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 28 to 62%,

and a ratio of the texture coefficient of the (220) surface to the total sum of texture coefficients of the (111) surface, the (200) surface and the (220) surface is 15 to 40%,

[1b] wherein the texture coefficient satisfies the following equation:

$$TC(hkl) \geq \frac{\frac{I(hkl)}{I_0(hkl)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

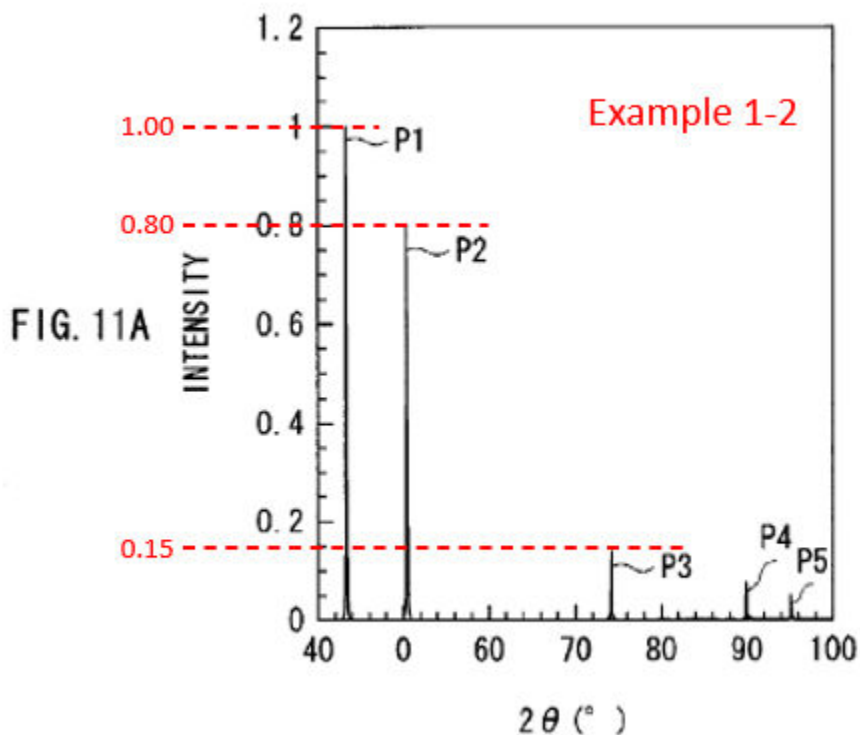
wherein $I(hkl)$ represents a measured diffraction intensity with respect to a (hkl) surface, and $I_0(hkl)$ represents a standard diffraction intensity of ASTM (American Society of Testing Materials) standard powder-shaped diffraction data,

183. As I demonstrate below, in combination, Hirose renders obvious [1a]-

[1b].

184. Hirose explains that “[a]s a representative of Examples 1-1 to 1-7 described above, when the anodes 54 used for the secondary batteries of Examples 1-2 and 1-4 were analyzed by an XRD device, the results shown in FIGS. 11A and 11B were obtained. FIG. 11A and FIG. 11B respectively show Examples 1-2 and 1-4.” SOLUS-1007, [0155].

185. FIGS. 11A and 11B of Hirose, which correspond to Example 1-2 and Example 1-4 of Hirose, respectively, are reproduced below with annotations in red to show the values of the peaks of the X-ray diffraction measurements for the two samples. Further, based on FIGS. 11A and 11B of Hirose, below Tables 5-8 have been developed to better illustrate the TC and TC ratios. The normalization values I_0 originate from the JCPDS 04-0836 standard. SOLUS-1005, 16.



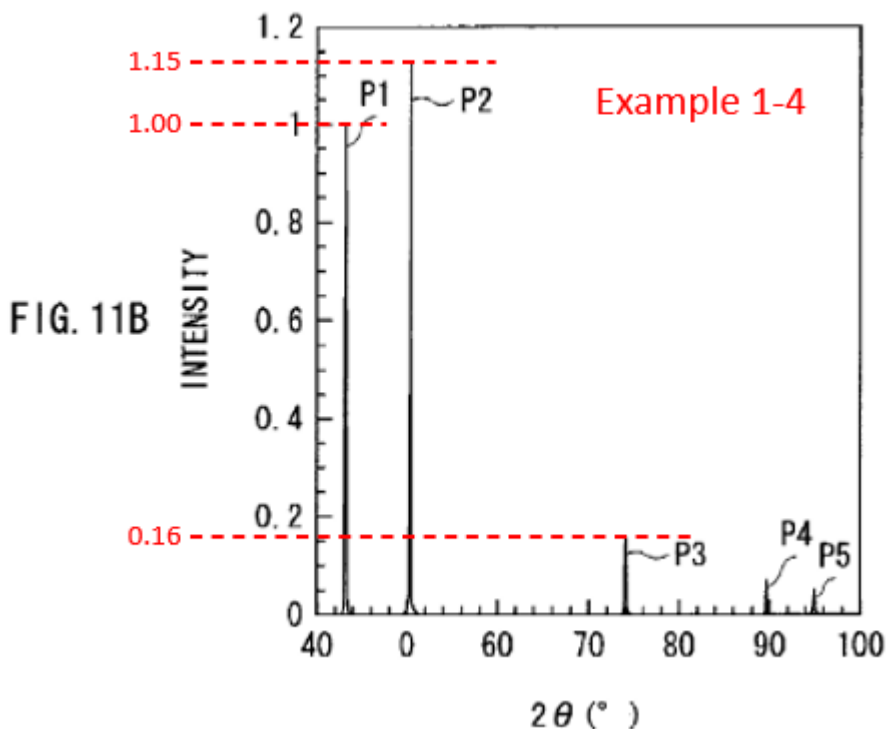
Hirose (SOLUS-1007), FIG. 11A with annotations in red.

186. Table 5 Hirose Example 1-2 TC calculation

Peak	I(hkl)	I ₀ (hkl)	I/I ₀	TC(hkl)
P1 = (111)	1.00	100	0.0100	0.86
P2 = (200)	0.80	46	0.0174	1.50
P3 = (220)	0.15	20	0.0075	0.64
				3.00

187. Table 6 Hirose Example 1-2 TC ratio check

Ratio	Claimed Lower Limit	Value	Claimed Upper Limit
1 st ratio = (111) + (200)	60%	78.5%	85%
2 nd ratio = (111)	18%	28.7%	38%
3 rd ratio = (200)	28%	49.8%	62%
4 th ratio = (220)	15%	21.5%	40%



Hirose (SOLUS-1007), FIG. 11B with annotations in red.

188. Table 7 Hirose Example 1-4 TC calculation

Peak	I(hkl)	I ₀ (hkl)	I/I ₀	TC(hkl)
P1 = (111)	1	100	0.0100	0.70
P2 = (200)	1.15	46	0.0250	1.74
P3 = (220)	0.16	20	0.0080	0.56
				3.00

189. Table 8 Hirose Example 1-4 TC ratio check

Ratio	Claimed Lower Limit	Value	Claimed Upper Limit
1 st ratio = (111) + (200)	60%	81.4%	85%
2 nd ratio = (111)	18%	23.3%	38%
3 rd ratio = (200)	28%	58.1%	62%
4 th ratio = (220)	15%	18.6%	40%

190. As described above, Table 6 and Table 8 show that Hirose's electrolytic

copper foils satisfy the claimed TC ratios of the '541 patent. Thus, based on Hirose's copper foils having the TC ratios that satisfy the claimed ranges, the Hirose-Hara-Otsuka/Matsuda combination renders obvious [1a]-[1b].

[1c] wherein the copper foil has a weight deviation of 3% or less,

191. In the Hirose-Hara-Otsuka/Matsuda combination, Hara renders obvious [1c]. For example, Hara teaches using an electrolytic copper foil for the negative electrode current collector "with a variation in weight per unit area of 2% or less" and provides specific examples such as 1.0% and 2.0% in Examples 1 and 2. SOLUS-1009, Abstract, [0011], [0012], [0015], [0027], [0029], [0048].

192. Thus, based on Hara's teaching of the weight deviation of 2% or less, which falls within the claimed range, the Hirose-Hara-Otsuka/Matsuda combination renders obvious [1c].

[1d] and wherein the copper foil has a tensile strength of 30 to 40 kgf/mm²,

193. As I demonstrate below, in combination, Otsuka or Matsuda renders obvious [1d].

194. First, Otsuka teaches an electrolytic copper foil having a tensile strength of "not more than 40 kg[f]/mm²" and lists examples of tensile strengths such as 32, 36, and 38 kgf/mm² in Table 1, which fall within the teachings of the '541 patent's

claimed tensile strength range of 30 to 40 kgf/mm². SOLUS-1010, [0020], [0046], Table 1. Additionally, Otsuka describes that the electrolytic copper foil having such tensile strength maintains or enhances adhesion between current collector and active material of the battery, which results in superior “charge/discharge cycle life and productivity” of secondary batteries. SOLUS-1010, Abstract, [0020], [0029], [0030], [0031], [0033].

195. Accordingly, in the Hirose-Hara-Otsuka/Matsuda combination, tensile strength of “not more than 40 kg[f]/mm²” and examples of tensile strengths such as 32, 36, and 38 kgf/mm² fall within the claimed tensile strength range of 30 to 40 kgf/mm². Thus, these specific tensile strength values disclosed by Otsuka and applied to Hirose’s copper foil in the combination renders obvious [1d].

196. Second, Matsuda explains that “in order to prevent breakage of current collector upon repeated expansion/contraction, “mechanical properties of copper foil as current collecting material, for bearing the repeated expansion/contraction behavior, are required to have a favorable balance between the tensile strength and elongation” and presents “tensile strength of not less than 33 kgf/mm² and an elongation of not less than 5%.” SOLUS-1012, [0012], [0019], [0020].

197. Accordingly, in the Hirose-Hara-Otsuka/Matsuda combination, the tensile strength of not less than 33 kgf/mm² taught by Matsuda and applied to the Hirose’s copper foil also renders obvious [1d].

[1e] so as to prevent the generation of wrinkles at a surface of the copper foil.

198. I believe this phrase recited in [1e] should carry no patentable weight because it seems to merely state the desired outcome or intended use. However, to the extent that wrinkle prevention purpose is deemed limiting, the Hirose-Hara-Otsuka/Matsuda combination renders obvious [1e]. For example, if the material parameters (the limitations recited earlier in the claim) are met, then, by the Patentee's own explanation, this material is prevented from having wrinkles.

199. For example, during the prosecution stage of the '541 Patent, the Patentee asserted that "referring to Table 1 of this application, all Examples 1-7 satisfy the numerical ranges of all conditions, defined in Claim 1 of this application, thereby preventing wrinkles." SOLUS-1002, 35 (emphasis in original). In parallel, as described above, the Hirose-Hara-Otsuka/Matsuda combination satisfies "all conditions [or claimed ranges]" of the texture coefficient ratio, the tensile strength and the weight deviation ranges. Therefore, the Hirose-Hara-Otsuka/Matsuda combination renders obvious [1e].

200. Alternatively, to the extent that wrinkle prevention purpose is limiting, in the combination, Hirose-Hara-Otsuka further renders obvious this feature.

201. First, a POSITA would have understood that Hirose describes how the electrodeposition parameters of forming the copper foil are relevant to its texture and ductility and thus also to the likelihood of forming wrinkles.

202. Second, Hara confirms that the copper foil with an elongation of 5% or less, addresses the wrinkle formation issues to at least some extent. For instance, Hara aims to ensure controlled elongation of Cu foil, which helps prevent the formation of wrinkles during the winding process and by using Cu foil with minimal weight variability and controlled elongation, the risk of undulation and misalignment, which lead to wrinkles, can be reduced. SOLUS-1009, [0008] (“If the negative electrode stretches too much, it will undulate in the width direction, causing problems such as wrinkles during the winding process and misalignment of the opposing positive and negative electrodes”). In this regard, Hara focuses on controlling (1) elongation and (2) weight variation, and Hara’s teachings are applied to the combination.

203. Third, as evidenced by prior art, tensile strength would have affected both the handleability of copper foil as well as the **formation of wrinkles** and other surface defects. For example, “[t]he *implication of the increase in tensile strength. . . is the significant improvement of its handleability and resistance to plastic deformation* under low to medium load conditions. *Indeed, fewer wrinkles* and other surface defects *are being reported by several users of the foil.*” SOLUS-1014, 2.

204. Accordingly, the Hirose-Hara-Otsuka/Matsuda combination renders obvious [1e].

(ii) Claim 2

[2] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a surface roughness (Rz - JIS) of 2 μm or less.

205. As I demonstrate below, In the Hirose-Hara-Otsuka/Matsuda combination, Hirose renders obvious [2]. For example, Hirose describes that the “[t]en point height of roughness profile Rz of the surface of the anode current collector 1 is preferably in *the range from 1.5 μm to 5.5 μm* ” and that “[t]he definition of the ten point height of roughness profile Rz is based on JIS B 0601.” SOLUS-1007, [0051], [0086], FIG. 16. Thus, the range of Rz values (*1.5-5.5 μm*) for the copper foil of the Hirose-Hara-Otsuka/Matsuda combination overlaps with the recited range of Rz values (*2 μm or less*). Further, the ’541 Patent provides no discussion or evidence of unexpected results or criticality associated with copper foils having Rz values within the claimed range. Thus, based on the overlapping range disclosed by Hirose, Hirose-Hara-Otsuka/Matsuda combination renders obvious [2].

206. Alternatively/additionally, in the combination, a POSITA would have applied Hara’s teachings of Rz values to Hirose’s copper foil in supplant of Hirose’s Rz values, which also renders obvious [2]. For example, Hara describes Rz values that fall within the claimed range, along with associated advantages that would have motivated a POSITA to apply Hara’s teachings to the Hirose’s copper foil. More

specifically, Hara explains that that “it is preferable that the negative electrode current collector has . . . *a surface roughness R_z of 2.0 μm or less*” and that “by using electrolytic copper foil with . . . *a surface roughness of R_z of 2.0 μm or less* in the negative electrode current collector, a battery with *excellent cycle life characteristics can be realized.*” SOLUS-1009, [0013], [0051]. Moreover, Hara discloses examples such as “*surface roughness R_z (a ten-point average surface roughness) = 1.5 μm* ” and cites to a JIS standard. SOLUS-1009, [0031], [0035].

207. In addition, it was indeed common and perhaps conventional knowledge to a POSITA that copper foil with a “surface roughness (R_z - JIS) of 2 μm or less” would be effective for adhesion between the current collector and the active material. Numerous prior art references teach R_z values of copper foil that anticipate the claimed range of “2.0 μm or less,” specifically for use in current collectors of secondary batteries. For instance, see SOLUS-1011, [0012], [0029]; SOLUS-1017, Abstract, 3, 4; SOLUS-1022, [0018], [0057], [0107]; SOLUS-2023, Abstract, [0012]).

208. Thus, Hirose-Hara-Otsuka/Matsuda combination renders obvious [2].

(iii) Claim 3

[3] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has an elongation of 3 to 20%.

209. As I demonstrate below In the Hirose-Hara-Otsuka/Matsuda combination, Hara renders obvious [3]. For example, Hara teaches an elongation rate of 5% or less and provides examples such as 4.8%, describing advantages of such elongation rate including realization of excellent cycle life characteristics of a battery. SOLUS-1009, [0031], [0050].

210. Thus, the elongation values applied to Hirose's copper foil in the combination fall within the claimed range of 3 to 20%.

211. Alternatively/additionally, the range of elongation (**5% of less**) for the copper foil of the Hirose-Hara-Otsuka/Matsuda combination overlaps with the recited range of elongation (**3 to 20%**). Further, the '541 Patent provides no discussion or evidence of unexpected results or criticality associated with copper foils having an elongation within the claimed range. Thus, based on the overlapping range disclosed by Hirose, Hirose-Hara-Otsuka/Matsuda combination renders obvious the recited range of elongation.

(iv) Claim 4

[4] The copper foil for a current collector of a lithium secondary battery according to claim 1, wherein the copper foil has a thickness of 1 to 35 μm .

212. As I demonstrate below, in the combination, Hirose renders obvious [4]. For example, Hirose describes that *“thickness of the original foil 1A is preferably*

in the range from 10 μm to 25 μm ,” with the thickness values falling within the claimed range. SOLUS-1007, [0053], [0084], [0145].

213. Thus, based on the thickness values disclosed by Hirose, Hirose-Hara-Otsuka/Matsuda combination renders obvious [4].

VIII. LEGAL PRINCIPLES

A. Anticipation

214. I have been informed that a patent claim is invalid as anticipated under 35 U.S.C. § 102 if each and every element of a claim, as properly construed, is found either explicitly or inherently in a single prior art reference. Under the principles of inherency, if the prior art necessarily functions in accordance with, or includes the claimed limitations, it anticipates.

B. Obviousness

215. I have been informed that a patent claim is invalid as “obvious” under 35 U.S.C. § 103 in light of one or more prior art references if it would have been obvious to a POSITA, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long felt need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others.

I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason to modify the single prior art reference, or combine two or more references, in order to achieve the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference or references themselves, the knowledge or “common sense” of one skilled in the art, or from the nature of the problem to be solved, and may be explicit or implicit from the prior art as a whole. I have been informed that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

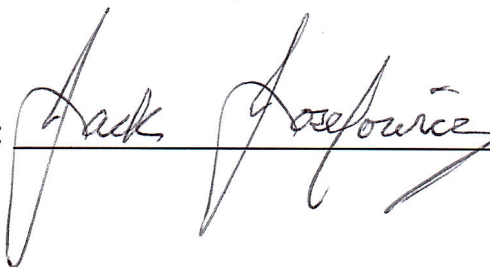
IX. CONCLUSION

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

217. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both

under Section 1001 of Title 18 of the United States Code.

Dated: Oct. 3, 2024.

By: 

APPENDIX A

Dr. Jack Josefowicz/jack.josefowicz@gmail.com

Cell: (310) 874-2261

PROFESSIONAL COMPETENCE OVERVIEW:

Dr. Jack Josefowicz's background includes basic research and downstream "real world" issues in electronic materials, electronic micro-devices, electronic systems design, electrochemical systems, and failure analysis. Dr. Josefowicz also has expertise in surface science, including deposition techniques for thin films in applications that include, printed circuit board fabrication (PCB) technology, root cause failure analysis in PCBs as well as semiconductor microchip and microprocessor devices.

Dr. Josefowicz is an independent consultant, working with both the commercial and aerospace electronic industries. Dr. Josefowicz has worked with law firms to support litigation, defend patent infringement cases and served as an expert witness in legal mediation cases. Dr. Josefowicz is an expert in electronic system reliability prediction analysis, electronic systems failure and root cause analysis, electronic fabrication "best practice." Holding the position of Director of Technology Research and Development at Tyco Printed Circuit Division, Dr. Josefowicz headed the Engineering teams at 13 printed circuit board manufacturing facilities (with sales of \$1.3 Billion) located throughout the world. This position included best practice manufacturing development involving statistical process control, design for manufacturing and reliability testing. Dr. Josefowicz was the lead and responsible for "root cause" analysis PCB failures related to production related process deviations that resulted in electronic system failures. This included surface finishes problems, as well as plating and through hole plating failures. Additionally, such failures often caused overheating of devices resulting in burns and fires. In one expert witness case, Dr. Josefowicz's expert witness analysis of electronic system failures related surface finish problems involving electroless Ni immersion gold that had an exposure of \$100 million resulted in a positive settlement and no liability for his client, and the chemical supplier who had a problem was identified. During his tenure at Tycoelectronics, Dr. Josefowicz headed a task force for contingent liabilities and was the lead in 45 cases that had an exposure of over \$500M. In most of those liability cases, Dr. Josefowicz participated in depositions and mediations in front of a judges. In all those cases, Dr. Josefowicz headed all the analysis, wrote the analysis reports, and defended the results of analysis.

Dr. Josefowicz was also head of research and design applied to large scale Li-Ion battery development for space satellites at Hughes Research Laboratories, Malibu, CA, including manufacturing, testing and product design and large area Li-Ion cell fabrication technology.

Dr. Josefowicz also has hands on expertise includes materials science. This includes a wide range of atomic level analytical methods that includes, Scanning Electron Microscopy, 3-D Digital High Resolution Micrography, Electron Dispersive X-Ray analysis (XRD), Auger Depth Profiling Electron Spectroscopy, Fourier Transform Infrared Analysis, Thermogravimetric Analysis, Cross-section analysis and other microscopic methods that determine the chemical and structural composition of materials related to electronic devices, including LED device battery analysis.

Dr. Josefowicz has hands on electronic and engineering applications that include the Light Emitting Diode (LED) device design, LED light fixture design and optimization, LED Light Engine printed circuit boards (PCB, including design and fabrication of advanced high layer count printed circuit boards up to 64 layers,), LED assembly on metal core PCBs including pick and place SMD LED devices and reflow assembly, SMD surface finish materials expertise, advanced electronics for LED power supply drivers and controllers, electronic system reliability, semiconductor device reliability. As an independent consultant, Dr. Josefowicz has served as expert witness in 45 cases involving all aspects of LED luminaire design, including claim definition, IPR, patent claim invalidity and has been deposed in these cases.

Dr. Josefowicz's career began with basic research at Harvard University, followed by applied industrial R&D (at Hughes Research Laboratories (HRL)) as well as university research as Professor of Material Science and Engineering (University of Pennsylvania). Projects at HRL included design and fabrication of unique thin film depositions systems, including sputtering, e-beam evaporation, chemical vapor deposition, doctor blade coating techniques for cathodes,

anodes and electrolyte gels used in Li-Ion large area batteries, induction heat deposition and other methods where the thin films were applied to optical and electronic systems. Having established a reputation in several science fields through publications and patents. Dr. Josefowicz led the design of Light Emitting Diode (LED) lighting fixtures at LED Roadway Lighting Ltd. (LRL). As Executive VP of Technology, Dr. Josefowicz helped launch LRL and led the design of new globally acclaimed high efficiency and high reliability LED streetlights, including electronics power supply driver, LED control systems including dimming and on/off controls, optics design, and fixture housing design for optimized thermal management. Dr. Josefowicz also directed the qualification of suppliers for all the components that included, electronic devices and components, PCB suppliers, die cast and mould design for lean and design for manufacturing, as well as parts and system integration. The intimate bridging between R&D and manufacturing design were pursued and were critical to high yield and reliability of the manufactured parts.

Having given invited talks and presentations at international conferences, Dr. Josefowicz has strong communication skills in making science and engineering accessible to non-experts and experts alike.

Technology Expertise:

1. Li ion battery design, materials development and engineering optimization (liquid and polymer gel ionic separator selection and design); thin film coating technology (doctor blade, spray and spreading methodologies), including testing; charging and discharging characteristic analysis and optimization.
2. LED light design:
 - a. LED device design including semiconductor p-n junction fabrication and phosphor wavelength conversion materials science
 - b. Optics for LED devices
 - c. Optics design for street lighting applications
 - d. Power supply driver electronics including dimming and on-off controls
 - e. Luminaire fixture design and thermal management design
 - f. Driver electronics reliability prediction analysis using Telcordia SR332
3. Thin Film Surface Finish Performance and Evaluations – Failure Root Cause Analysis
4. Thin film coating technology, including vacuum deposition design of equipment for plasma sputtering, electron beam deposition, RF plasma, and chemical vapor deposition.
5. Printed Circuit Design, Manufacturing Process Design for “Best Practice”
6. Molecular and Atomic analysis using Atomic Force Microscopy; Scanning Tunneling Microscopy for material science investigations of metals and insulators (ceramics, plastics, oxides, organometallics).
7. Expertise (hands on) in thin film coating of metals, semiconductors and insulators by methods including:
 - a. Thermal evaporation
 - b. Chemical Vapor Deposition
 - c. Radio frequency discharge deposition
 - d. Electron beam evaporation
 - e. Sputtering deposition
8. Electronic Reliability Prediction Modeling and Design for Long Life

WORK EXPERIENCE:

- A. Independent Consultant**
- B. LED Roadway Lighting Limited – Halifax, Nova Scotia, Canada/Executive VP, Technology Solutions and Head of R&D 2008 – 2012**
- C. Tycoelectronics/Printed Circuit Group – Los Angeles, CA
Director of Technology and R&D 1996 – 2008**
 - a. Direct manufacturing and operations in new emerging technology, overseeing the Tycoelectronics Printed Circuit Group, Aerospace, Military-High Reliability-10 manufacturing facilities >\$1Billion
- D. Hughes Research Laboratory, Malibu, CA-1985-1996**
 - a. **Principle Scientist and Project Leader 1984 – 1996**
 - b. **Li-Ion Design and Development Program to design and fabricate Li-Ion batteries for Space Satellites using advanced solid state thin film lithium polymer electrolyte battery designs**
 - c. Establish collaborative program (DARPA) between Hughes Research Labs and University of Pennsylvania (Penn) for the research and development of advanced solid-state thin film lithium polymer electrolyte batteries for Space Satellites
 - d. Constructed the first Atomic Force Microscopy laboratory at Penn for atomic analysis of materials applied to materials research and electrochemical analysis
 - e. Designed and fabricated Plasma RF Sputtered Superconducting Lattice Matched-on Sapphire Thin Films for Radio Frequency Devices band pass filters for space satellite applications
 - f. Program Lead: high temperature superconductors: DARPA Superconductor thin films program
 - g. Fabricated the world's first gallium arsenide high speed integrated circuits using self-aligned field effect transistors with pure tungsten gates; fabrication of large-scale high-speed integrated circuits using simple and reliable processes
- E. University of Pennsylvania**
 - a. **Professor**
- F. Harvard University: Cambridge, MA
Research Associate; 1975-1980**
- G. EDUCATION:**
 - a. **PhD 1975 Physics, University of Waterloo, Waterloo, Ontario, Canada**
BSc 1969 Mathematics & Physics, Concordia University, Montreal, Quebec, Canada
 - b. **TEACHING RELATED EXPERIENCE:**
 - i. **Harvard University:** Associate Research Scientist
 - ii. **University of Pennsylvania:** Professor in Material Science and Engineering; Laboratory for Research on the Structure of Materials
 - iii. **Technical Reviewer:** Thin Solid Films and other journals
 - iv. **Invited Lecturer:** Technology Workshops and Presentations at: Cisco, Celestica, Flextronics, Solectron, Jabil, Northrop Grummund, Motorola, Nokia, Raytheon, Boeing; and many other companies.

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