

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Kim et al.
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Title: ELECTROLYTIC COPPER FOIL HAVING EXCELLENT
HANDLING CHARACTERISTICS IN POSTPROCESSING, AND
MANUFACTURING METHOD THEREFOR

Declaration of Dr. Michael Randall

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LIST OF EXHIBITS

SOLUS-1001	U.S. Patent No. 11,591,706 (“the ’706 Patent”)
SOLUS-1002	U.S. Patent No. 11,591,706 File History
SOLUS-1003	Declaration of Dr. Michael Randall
SOLUS-1004	Korean Patent Publication No. 10-2017-0000761
SOLUS-1005	Translation of SOLUS-1004 (“Kim ’761”) and Certificate of Translation
SOLUS-1006	[Reserved]
SOLUS-1007	U.S. Patent No. 9,209,485 (“Cheng”)
SOLUS-1008	U.S. Patent No. 5,834,140 (“Wolski”)
SOLUS-1009	U.S. Patent No. 9,457,541 (“Kim ’541”)
SOLUS-1010	U.S. Patent Application Publication No. 2016/0260981 (“Lee”)
SOLUS-1011	WIPO Publication No. 2014/115681
SOLUS-1012	Translation of SOLUS-1011 (“Shinozaki ’681”) and Certificates of Translation ¹
SOLUS-1013	[Reserved]
SOLUS-1014	U.S. Patent No. 8,715,836 (“Dobashi”)
SOLUS-1015	U.S. Patent Application Publication No. 2013/0108922 (“Shinozaki ’922”)

¹ Title page translated by Michael Fletcher, remainder translated by Dwaine Palmer

SOLUS-1016	U.S. Patent Application Publication No. 2015/0267313 (“Chou”)
SOLUS-1017	ASME B46.1-2009
SOLUS-1018	Excerpts from ASME B46.1-2019
SOLUS-1019	[Reserved]
SOLUS-1020	U.S. Patent No. 10,547,081 (“Kim ’081”)
SOLUS-1021	JIS B 0601 (1994)
SOLUS-1022	JIS B 0601 (2001)
SOLUS-1023	U.S. Patent No. 9,365,942 (“Tsai”)
SOLUS-1024	U.S. Patent No. 7,789,976 (“Sano”)
SOLUS-1025	John A. Marshall, “Measuring Copper Surface Roughness for High Speed Applications”
SOLUS-1026	Declaration of June Munford
SOLUS-1027	Korean Publication No. 10-2014-0078883
SOLUS-1028	Translation of SOLUS-1027 (“Lee ’883”) and Certificate of Translation
SOLUS-1029	[Reserved]
SOLUS-1030	Young, H. (1962). <i>Statistical treatment of experimental data</i> . McGraw-Hill.
SOLUS-1031	U.S. Patent Publication No. 2016/0212846 (“Kohiki”)

SOLUS-1032	Song et al., “Texture and temperature dependence on the mechanical characteristics of copper electrodeposits,” <i>Mat. Sci. and Eng. A</i> , 559 (2013) (“Song”)
SOLUS-1033	U.S. Patent Application Publication No. 2014/0302281 (“Yacovone”)
SOLUS-1034	[Reserved]
SOLUS-1035	Harrington, G.F., Santiso, J. “Back-to-Basics tutorial: X-ray diffraction of thin films,” <i>J Electroceram</i> 47, 141–163 (2021)
SOLUS-1036	ASTM E8/E8M standard
SOLUS-1037	[Reserved]
SOLUS-1038	[Reserved]
SOLUS-1039	<i>Modern Electroplating</i> , 3 rd Ed., Ed. Lowenheim, J. Wiley and Sons, NY, 1974
SOLUS-1040	Rodgers, <i>Professional Manual of Electroplating</i> , University Publishing House, Utah, pp. 115-129
SOLUS-1041	Screen capture of www.textech.co.jp/en/products/foil-electrolytic (September 14, 2024)
SOLUS-1042	Screen capture of www.denora.com/applications/copper-foil-electrodeposition.html (September 14, 2024)
SOLUS-1043	Huang, “Studies of Interfacial Adhesion and Copper Plating Chemistry for Metallization of Through-Package-Vias in Glass Interposers,” Thesis, Georgia Institute of Technology, December 2017
SOLUS-1044	U.S. Patent No. 6,776,893

SOLUS-1045

Vereecken et al., "The chemistry of additives in damascene copper plating," in IBM Journal of Research and Development, vol. 49, no. 1, pp. 3-18, Jan. 2005

I, Dr. Michael Randall, of Simpsonville, South Carolina, declare that:

I. ASSIGNMENT

1. I have been retained on behalf of Solus Advanced Materials Co., Ltd ("Petitioner") and asked to review and provide my opinion on the patentability of claims 1-10 of U.S. Patent No. 11,591,706 ("the '706 Patent"). I understand that Petitioners are requesting that the Patent Trial and Appeal Board ("PTAB" or "Board") institute an *inter partes* review ("IPR") proceeding of the '706 Patent.

2. I have been asked to provide my independent analysis of the '706 Patent 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 for my work as an expert at my standard hourly consulting rate. My compensation is not dependent on the outcome of these proceedings or the content of my opinions.

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

II. BACKGROUND

5. I am over the age of 18 and am competent to write this declaration. I have personal knowledge, or have developed knowledge of these technologies based upon education, training, or experience, of the matters set forth herein.

6. A detailed description of my professional qualifications, including a listing of my specialties/expertise and professional activities, is contained in my

curriculum vitae, a copy of which is attached as an appendix. In what follows, I provide a short summary of my professional qualifications.

7. I received my PhD in Materials Science and Engineering from the University of Florida in 1993 after obtaining an MS in Materials Science and Engineering, and a BS in Ceramic Engineering, minoring in chemistry. I have worked in the materials and electronic materials industries since 1983 with numerous companies (both large and small) that operate in these industries. I have extensive experience with electronic materials and devices, including electronic materials and components, and including battery materials. During my career, I have gained experience in manufacturing techniques (both additive and subtractive), including coatings (both thin and thick film), including electroplating, and including the electroplating of copper. I have also used material analysis tools extensively, including but not limited to, surface analysis, including surface metrology (contact and non-contact). I have also gained experience in the area of materials analysis techniques, including X-Ray diffraction (XRD), as well as with thermal analysis tools such as differential thermal analysis (DTA), thermal mechanical analysis (TMA) and the like. During my career, I have also gained experience with chemical analytical tools and techniques for the analysis of surface and bulk chemistries, including chemical analysis techniques such as atomic absorption spectroscopy (AA) and the like. Further, I have gained experience with

mechanical characterization techniques such as tensile testing, film adhesion testing and the like, as well as numerous other analytical techniques that are pertinent to the electronic devices and materials industries as detailed in my CV.

8. It is for at least these reasons that I am an expert in the analysis and manufacture of battery materials.

III. MATERIALS REVIEWED

9. In forming my opinions, I have reviewed the '706 Patent and considered each of the documents listed in the Exhibit List above and the other references cited in my declaration. In reaching my opinions, I have relied upon my experience in the field and also considered the viewpoint of a person of ordinary skill in the art at the time of the earliest claimed priority date of the '706 Patent, i.e., early 2018. As explained below, I am familiar with the level of skill of a person of ordinary skill in the art regarding the relevant technology at issue as of that time.

IV. DESCRIPTION OF THE RELEVANT TIMEFRAME, THE RELEVANT FIELD, AND A PERSON OF ORDINARY SKILL IN THE ART

10. I understand that the '706 Patent claims a priority date of January 31, 2018 (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 January 31, 2018 date as the relevant date for my analysis of the prior art.

11. I considered several factors to determine the skill level of a person of ordinary skill in the art of the '706 Patent in January 2018, including the types of problems encountered in the art, the solutions to those problems, the pace of innovation in the field, the sophistication of the technology, and the education level of active workers in the field.

12. Based on my knowledge, expertise, and the prior art cited for the '706 Patent, it is my opinion that a person of ordinary skill in the field of the '706 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 can compensate for less work experience, and vice-versa.

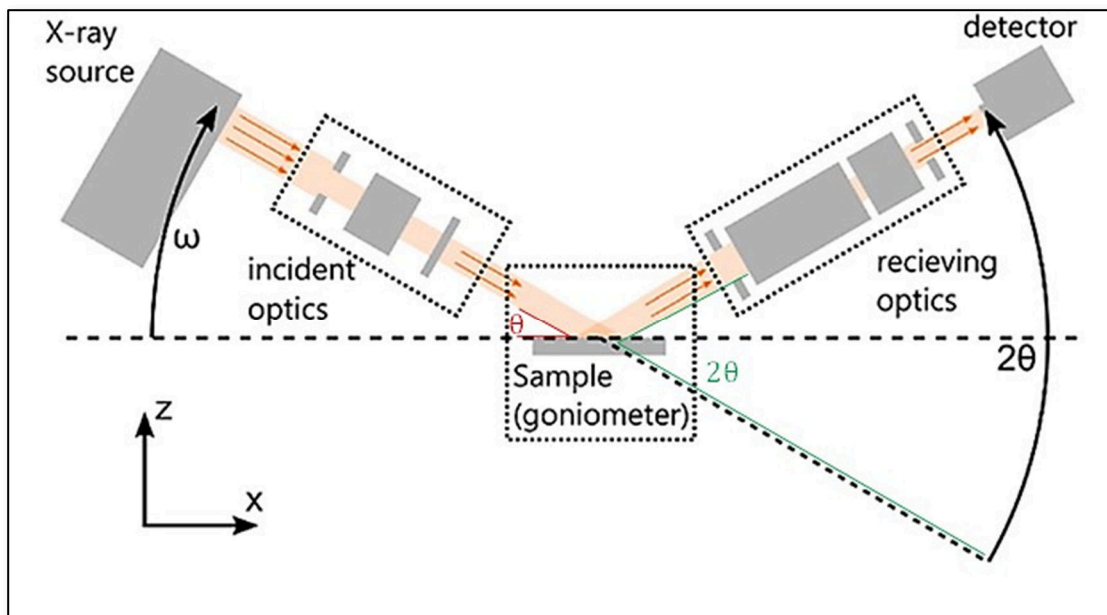
13. Unless noted otherwise, when I state that something would be known or understood by one skilled in the art, or a skilled artisan, or a person having ordinary skill in the art ("POSITA"), I am referring to a person with this level of education and experience at the time of the alleged invention, which I am assuming to be in or around January 2018.

V. REVIEW OF RELEVANT TECHNICAL ASPECTS

A. Texture Coefficient (TC)

14. The texture coefficient (TC) of a crystal plane is a measure of the

prominence (or relative intensity) of the X-ray diffraction (XRD) peak corresponding to the plane, relative to other planes. In an XRD analysis, nearly monochromatic X-rays (for example, Cu $K_{\alpha 1}$ X-rays having wavelength (λ) of 1.54059 Å), are projected toward a sample over a range of angles (typically termed “ 2θ ”) and the diffracted X-rays are collected at the detector over the range of angles of interest as shown below. SOLUS-1035, 144.



XRD Experimental Apparatus (SOLUS-1035)

15. When the sample is crystalline (i.e., has long range atomic order), both constructive (and destructive) interference of the X-rays reflecting off different crystal planes in the sample result in higher (or lower) detected intensities respectively at certain angles, relative to other angles, per Bragg’s equation:

$$n\lambda = 2d_{hkl}\sin(\theta)$$

where:

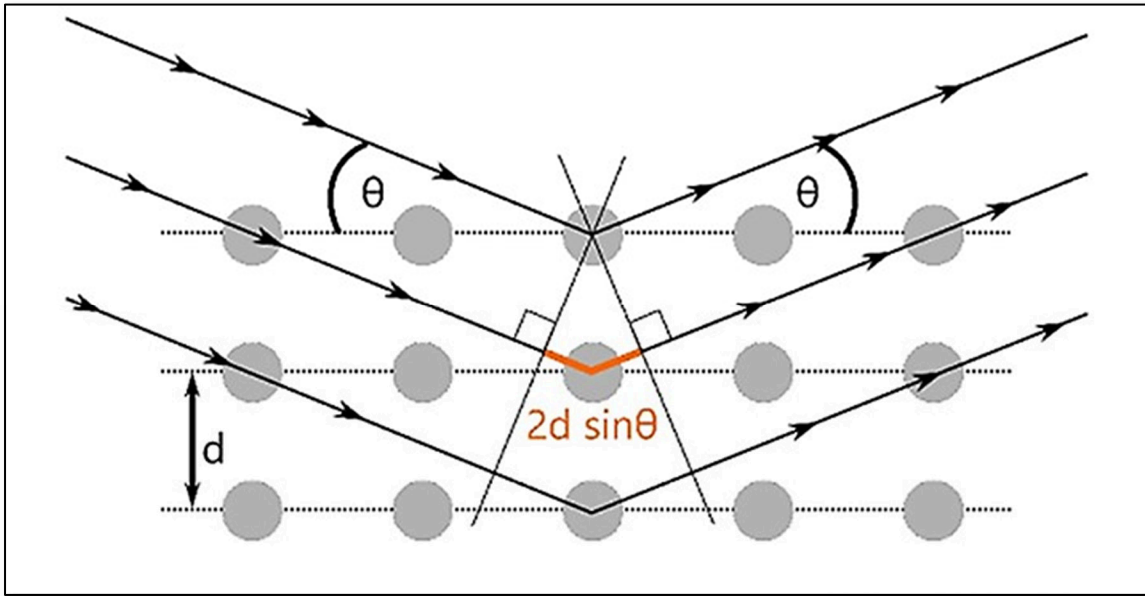
n is an integer

λ is the wavelength of the X-ray in Angstroms ($\text{\AA}$)

d_{hkl} is the crystal interatomic planar spacing between adjacent crystallographic planes having Miller index designation “ hkl ”

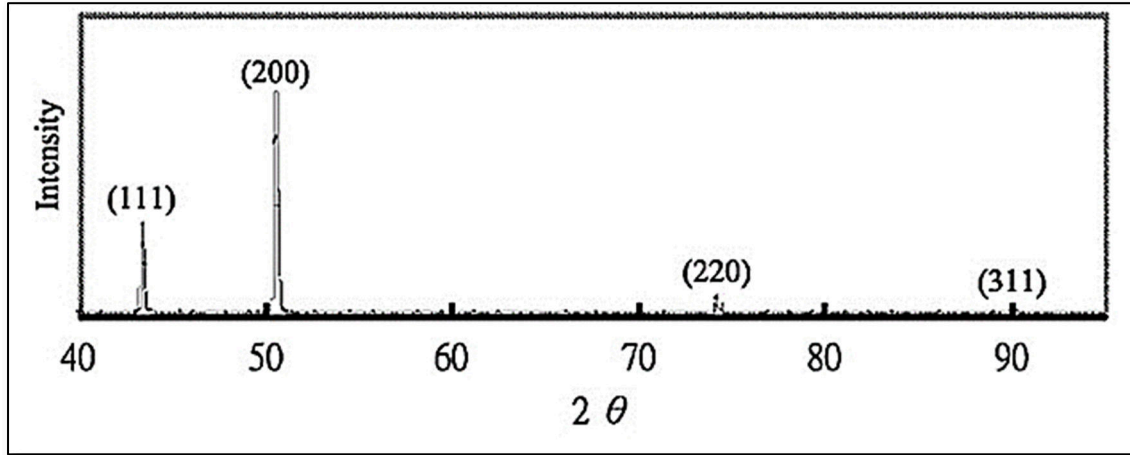
θ is the incident angle (Bragg angle) in degrees

as depicted below:



X-Ray Diffraction (SOLUS-1035)

16. In a typical XRD analysis (but not in all such analyses), the X-ray source is rotated relative to the sample to be analyzed at a set angular rate (typically expressed in degrees/minute or the like), and the reflected X-rays are detected over a specified range of angles of interest (2θ), each particular angle being set using a goniometer. The resulting detected X-ray data are typically presented as a plot of intensity (I) vs. 2θ (the angle of the detector) as illustrated below.



Chou FIG. 3

17. At certain angles (e.g., Bragg angles) the intensity of the reflected X-rays detected increases due to constructive interference according to Bragg's equation above. Peaks in the intensity vs. angle plot correspond to certain planes in the crystal structure of the sample, and the relative height of the corresponding peak intensity corresponds to the prominence (or relative concentration) of the crystal plane of interest within in the sample.

18. For calculating the texture coefficient of copper's (220) plane, the '706 Patent provides the following expression (SOLUS-1001, 2:20):

$$TC(220) = \frac{\frac{I(220)}{I_0(220)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

19. In this formula, I is the measured diffraction intensity for the indicated plane (Miller index) in the sample (for example, the diffraction intensity of the detected signal at the angle (2θ) corresponding to the plane) and I_0 indicates the

diffraction intensity of the (hkl) Miller index crystal plane of standard copper powder, set forth by the Joint Committee on Powder Diffraction Standards (JCPDS) (X-ray source Cu $K_{\alpha 1}$). SOLUS-1001, 3:58-63. When comparing TC values between different publications, it is important to note which planes were considered in the calculation. For example, a TC(220) based on consideration of three planes ($n = 3$) should not be directly compared to a TC(220) calculated using four planes ($n = 4$), absent compensating calculations.

B. Ra

20. “Ra” is a measure of surface roughness obtained by profilometric analysis of a sample. In a typical profilometry measurement, a contacting probe is scanned across the surface of a sample. The vertical deflection of the probe is indicative of the underlying topography of the sample.

21. The '706 Patent cites the JIS B 0601 standard (2001 version) for defining Ra. SOLUS-1001, 8:27. According to this standard, Ra is the “arithmetic mean roughness” of a profile. SOLUS-1022, 13. Mathematically, Ra is calculated by integrating the absolute value of the “height of the assessed profile” “Z(x)” over the measurement length, and dividing by the measurement length. *Id.*, 8, 13

22. Conceptually, Ra is a simple, basic measure of surface roughness: higher Ra values indicate overall higher roughness.

C. Rz

23. “Rz,” as used in the ’706 Patent, refers to the “ten-point average roughness.” SOLUS-1001, 4:26. According to the cited JIS B 0601-2001 standard, this “ten-point mean roughness” is referred to as R_{zJIS} and can be calculated as “the sum of the mean of profile peaks from the highest to fifth [highest] and the mean of profile depths from the deepest valley to fifth deepest valley.” SOLUS-1022, 24. That is, unlike Ra, which is concerned with the average roughness of the surface as a whole, Rz provides a measure indicative of the five highest and five lowest points, reflecting the most extreme aspects of the profile.

D. PD

24. The ’706 Patent describes that “peak density PD was measured according to ASME Bb [sic] 46.1 standards.” SOLUS-8:36-37. According to the version of the standard in force as of the Critical Date (the 2009 version), the “peak density” is not “PD” but “Pc: the number of SAE peaks per unit length measured at a specified peak count level over the evaluation length.” SOLUS-1017, 21. Generally, this “peak density” is a measure of how many peaks are present along a given line on the sample, or, equivalently, tells us how many peaks exist per unit length.

25. However, calculation of PD (or Pc) is complicated by the definition’s reference to “SAE peaks.” According to the ASME standard, an “SAE peak” is “a profile irregularity wherein the profile intersects consecutively a lower and an

upper boundary line. The boundary lines are located parallel to and equidistant from the profile mean line (see FIG. 1-14), and are set by a designer or an instrument operator for each application.” SOLUS-1017, 21. That is, in order to “count” as a peak for purposes of calculating PD (or P_c), the measured profile must first pass below a lower boundary line, then pass above an upper boundary line (or vice versa). The ASME standard provides a visual example of the analysis used for calculating peak density:

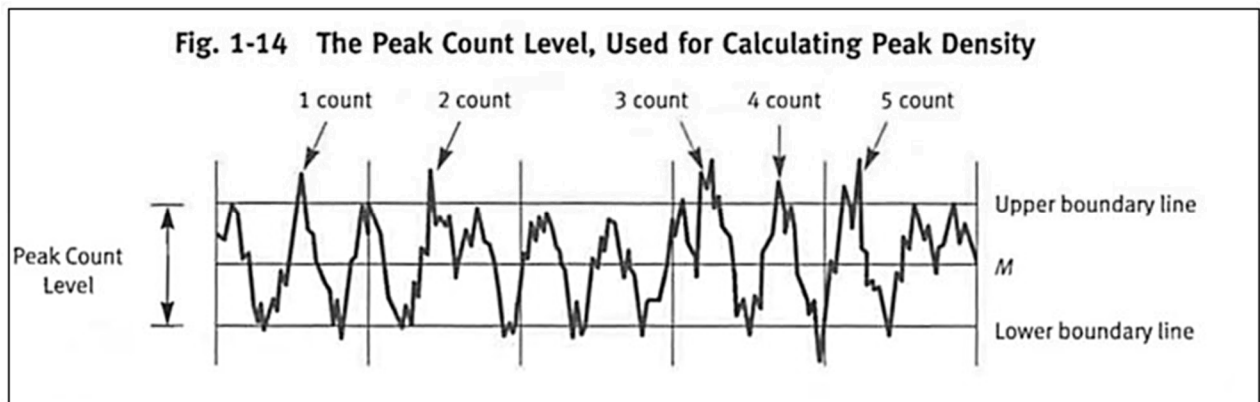


FIG. 1-14, SOLUS-1017

26. This calculation method means that PD (or P_c) is dependent upon the chosen upper/lower boundary lines. Boundary lines of greater magnitude (with respect to the center or midline (M)) will almost certainly result in lower PD (or P_c), because fewer portions of a measured profile will almost certainly be counted as peaks. Conversely, boundary lines of smaller magnitude will almost certainly result in higher PD (or P_c), because a higher number of profile irregularities will almost certainly be counted as peaks.

E. Surface profile of shiny side

27. Because it is relevant to several aspects of the discussion below, I note here that, in a copper electrolytic deposition process, the surface properties (including roughness, etc.) of the “shiny” side of the electrodeposited (or electroformed) copper foil very closely match or replicate (i.e., are a mirror image of) that of the surface finish on the cathode drum on which it is deposited or formed. Thus, the surface properties of an electrodeposited copper foil can be tuned with a high degree of precision and confidence by tuning the surface finish of the drum on which it is formed. In other words, during the copper electrolytic deposition process, the shiny side of the copper foil that is formed, is the side that is in-contact with the surface of the cathode drum to which the copper ions are attracted, and thus the shiny side conforms to and replicates the surface of the cathode such that it largely becomes a mirror image of the cathode drum’s surface.

28. Because of this, it was well within the skill of a POSITA to achieve arbitrary or near-arbitrary shiny-side profiles (e.g., roughness characteristics such as Ra, Rz, and PD (or Pc)) by causing the surface of the cathode drum to have a mirrored version of that profile. For example, as described by Kim ’761, a POSITA could select a suitable polishing grit and polish the drum with that grit to achieve targeted shiny-side roughness characteristics. SOLUS-1005, [0051], [0063], Table 1. As another example, as described by Lee ’883, structures on the

drum surface could be fabricated with particular spacings and depths/heights to cause corresponding shiny side features to have the same spacings and heights/depths. SOLUS-1028, [0015]-[0016], [0037]. *See, e.g.*, Kim '761 at [0051] (“in order for the shiny surface 111a to have a peak count roughness R_{pc} of 10 to 100 [], the surface of the rotational anode drum is polished with a #800 to #1500 grit polishing brush”); also Dobashi at 7:40-42 (“the shiny side [] has a mirror shape of the surface of a rotating cathode polished”); and Chou at [0009] (“the roughness of the S surface of the electrodeposited copper foil depends upon the roughness of the surface of the titanium-made roller. Therefore, the roughness of the S surface is more constant”); Sano at 1:49-51 (“since a shiny side copies a smooth shape of a cathode drum surface...”); Lee '883 (describing that “fine embosses” or “grooves” are formed in the “cathode rotary drum” so as to directly set the inter-valley spacing F1 in the resulting copper foil). SOLUS-1028, [0040], [0054], [0056].

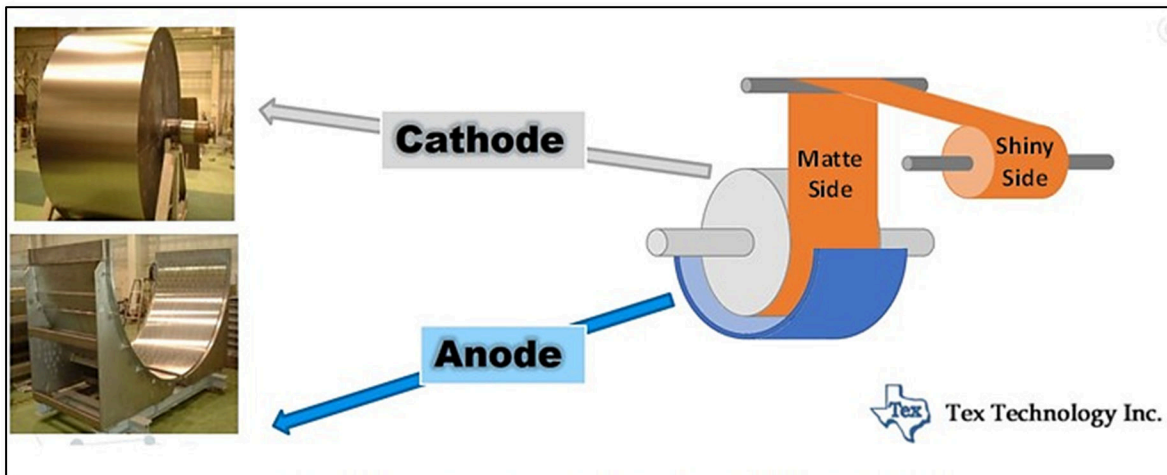
29. As such, some aspects of the following discussion will be based on the finding that a POSITA would have had a reasonable expectation of success in achieving targeted shiny side profile characteristics, based on the foregoing discussion and the teachings of the art discussed below.

F. Copper Foil Electrodeposition

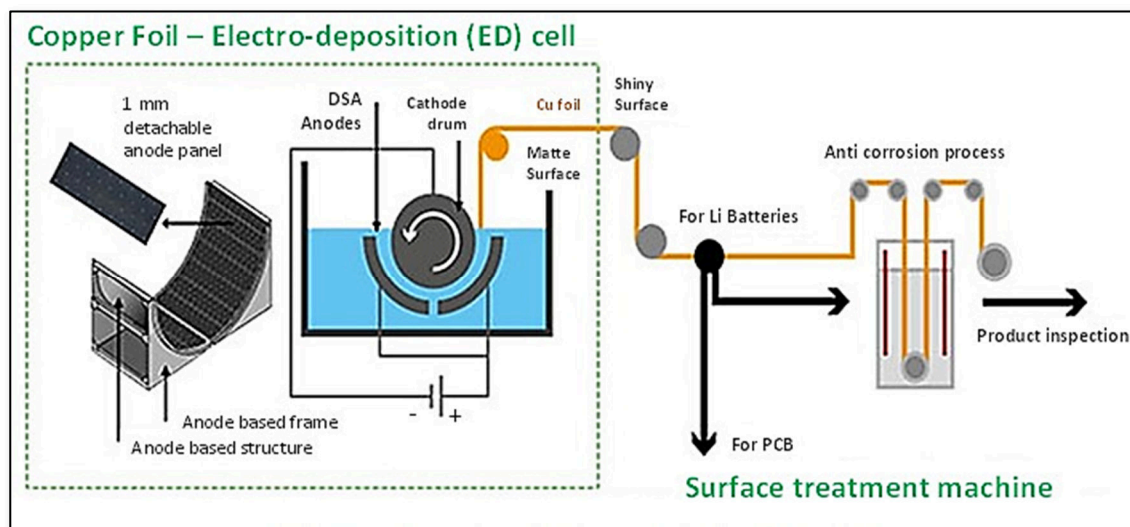
30. Electrodeposition of copper foils involves plating (reduction) of

positively charged copper cations (in solution) at a cathode surface to form copper metal via a reduction process, where the copper cations gain electrons and become copper metal that is deposited on the cathode. In the case of Cu electrodeposited foil, the cathode is typically a prepared drum that is negatively biased, such that the production of the foil may be continuous as illustrated and annotated below. The anode is typically placed closely to the cathode drum to help ensure consistent electrodeposition of the copper foil on the cathode. The resulting copper foil has two sides that are characterized as shiny (the side that was in contact with the cathode drum surface), and matte (the side away from contact with the cathode drum surface).

31. The continuous electrodeposition process (and associated plating chemistry) is carefully controlled in order to achieve uniform thickness, as well as desired surface finish and mechanical properties, etc. of the finished foil. In the case that the foils are to be used as current collectors in Li ion secondary batteries, the copper foil may be coated with an anti-corrosion material, such as a chromate coating, or the like. The product is then inspected and packaged for shipping and use by the customer.



Copper foil electrodeposition (SOLUS-1041)



Copper foil process sequence (SOLUS-1042)

32. The chemistry used to produce electrodeposited foils in the above process is typically a copper sulfate-sulfuric acid-aqueous chemistry, known as an acid copper bath. These chemistries have been used in the industry for more than 65 years. SOLUS-1040, 11. In addition to the basic acid copper electrolyte components (e.g., copper sulfate, sulfuric acid, and water), acid copper electrolytes also typically contain additives to optimize the properties of the resulting Cu foil

33. There are several categories of additives for copper acid electrolyte

chemistries. The important additive categories for purposes of this matter include:

1. Halides
2. Suppressors
3. Accelerators
4. Levelers

34. Specific additive chemistries may serve in one or more of these categories. Additives are typically used in small levels within the electrolyte (*ca.* <1,000 ppm) and are typically controlled within limits in order to achieve their associated desired functions.

35. Halides are used as anions in the electrolyte, and include anions of Cl, F, Br, I, with Cl⁻ being the most common by far. Halide ions facilitate the interaction between the cathode and organic additives. SOLUS-1043, 19-20.

36. Suppressors or inhibitors create a physical layer or film on the cathode, and on the deposited copper so as to increase cathode polarization and inhibit copper cation interaction, and thus copper deposition. SOLUS-1043, 20. Typical suppressors include polyethers such as polyethylene glycol (PEG) and polypropylene glycol (PPG). *Id.*

37. Accelerators are also known as brighteners or grain refiners. They serve to catalyze the reduction reaction at the cathode surface. SOLUS-1043, 20. Accelerators include, for example, organic sulfonates such as SPS, MPS, ZPS, and UPS. SOLUS-1043, 20; SOLUS-1044, 5:1-20, 10:65-67; SOLUS-145, 3.

38. Levelers function to selectively inhibit Cu plating in regions of high

current density (e.g., peaks) of the depositing Cu surface preferentially to areas of low current density (e.g., troughs). SOLUS-1043, 20. Levelers include, but are not limited to dye based levelers such as Janus Green B (JGB) and Diazine Black (DB), as well as other materials such as polyvinylpyrrolidone (PVP). *Id.*

VI. SUMMARY OF THE '706 PATENT

A. Brief Description

39. The '706 Patent purports to describe “an electrolytic copper foil having excellent handling characteristics in the manufacture of copper foil and in post-processing for manufacturing a secondary battery.” SOLUS-1001, Abstract. As discussed in the '706 Patent's Background, and as was well-known in the field of copper foil manufacture at the Critical Date, electrolytic copper foils are commonly used as a negative electrode current collector in lithium batteries. *Id.*, 1:31-33. However, according to the '706 Patent, these copper foils may exhibit “curls, wrinkles, or tears.” *Id.*, 1:51-52.

40. The '706 Patent purports to provide coppers foils “such that the possibility of the electrolytic copper foil being curled, wrinkled, and/or torn is reduced.” *Id.*, 1:67-2:1. In view of the features of claim 1, I will review several features that the '706 Patent highlights as allegedly providing an improvement.

41. First, the '706 Patent describes that the “texture coefficient of (220) plane” of the copper foil “is 0.4 to 1.32.” *Id.*, 2:14-16. The '706 Patent explains

that a (220) texture coefficient in this range can provide reduced wrinkles and tearing. SOLUS-1001, 4:9-21.

42. In addition, the '706 Patent describes that a “difference ($|\Delta(Rz/Ra)|$) between Rz/Ra at [a] first surface of the electrolytic copper foil and Rz/Ra at [a] second surface of the electrolytic copper foil is less than 2.42.” *Id.*, 2:24-27, where Rz “indicates ten-point average roughness,” Ra “indicates arithmetical average roughness,” and both Rz and Ra are “measured according to JIS B 0601(2001) standards.” *Id.*, 4:26-28, 4:33-35.

43. Further, for the copper foils of the '706 Patent, “it is preferable for the difference between the peak density PD at the first surface of the electrolytic copper foil and the peak density PD at the second surface of the electrolytic copper foil, i.e. $|\Delta PD|$, to be 96 ea or less.” SOLUS-1001, 4:28-32. PD is a roughness parameter measured according to ASME B46.1 standards. *Id.*, 4:34-35.

44. The '706 Patent explains that if $|\Delta(Rz/Ra)|$ and $|\Delta PD|$ “deviate from the above numerical ranges,” curls are formed in the copper foil “due to the difference in the surface properties between the opposite surfaces.” *Id.*, 4:36-41.

45. The '706 Patent also provides a composition for the electrolytic solution used to form the copper foil. *Id.*, 6:1-7:17.

B. Prosecution History of the '706 Patent

46. I have reviewed the prosecution history of the '706 Patent. I note in

particular that, in an initial non-final Office Action, the Examiner stated that

[t]he closest prior art to the instant claims is that of Kim (US 2018/0062199), which teaches a similar foil, (220), and PD as that which is claimed. However, this document was published less than one year from the instant effectively filed date and has common inventors and a common assignee and is therefore excepted under 35 USC 102(a)(2) by 35 USC 102(b)(2)(c). SOLUS-1002, 437.

47. Although US 2018/0062199 may not be prior art to the '706 Patent, the Examiner appears to have overlooked the fact that Kim '761, an earlier document sharing inventorship and a common assignee with the '706 Patent, provides explicit disclosure of the PD element of claim 1.

VII. GROUND 1A: Claims 1-5 are obvious over Kim '761 in view of Cheng and Wolski

A. Kim '761

48. Kim '761 appears to share inventor Seung Min Kim with the '706 Patent and corresponds to U.S. Patent No. 10,480,090, which has been asserted alongside the '706 Patent in co-pending litigation.

49. Kim '761 relates to “an electrolytic copper foil” having “a first surface and a second surface opposite to the first surface, wherein each of the first and second surfaces has a peak count roughness R_{pc} of 10 to 100.” SOLUS-1005, Abstract. The copper foil has a “shiny surface 111a” “which contacts the rotational anode[sic] drum in the process of electroplating” and a “matte surface 111b”

opposite the shiny surface 111a. *Id.*, [0030].

50. Kim '761 describes that “[a]s a result of repeated research, the present applicant found that a peak count roughness R_{pc} of the electrolytic copper foil 111 is an important factor in stably securing capacity maintenance of 90% or higher.” *Id.*, [0039]. In relation to the preferred R_{pc} range of 10 to 100, Kim '761 describes that “[w]hen the peak count roughness R_{pc} is less than 10, capacity maintenance of the secondary battery is deteriorated. This is because the stress caused during the charge/discharge of the secondary battery is concentrated on mountains which locally protrude” and that “when the peak count roughness R_{pc} exceeds 100, capacity maintenance of the secondary battery is also deteriorated. This is because the active material cannot be uniformly coated on the electrolytic copper foil 111 due to the excessive number of mountains.” *Id.*, [0043]-[0044].

51. Further, Kim '761 discusses the comparative peak count roughness R_{pc} between the two opposite surfaces 111a and 111b, stating that “[t]he difference in peak count roughness R_{pc} between the shiny surface 111a and the matte surface 111b of the electrolytic copper foil 111 is preferably 60 or less because, according to an embodiment of the present invention, both surfaces of the current collector 110 are coated with the active material. When the difference in the peak count roughness R_{pc} exceeds 60, capacity maintenance of the secondary battery is deteriorated due to difference in surface appearance between both surfaces 111a

and 111b.” *Id.*, [0045].

1. Equivalence of R_{pc} and PD

52. Based on my analysis, Kim ’761’s peak count roughness R_{pc} corresponds to the peak density PD of the ’706 Patent, to within the level of detail provided by the ’706 Patent. I base this opinion on several factors. First, the ASME B46.1-2009 standard cited by the ’706 Patent provides a definition for “peak density” (referred to in the standard as “Pc” – cf. Kim ’761’s use of the term “ R_{pc} ”) that matches the definition in the ’761 Patent. SOLUS-1017, 21. Kim ’761 describes that “the peak count roughness R_{pc} of each of the first and second surfaces is an average of peak count roughness R_{pc} values measured at three random points, the peak count roughness R_{pc} of each point is the number of effective peaks which rise above an upper criteria line C1 of 0.5 μm per unit sampling length of 4 mm in a surface roughness profile obtained according to steel-iron test schedule (SEP 1940), and there is at least one valley deeper than a lower criteria line C2 of -0.5 μm between adjacent ones of the effective peak.” SOLUS-1005, [0014]. That is, like the ASME standard discussed above, Kim ’761 instructs that R_{pc} is a number of effective peaks per unit length, where “effective peaks” refers to a peak “ris[ing] above an upper criteria line [and having] at least one valley deeper than a lower criteria line [] between adjacent ones of the effective peak.” SOLUS -1005, [0014]. These documents describe the same

calculation and the same calculation method.

53. Second, as I discussed above, PD (or R_{pc}) depends upon the criteria lines used to define an “effective peak” or “SAE peak.” In this case, the criteria lines used by the ’706 Patent and Kim ’761 are the same (i.e., $\pm 0.5 \mu\text{m}$, or $+0.5 \mu\text{m}$ for the upper criterion line, and $-0.5 \mu\text{m}$ for the lower criterion line), such that the ’706 Patent’s PD and Kim ’761’s R_{pc} can be directly compared to one another, without having to account for the potential use of different criteria lines. SOLUS-1001, 8:40; SOLUS-1005, [0014].

54. Third, in an effort to clarify the various terminologies used in the ’706 Patent, Kim ’761, and the 2009 ASME standard, I also consulted the 2019 updated version of the ASME standard. The 2019 version uses the abbreviation “ R_{pc} ” for “peak density,” suggesting that the term “ R_{pc} ” (i.e., the same term used by Kim ’761) was in use to refer to the peak density PD discussed in the ’706 Patent. SOLUS-1018, 11.

55. Fourth, the ’706 Patent and Kim ’761 (which share a common inventor) include very similar descriptions of the measurement of these parameters, including the use of the same roughness tester (Mahrsurf M300), the same upper/lower criteria levels ($\pm 0.5 \mu\text{m}$), and the same sampling/measurement length (4 mm). SOLUS-1001, 8:36-45; SOLUS-1005, [0064-0065]. And both of these passages are themselves very similar to the description of peak density PD

provided in Kim '081. SOLUS-1020, 6:56-7:4. The relevant portions of each document are provided in the table below. The '706 Patent, Kim '761, and Kim '081 share the common inventor Seung Min Kim. In my opinion, the similarity of these three passages and the match between their parameters suggests that this inventor used “peak density PD” and “peak count roughness R_{pc} ” interchangeably to indicate the same parameter, measured using the same measurement parameters.

'706 Patent describing PD (Id. at 8:36-45)	Kim '761 describing R_{pc} (Id. at [0064-0066])	Kim '081 describing PD (Id. at 11:40-54)
“The peak density PD was measured according to ASME Bb[sic] 46.1 standards, and the peak density was measured using a roughness tester from Mahr Company (Model name: Marsurf M300) and a stylus tip having a radius of 2 μm . The peak count level was $\pm 0.5 \mu\text{m}$ from the center line of the profile, the measurement length, excluding the cut-off length, was 4 mm, and the cut-off length was 0.8 mm at the first stage and the last stage. The measurement pressure was 0.7 mN. The average of the values obtained by performing the measurement three times was taken as the peak density.”	“[T]he peak count roughness R_{pc} of the shiny surface and matte surface of the electrolytic copper foils was measured using MahrSurf M300 roughness tester available from Mahr company []. As described above, the peak count roughness R_{pc} [] means an average of peak count roughness R_{pc} values obtained at three random points, the peak count roughness R_{pc} of each point is the number of effective peaks which rise above an upper criteria line C1 of 0.5 μm per unit sample length of 4 mm in the surface roughness profile obtained according to the steel iron test schedule (SEP 1940). If there is no valley deeper than a lower criteria line C2 of -0.5 μm between adjacent peaks rising above the upper criteria line C1, relatively lower one is excluded in determining the number of ‘effective peaks.’”	“The PDs of the first and second surfaces of the electrolytic copper foils were measured using a MahrsurfM300 [] [T]he PD is an average value of PDs of any three points, and the PD of each of the points is the number of effective peaks which rise above a 0.5 μm upper criteria line per 4 mm unit sample length in a surface roughness profile obtained according to U.S. standard ASME B46.1-2009. When there is no valley deeper than a -0.5 μm lower criteria line between adjacent peaks which rise above the upper criteria line, relatively lower peak(s) among the peaks were ignored when obtaining the number of ‘effective peaks.’”

56. With respect to the units of R_{pc} and PD, claim 1 of the '706 Patent uses units for PD of “ea.” In scientific fields, “ea” is typically used to refer to “each”; an absolute count of something (i.e., the same as # or “count”), e.g., as opposed to a count normalized for space (e.g. length) or time. Based on the plain meaning of this term, a POSITA would have understood “ea” to refer to an absolute count of peaks over the '706 Patent’s measurement length, that is, 4 mm.

SOLUS-1001, 8:31-32. Meanwhile, Kim '761 uses units of “count” for R_{pc} . SOLUS-1005, [0067]. The term “count” is equivalent to “ea” and, like “ea,” the term “count” would have been understood to be a peak count over Kim '761's sampling length, which matches the 4 mm measurement length of the '706 Patent. Equivalently, as Kim '761 explains, ‘count’ is a number of peaks per unit sampling length of 4 mm.” SOLUS-1005, [0041]. Based on this analysis, PD in claim 1 of the '706 Patent and the disclosed R_{pc} values in Kim '761 can be compared to each other one-to-one, without requiring conversion.

57. However, in my review, I also noticed that, although the plain meaning of claim 1 indicates the units of $|\Delta PD|$ as “ea,” Table 2 of the '706 Patent discloses four $|\Delta PD|$ values in units of “ea/cm,” the highest of which is 96 ea/cm. Given the match between this upper limit and that of claim 1, it occurred to me to analyze claim 1 for the case that the claimed range of “96 ea or less” is interpreted as “96 ea/cm or less.” To convert 96 ea/cm to 96 ea over the 4 mm sampling length, we multiply 96 ea/cm by 0.4. For example, if 10 peaks were measured over a 1 cm sampling length, we would measure 4 peaks over a 4 mm sampling length. Using this conversion factor, the alternative range of “96 ea/cm or less” can be straightforwardly converted to “38.4 ea or less.”

B. Cheng

58. Cheng relates to “[a]n electrolytic copper foil [having] a shiny side

and a matte side with a roughness of less than 2 μm .” SOLUS-1007, Abstract.

Cheng notes that “the (220) surface and (311) surface of the electrolytic copper foil of the present invention have promising crystalline phase characteristics, such that the elongation of the electrolytic copper foil can be greater than 14%. It is further discovered that the electrolytic copper foil with these crystalline phase characteristics resolves the problem of not [being] suitable for use in a lithium ion secondary battery caused by the high roughness of traditional products.” SOLUS-1007, 3:16-23. For example, claim 1 of Cheng recites that “a sum of texture coefficients [TC] of the (220) surface and the (311) surface of the electrolytic copper foil is greater than 60%.” SOLUS-1007, 10:55-57. Among other descriptions, Cheng discloses TC(220), Rz (ten-point roughness), tensile strength, and elongation for copper foils manufactured according to various process parameters. SOLUS-1007, Table 3.

59. Cheng’s texture coefficients (TC) correspond to the TC of the ’706 Patent, to within the level of detail provided by the ’706 Patent. Notably, the TC calculation formulas provided in each document are the same, and the same four crystal planes ((111), (200), (220), and (311)) are considered in TC calculations in each document. SOLUS-1001, Equation 1, 3:55, 4:1-8; SOLUS-1007, 2:52-54, Equation 1, 7:25. I note that my discussion above, which cites the consideration of the same crystal planes as a key aspect for determining whether TC can be

compared to one another. Although the '706 Patent used an X-ray diffraction scanning range (2θ) of 30° - 95° compared to Cheng's use of 40° - 95° , each of the important Bragg angles (and associated 2θ values) for each of the four crystallographic planes noted ((111), (200), (220), and (311)) are included in both of the 2θ ranges disclosed, and thus the use of different scanning ranges would not result in a difference in TC, as the ranges are both sufficient to capture the entire set of diffraction peaks corresponding to each of the associated crystal planes of interest. SOLUS-1001, 3:67, SOLUS-1007, 7:20. Evaluation of the same set of crystallographic planes (i.e., Miller indices (111), (200), (220), and (311)) is an important factor in the TC calculations. Thus, both 2θ scanning ranges are suitable for that purpose, and would not affect the TC(220) values in either case. *See also* FIGS. 3-4 of Chou (SOLUS-1016), which show peaks corresponding to (111), (200), (220), and (311) all lying between approximately 45° and 90° , that is, within the scanning ranges of both Cheng and the '706 Patent. Physics-based calculations of the expected diffraction angles corresponding to these crystal planes would show similar peak locations.

C. Wolski

60. Wolski relates to "an electrodeposited copper foil" in which "the surface roughness R_z of the matte side of the untreated copper foil is the same as or less than the surface roughness R_z of the shiny side of this untreated copper foil."

SOLUS-1008, Abstract. Wolski describes the electrodeposition conditions of “untreated copper foils” and provides R_z and R_a values for each of the matte side and the shiny side of the copper foils. *Id.*, 6:51-9:21, Table 2.

61. Further, Wolski describes that “the surface roughness R_z at the matte side of the untreated copper foil of the present invention is the same or smaller than the surface roughness R_z at the shiny side of said untreated copper foil so that the surface treated copper foil after subjecting to bond enhancing treatment onto the matte side becomes more low-profiled one as compared with the conventional foil”. *Id.*, 6:36-42.

62. The R_z and R_a disclosed by Wolski correspond to the R_z and R_a described and claimed by the '706 Patent, to within the level of detail provided by the '706 Patent. The '706 Patent describes that “ R_z indicates ten-point average roughness, and R_a indicates arithmetical average roughness” and that “ R_z and R_a may be measured according to JIS B 0601(2001) standards.” SOLUS-1001, 4:26-34. Similarly, Wolski describes that “the surface roughnesses R_z and R_a are R_z and R_a defined in [] JIS B 0601-1994. That is, R_z is a ten-point mean roughness [] and R_a is a center-line mean roughness [] which is the value, when the roughness curve has been expressed by $y = f(x)$, obtained from the following formula [] $R_a = \frac{1}{l} \int_0^l |f(x)| dx$ ” SOLUS-1008, 7:10-55. The 1994 and 2001 versions of the cited JIS standard provide equivalent formulas/descriptions for calculation of each of R_z and

R_a , with the proviso that the 2001 version renames the ten-point average roughness to R_{zJIS} . SOLUS-1021, 13-15; SOLUS-1022, 24-25. As such, a POSITA would have interpreted Wolski's and the '706 Patent's R_z (or R_{zJIS}) and R_a to correspond to one another, to within the level of detail provided by the '706 Patent.

D. Combination of Kim '761, Cheng, and Wolski

63. It would have been obvious to a POSITA to apply the teachings of Cheng and Wolski to the copper foil of Kim '761 in order to, among other things, obtain modified copper foils having (i) the peak count roughnesses R_{pc} (and, correspondingly, $|\Delta PD|$) of Kim '761, (ii) the R_z/R_a ratios of Wolski, and (iii) the (220) texture coefficients of Cheng.

64. At the outset, although this copper foil is referred to herein as a "modified" copper foil, it is not at all clear to me that any modifications to Kim '761 would actually be necessary in order to obtain the copper foil parameters recited in claims 1-5 of the '706 Patent. Kim '761 provides R_{zJIS} (ten-point roughness, corresponding to R_z in the '706 Patent) values for its two surfaces, but does not explicitly mention R_a for those surfaces, and also does not mention specific texture coefficients. Meanwhile, Cheng discloses texture coefficients but does not explicitly mention PD or R_z/R_a for both surfaces, and Wolski provides full disclosure of R_z/R_a for both surfaces, but lacks a detailed description of texture coefficients and PD.

65. As such, the combination of Kim '761, Cheng, and Wolski (“Kim’761-Cheng-Wolski”) discussed with respect to claims 1-5 does not, to me, indicate or concede any substantive difference between Kim '761’s copper foil and that of claims 1-5 of the ‘706 Patent. Rather, the combination accounts for claim 1’s recitation of three specific material properties that do not appear to have been measured (or were simply not mentioned) together in any single identified reference.

66. The foregoing notwithstanding, the prior art provides ample motivation and guidance for modifying Kim '761’s copper foil to obtain the TC(220) and Rz/Ra values disclosed by Cheng and Wolski.

1. TC(220)

67. It would have been obvious to modify Kim '761’s copper foil to obtain the TC(220) values disclosed by Cheng. Cheng recognizes that TC(220) is correlated with crystalline grain size and roughness, noting that “when [] the texture coefficients of a (220) surface and a (311) surface of an electrolytic copper foil are higher, the crystalline grains of the electrolytic copper foil become larger and the roughness of the M side become higher.” SOLUS-1007, 2:30-35. For example, Cheng notes that certain TC(220) values (in combination with TC(311) values) are associated with “significantly increased” elongation as well as a low matte-side roughness. *Id.*, 4:18-28. Cheng discloses that foils having the crystalline

phase structure associated with the disclosed TC(220) values (in combination with TC(311) values) also have a “roughness difference between both sides” that is “extremely small [such that] it was thus not easy for the electrolytic copper foil to break or fracture.” *Id.*, 10:27-34. As I discuss throughout this Declaration, the prior art was in general agreement that it was desirable to have similar roughnesses or roughness properties between the two sides of the foil. *See, e.g.*, my comments below on the Rz/Ra ratio. Thus, a POSITA would have been motivated to optimize textures coefficients such as TC(220) at least in order to obtain the foregoing benefits.

68. As such, Cheng provides a clear recognition of texture coefficients including TC(220) as result-effective variables. I am advised that, when a variable has been recognized as result-effective, it is normally obvious to find the optimum value of that variable. By that logic, it would have been obvious to a POSITA to optimize TC(220) by, for example, fabricating a copper foil having the texture coefficients – including TC(220) – that Cheng describes as providing effective results.

69. I am also advised that the obviousness of such optimization or experimentation is reinforced when a POSITA would have had “a reasonable expectation of success” in optimizing a variable. In this case, a POSITA would have had a reasonable expectation of success in obtaining the TC(220) values

described by Cheng. For example, Cheng describes process parameters such as electrolytic solution composition, temperature, and electrolysis current associated with manufacture of the disclosed foils. SOLUS-1007, 4:40-59, 4:66-5:2, 5:11-18, Table 1. Cheng also notes that the disclosed foils were “thus-obtained” by “the addition of acid-denatured polyvinyl alcohol [] to the copper sulfate electrolyte.” SOLUS-1007, 4:4-11. These process parameters could easily be selected and modified by an experimentalist based on Cheng’s disclosure, for example, by adding the disclosed components to the solution.

70. Moreover, the electrodeposition process described by Cheng represents no great departure from that described in Kim ’761. The two references describe deposition at similar temperatures, using similar plating currents, in solutions composed primarily of similar amounts of copper ions and sulfuric acid. It would have been obvious to try slightly modifying Kim ’761’s solution by, for example, including the polyvinyl alcohol and/or small molecular weight glue incorporated into Cheng’s solution, to obtain Cheng’s TC(220) values.

2. Rz/Ra

71. It would also have been obvious to modify Kim ’761’s copper foil to obtain the Rz and Ra values (and, accordingly, the Rz/Ra values) disclosed by Wolski. Wolski describes the desirability of having “both surfaces of the untreated copper foil” be “flat,” e.g., to obtain “excellent” elongation characteristics.

SOLUS-1008, 9:27-28, 12:22-23. Considering the two surfaces together, Wolski describes the desirability of having “the surface roughness R_z at the matte side of the untreated copper foil [be] the same or smaller than the surface roughness R_z at the shiny side of said untreated copper foil so that the surface treated copper foil after subjecting to bond enhancing treatment onto the matte side becomes more low-profiled one as compared with the conventional foil.” *Id.*, 6:36-42. The copper foils having the disclosed R_z and R_a values also exhibit “excellent” “elongation characteristics” and “high tensile strength” and are, based on their surface roughness, particularly compatible with a subsequent bond enhancing treatment. *Id.*, 9:28-29, 11:37-12:5, 12:16. A POSITA would have thusly been motivated to optimize R_z and R_a , at least in order to obtain the foregoing benefits.

72. This disclosure by Wolski comports with a broad recognition in the art that similar surface profiles (e.g., roughness) between the matte side and the shiny side were desirable. For example, Cheng discusses that a “small” “roughness difference between both sides” results in decreased breaking and fracturing during charging-discharging cycles, thus increasing battery life. SOLUS-1007, 10:30-34. Tsai teaches the desirability of “low roughness at both sides and extremely small difference in roughness between both sides.” SOLUS-1023, 3:14-15. And Sano notes that “in recent years [] a thin electrodeposited copper foil having [] a small roughness difference between a shiny side and a matte [] has been demanded.”

SOLUS-1024, 1:44-52. And, of course, Kim '761 emphasizes the desirability of having similar peak densities between the matte side and the shiny side. SOLUS-1005, [0045].

73. Accordingly, roughness parameters such as the ten-point mean roughness R_z (or R_{zJS}) and the mean roughness R_a were well-established as result-effective, such that it would have been obvious to a POSITA to optimize R_z and R_a by, for example, fabricating a copper foil having the R_z and R_a values, on both matte and shiny sides, disclosed by Wolski and known to provide good results. For example, based at least on the foregoing art disclosures that target similar roughness between the two sides, it would have been obvious to produce a copper foil having similar surface properties between matte and shiny sides, e.g., a low difference in R_z/R_a ratio ($|\Delta(R_z/R_a)|$) between the two sides. In arriving at the R_z and R_a values disclosed by Wolski, a POSITA would have also arrived at the R_z/R_a ratios disclosed by Wolski, as they follow directly from the R_z and R_a values.

74. I also note that the R_z/R_a ratio itself was recognized by the art as result-effective. Marshall describes that “higher $R_z : R_a$ [i.e., R_z/R_a] indicat[es] increased non-uniformity.” SOLUS-1025, 2. In seeking similar roughness properties between the two sides, it would have been obvious to a POSITA to seek similar uniformities between the two sides, i.e., similar R_z/R_a ratios, which would correspond to low $|\Delta(R_z/R_a)|$ as recited in claim 1 of the '706 Patent. Also, a

POSITA seeking an optimized uniform surface would have been motivated to obtain a small R_z/R_a ratio.

75. Moreover, a POSITA would have had a reasonable expectation of success in obtaining these R_z and R_a values. For example, Wolski provides detailed description regarding process parameters such as electrolytic solution composition, temperature, and electrolysis current associated with manufacture of the disclosed foils. SOLUS-1008, 6:52-7:3, Table 1. Wolski specifically notes the efficacy of including “3-mercapto 1-propanesulfonate” (MPS) in combination with a “low molecular weight glue” and a small amount of chlorine ions in order to obtain the disclosed roughness values. *Id.*, 4:66-6:35. With respect to those specifically-noted solution components, Kim ’761 already discloses the inclusion of chlorine ions, and Cheng already discloses the inclusion of MPS and low molecular weight glue. SOLUS-1005, [0049]; SOLUS-1007, 3:66-4:4. Also, the electrodeposition temperatures, current densities, and primary solution components (copper ions, sulfuric acid) and proportions are the same or similar between Kim ’671, Cheng, and Wolski. SOLUS-1005, [0049]; SOLUS-1007, 4:43-59; SOLUS-1008, 8:46-54, Table 1. It would have been obvious to try slightly modifying Kim ’761’s solution by, for example, by including the MPS, the low molecular weight glue, and chlorine ions in the proportions disclosed by Wolski, to obtain Wolski’s R_z and R_a values.

76. See also Section V.E for an explanation of why a POSITA would have had a reasonable expectation of success in obtaining target Rz and Ra values for the shiny side.

3. A POSITA would have had a reasonable expectation of success in optimizing PD, TC(220), and Rz/Ra in combination

77. As discussed above in Sections IV.D.1-2, a POSITA would have had a reasonable expectation of success in obtaining the PD, TC(220), and Rz/Ra values disclosed by Kim '761, Cheng, and Wolski, respectively. However, I am aware that these variables may not be independent from one another, or tunable entirely independently. For example, it is not out of the question that a change intended to modify TC(220) might have a secondary effect of changing Rz and/or Ra.

78. Nevertheless, this interdependency does **not** mean that simultaneous optimization of these variables, as discussed above and in the following Section VII.E, would have been beyond the skill of a POSITA, and in my experience, it would have been common to do so. For example, in order to investigate this interdependency, I examined the teachings of the '706 Patent with respect to each of $|\Delta PD|$, TC(220), and $|\Delta(Rz/Ra)|$. According to the '706 Patent, the claimed $|\Delta PD|$ values result from a particular PEG concentration range in the electrolytic solution. SOLUS-1001, 7:1-13. The claimed $|\Delta(Rz/Ra)|$ values result from a particular Mo concentration range in the solution. *Id.*, 6:49-57. The claimed

TC(220) values result from a particular sulfide-based compound composition range in the electrolytic solution. *Id.*, 6:5-20. That is, the '706 Patent teaches that the three claimed ranges can be achieved by optimizing three independent process parameters **separately**, without requiring special consideration or care to achieve the values jointly. And the disclosed compositions are not the only way to achieve the recited values: indeed, as discussed in the following Section VII.E, Kim '761 achieves the recited $|\Delta PD|$ without the inclusion of PEG, Wolski achieves the recited $|\Delta(R_z/R_a)|$ without including Mo in the electrolytic solution, and Cheng achieves the recited TC(220) using an amount of MPS (a sulfide-based compound) outside the range specified by the '706 Patent. For the foregoing reasons, the joint optimization of these three parameters would have been well within the skill of a POSITA.

E. Analysis of Claims

[1pre]: An electrolytic copper foil having a first surface and a second surface, wherein

79. The Kim '761-Cheng-Wolski copper foil discussed in Section IV.D satisfies or at least renders obvious an electrolytic copper foil having a first surface and a second surface. For example, Kim '761 discloses that “[t]he electrolytic copper foil [] of the present invention may be formed on a rotational [] drum by electroplating, thereby having a first surface [] which contacts the rotational []

drum in the process of electroplating, and a second surface [] opposite to the first surface.” SOLUS-1005, [0030].

[1a]: a texture coefficient of (220) plane of the electrolytic copper foil defined by Equation 1 below is 0.4 to 1.32,

$$TC(220) = \frac{\frac{I(220)}{I_0(220)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

80. The Kim '761-Cheng-Wolski foil, which adopts TC(220) values such as those disclosed by Cheng, satisfies or at least renders obvious a TC(220) of 0.4 to 1.32. For example, as shown in Cheng Table 3 (reproduced below), TC(220) for each of Cheng's six embodiments has a value within the claimed range. Further, of Cheng's six "comparative examples" (control samples fabricated without the use of polyvinyl alcohol), five have TC(220) within the claimed range. SOLUS-1007, 5:41-6:43. This latter finding suggests that the manufacture of copper foils having the claimed TC(220) is robust to various process conditions, as opposed to being highly sensitive to particular additives or additive concentrations. This reinforces my opinion that such manufacture would have been well within the skill of a POSITA, e.g., even without the polyvinyl alcohol of Cheng's high-performing embodiments.

TABLE 3-continued

Test results of the characteristics of electrolytic copper foil									
	Embodi- ment 1	Embodi- ment 2	Embodi- ment 3	Embodi- ment 4	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Roughness (Rz) difference between S side and M side (μm)	0.17	0.36	0.26	0.14	0.16	0.14	0.14	0.21	0.66
Weight resistivity ($\Omega\text{g}/\text{m}^2$)	0.154	0.156	0.154	0.155	0.163	0.162	0.160	0.161	0.155
TC (111)	0.23	0.62	0.33	0.32	1.03	0.98	0.91	1.01	0.30
TC (200)	0.23	0.58	0.30	0.33	1.85	1.51	1.66	1.63	0.18
TC (220)	1.04	1.08	1.07	1.06	0.82	0.72	0.77	0.70	3.20
TC (311)	2.50	1.72	2.30	2.29	0.30	0.79	0.66	0.66	0.32
TC (220) + TC (311)/TC (total)%	89	70	84	84	28	38	36	34	88
Crack on copper foil after charging-discharging test	No	No	No	No	Yes	Yes	Yes	Yes	Yes

TABLE 4

Test results of the characteristics of electrolytic copper foil			
	Embodiment 5	Embodiment 6	Comparative Example 6
Tensile strength (kg/mm^2)	33.7	33.5	34.5
Elongation (%)	9.4	9.7	6.2
Roughness of S side, Rz (μm)	1.85	1.77	1.74
Roughness of M side, Rz (μm)	1.55	1.54	1.58
Roughness (Rz) difference between S side and M side (μm)	0.30	0.23	0.16
Weight resistivity ($\Omega\text{g}/\text{m}^2$)	0.157	0.156	0.163
TC(111)	0.84	0.71	1.04
TC(200)	0.71	0.66	1.87
TC(220)	1.09	1.09	0.80
TC(311)	1.36	1.54	0.29
TC(220) + TC(311)/TC(total) %	61	66	27
Crack on copper foil after charging-discharging test	No	No	Yes

Annotated Cheng Tables 3-4

[1b]: a difference ($|\Delta(\text{Rz}/\text{Ra})|$) between Rz/Ra at the first surface of the electrolytic copper foil and Rz/Ra at the second surface of the electrolytic copper foil is less than 2.42, and

81. The Kim '761-Cheng-Wolski foil, which adopts R_z and R_a values such as those disclosed by Wolski, satisfies or at least renders obvious a $|\Delta(R_z/R_a)|$ of less than 2.42. As shown in Wolski's Table 2 below (which has been truncated and augmented to include a column for $|\Delta(R_z/R_a)|$), the foils of each of Wolski's Examples 1-4 have $|\Delta(R_z/R_a)|$ well within the claimed range, despite the different electrolytic solution compositions used to produce these foils. SOLUS-1008, Table 1. For example, Example 1 includes MPS and HEC additives; Example 4 includes MPS, HEC, and glue additives; Comparative Example 1 includes glue and thiourea additives; and Comparative Example 2 includes only a glue additive. Nevertheless, all of these foils satisfy the claimed $|\Delta(R_z/R_a)|$ range. This suggests that the claimed $|\Delta(R_z/R_a)|$ can be achieved robustly, as opposed to being highly sensitive to electrolytic solution composition. For at least these reasons and for the reasons provided above with respect to [1a], these values render obvious the claimed range.

	Matte side		Shiny side		
	roughness (μm)		roughness (μm)		
	R_z	R_a	R_z	R_a	$ \Delta(R_z/R_a) $
Example 1	1.3	0.30	2.0	0.40	0.67
Example 2	2.1	0.32	2.1	0.35	0.56
Example 3	1.1	0.20	1.8	0.35	0.36
Example 4	0.6	0.14	1.4	0.23	1.8
Comparative example 1	3.3	0.40	2.0	0.37	2.8
Comparative example 2	4.8	0.70	2.1	0.32	0.29

Modified Wolski Table 2

[1c]: a difference ($|\Delta PD|$) between a peak density (PD) at the first surface of the electrolytic copper foil and a peak density (PD) at the second surface of the electrolytic copper foil is 96 ea or less.

82. The Kim '761-Cheng-Wolski foil, having the R_{pc} values disclosed by Kim '761, satisfies or at least renders obvious a $|\Delta PD|$ of 96 ea or less. As I discussed in Section VII.A.1, Kim '761's R_{pc} can be compared directly to the '706 Patent's PD. As such, Kim '761's disclosure that "each of the first and second surfaces has a peak count roughness R_{pc} of 10 to 100" directly discloses the claimed $|\Delta PD|$ range, because the largest $|\Delta PD|$ attainable under Kim '761's

description is $|\Delta PD| = 90$ ea, corresponding to one surface with $PD = 100$ and another surface with $PD = 10$. SOLUS-1005, Abstract. That is, Kim '761's disclosed $|\Delta PD|$ range is **narrower** than the claimed range, rendering the claimed range obvious. Kim '761's disclosed $|\Delta PD|$ range also covers almost the entirety of the '706 Patent's claimed range, as the two ranges are nearly the same.

83. Additional disclosure of the claimed $|\Delta PD|$ range is found in Kim '761's Table 1, which provides specific "Difference in R_{pc} " values (corresponding to $|\Delta PD|$) for each of four example devices and four comparative examples (control samples), where the comparative examples were processed under different conditions than the four example devices. SOLUS-1005, [0063-0067], Table 1. As shown in the annotated table below, $|\Delta PD|$ for each of the four examples, and for three of the four comparative examples, lie within the claimed range. As such, Kim '761 discloses the claimed range.

<i>Table 1</i>						
	Heat treatment temperature of copper wire (°C)	Whether continuous filtration is conducted	Grit of polishing brush (#)	R _{pc} of matte surface (count)	R _{pc} of shiny surface (count)	Difference in R _{pc} (count)
Ex. 1	720	○	1200	13	42	29
Ex. 2	700	○	1400	20	24	4
Ex. 3	680	○	800	39	98	59
Ex. 4	660	○	1000	98	89	9
Comp. Ex. 1	810	○	1600	8	9	1
Comp. Ex. 2	-	○	700	112	128	16
Comp. Ex. 3	-	×	1200	181	47	134
Comp. Ex. 4	670	○	600	47	139	92

Annotated Kim '761 Table 1

84. Although it would represent a departure from the plain meaning of claim 1, I discussed above that, using an alternative interpretation of claim 1, “96 ea or less” can be interpreted as “96 ea/cm or less” or, equivalently, “38.4 ea or less” over the 4 mm measurement length. *See* Section VII.A.1. Using this conversion, each of Examples 1, 2, and 4 and Comparative Examples 1 and 2 satisfy the claimed range, disclosing or at least rendering obvious the claimed range under this alternative interpretation as well.

[2]: The electrolytic copper foil according to claim 1, wherein the second surface is an M surface, and Rz/Ra at the second surface is 4.2 to 9.0.

85. The Kim '761-Cheng-Wolski foil, adopting Rz and Ra values such as those disclosed by Wolski, satisfies or at least renders obvious that the second

surface is an M surface and has Rz/Ra of 4.2 to 9.0. According to the '706 Patent, "M surface" refers to the "matte surface." SOLUS-1001, 3:37-38. As shown in the modified Wolski Table 2 below, each matte side of each of Wolski's examples and comparative examples has Rz/Ra within the claimed range, rendering obvious the claimed range. I also note that all of Wolski's foils fall within the claimed range, despite their different electrolytic solution compositions. For example, even though Wolski's examples and comparative examples include different combinations and concentrations of four different compositions, all of them satisfy this Rz/Ra range. This suggests that the claimed Rz/Ra range is robustly achievable, as opposed to highly sensitive to the particulars of the electrolytic solution. Based at least on this reasoning, I believe that a POSITA would have had more than a reasonable expectation of success in fabricating the Kim'761-Cheng-Wolski copper foil having the matte-side Rz, Ra, and Rz/Ra disclosed by Wolski.

	Matte side		Shiny side		
	roughness (μm)		roughness (μm)		
	R_z	R_a	R_z	R_a	M surface R_z/R_a
Example 1	1.3	0.30	2.0	0.40	4.3
Example 2	2.1	0.32	2.1	0.35	6.6
Example 3	1.1	0.20	1.8	0.35	5.5
Example 4	0.6	0.14	1.4	0.23	4.3
Comparative example 1	3.3	0.40	2.0	0.37	8.3
Comparative example 2	4.8	0.70	2.1	0.32	6.9

Modified Wolski Table 2

[3]: The electrolytic copper foil according to claim 2, wherein the first surface is an S surface, and R_z/R_a at the S surface of the electrolytic copper foil is 5.1 to 6.8.

86. The Kim '761-Cheng-Wolski foil, adopting R_z and R_a values such as those disclosed by Wolski, satisfies or at least renders obvious that the first surface is an S surface and has R_z/R_a of 5.1 to 6.8. According to the '706 Patent, "S surface" refers to the "shiny surface." SOLUS-1001, 3:34. As shown in the modified Wolski Table 2 below, the shiny side of each of Wolski's examples 2-4 and comparative examples 1 and 2 has R_z/R_a within the claimed range, rendering obvious the claimed range. And the sole example of Wolski exhibiting a shiny surface R_z/R_a outside the claimed range has $R_z/R_a = 5.0$, which is within 2% of

the claimed range. As I discussed above in Section V.E, shiny surface roughness characteristics are primarily a function of the surface characteristics of the drum on which the shiny surface is grown, such that a POSITA would have had at least a reasonable expectation of success in fabricating the Kim'761-Cheng-Wolski copper foil having the shiny-side Rz, Ra, and Rz/Ra disclosed by Wolski.

	Matte side		Shiny side		
	roughness (μm)		roughness (μm)		
	R _z	R _a	R _z	R _a	S surface Rz/Ra
Example 1	1.3	0.30	2.0	0.40	5.0
Example 2	2.1	0.32	2.1	0.35	6.0
Example 3	1.1	0.20	1.8	0.35	5.1
Example 4	0.6	0.14	1.4	0.23	6.1
Comparative example 1	3.3	0.40	2.0	0.37	5.4
Comparative example 2	4.8	0.70	2.1	0.32	6.6

Modified Wolski Table 2

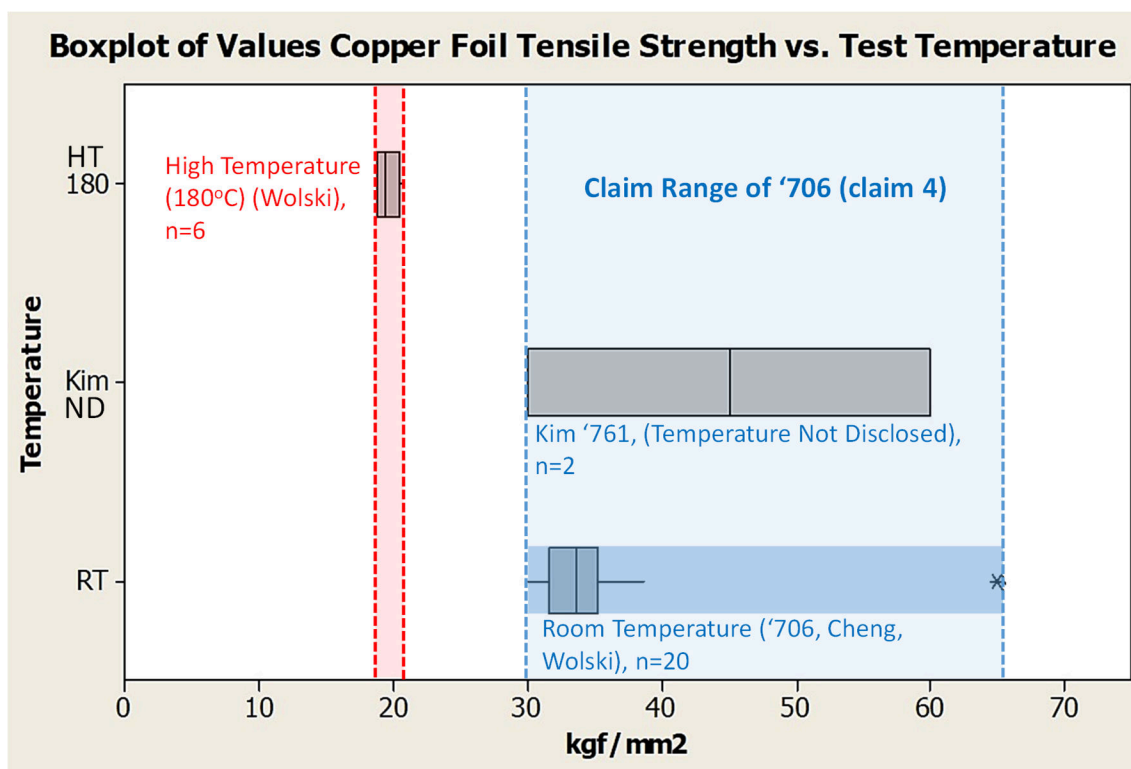
[4]: *The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has a tensile strength, measured at room temperature, of 30 to 65 kgf/mm².*

87. Kim '761-Cheng-Wolski renders obvious a room-temperature tensile strength of 30 to 65 kgf/mm². Each of these references discloses tensile strengths. SOLUS-1005, [0029]; SOLUS-1007, 6:56-63, Tables 3-4; SOLUS-1008, Table 2.

Cheng and Wolski describe that their measurements are conducted at room temperature. SOLUS-1007, 6:56-63; SOLUS-1008, Table 2. Kim '761 does not provide a measurement temperature. However, in the absence of a disclosed measurement temperature, a POSITA would have understood the measurement to have been conducted at room temperature since, in the fields of materials characterization and chemistry and the like, measurements or experiments are typically conducted at room-temperature unless indicated otherwise. I note that this is in line with Wolski, since where tensile tests were performed at high temperature, the temperature was specified (in this case 180°C). SOLUS-1008, Table 2. I note that this agrees with standard tensile testing of metals per the ASTM E8/E8M standard. SOLUS-1036.

88. I also note that Wolski provides both RT and 180°C tensile strength data. SOLUS-1008, Table 2. In order to investigate this further, I plotted the various tensile strength data vs. test temperature in the form of a box plot bar chart illustrated below. Note that in this analysis, I equated tensile strength units (i.e., the units of kg/mm^2 (Cheng) with the units of kgf/mm^2 ('706 Patent, Wolski, Kim '761)) as a POSITA would understand kgf and kg to be equivalent in tensile test data. This is because, as discussed in further detail below, on planet Earth (having an accepted gravitational field value of $\sim 9.81 \text{ m/s}^2$), both “units” are equal to $\sim 9.81 \text{ N}$ of force.

89. It is clear from the chart below that the tensile strength range of Kim '761 fits in the RT (room temperature) category and not the HT (high temperature (180°C)) category of tensile test data for these subject publications (the '706 Patent, Cheng, Wolski, and Kim '761). Since these are similar materials (copper foils) a POSITA would have understood from these disclosures that the tensile test temperature data of Kim '761 is for tensile testing conducted at room temperature (RT).



90. The ranges of the disclosed values are also shown in the table below. Kim '761 provides a range entirely within the claimed range ('706 Patent claim 4), and Cheng provides six examples of values, each within the claimed range, and Wolski provides four examples of values, each within the claimed range. SOLUS-

1005, [0029]; SOLUS-1007, 6:56-63, Tables 3-4; SOLUS-1008, Table 2. For Cheng and Wolski, the included values are those from the “Examples,” not the “Comparative Examples;” however, the values provided for the Comparative Examples are similar and also within the claimed range.

Claimed tensile strength (kgf/mm²)	Kim '761 tensile strength (kgf/mm²)	Cheng tensile strength (kg/mm²)	Wolski tensile strength (kgf/mm²)
30 - 65	30 - 60	31.3 – 33.7	33.6 – 37.2

91. In fact, the only tensile strength data, disclosed within these four documents, that are outside the claimed range of the '706 Patent's claim 4 are those disclosed in Wolski for samples that were expressly tested at high temperature (180°C). SOLUS-1008, Table 2. All of the room temperature data were within the range of claim 4 of the '706 Patent, further indicating the extreme breadth of claim 4 of the '706 Patent.

92. In my expert opinion, the modified foil – resulting from a combination of Kim '761, Cheng, and Wolski – would be expected to have tensile strength similar to those of Kim '761, Cheng, and Wolski. For example, in modifying solution compositions within the general conditions of these references in order to optimize foil parameters, it is very unlikely that the resulting foils' tensile strengths would have deviated sufficiently from the very similar ranges disclosed in each

reference to depart from the very broad range of the '706 Patent's claim 4. Thus, based upon the associated disclosed values of Cheng, Wolski and Kim '761 above, the resulting room temperature copper foil tensile strengths would be within the claimed range, rendering said range obvious.

93. Alternatively, claim 4 is obvious because it would have been obvious to optimize the foil to arrive at a tensile strength within the claimed range. By measuring and disclosing tensile strength, each of Kim '761, Cheng, and Wolski at least implicitly recognizes the importance of this parameter. Further, Wolski more explicitly describes the importance of "high tensile strength" for "dimensional stability." SOLUS-1008, 2:34-35. Accordingly, a POSITA would have been highly motivated to obtain an optimized tensile strength such as one within the claimed range.

94. I am advised that, where the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges by routine experimentation. Here, there can be no doubt that the "general conditions of the claim" are disclosed in the prior art: each of the three cited references discloses a tensile strength satisfying the claim. And I believe that a POSITA would have had a reasonable expectation of success in achieving the optimized tensile strength, (1) because the prior art provides detailed process parameters that provide tensile strengths in the claimed range, (2) because the prior

art achieves tensile strengths in the claimed range using a variety of different process parameters (corresponding to different examples), suggesting that these tensile strengths can be achieved robustly/insensitively and predictably, and (3) because Cheng describes specifically that TC(111) and TC(200) can be tuned to achieve a higher tensile strength (See e.g., SOLUS-1007 at 2:24-29), thereby providing an additional corroborating measurement and tool that a POSITA would have exploited in the optimization process. Accordingly, obtaining a room-temperature tensile strength in the claimed range would have been well within the skill of a POSITA to achieve by routine experimentation.

95. For at least the foregoing reasons, the claimed room-temperature tensile strengths are obvious.

96. As an additional note, although Cheng discloses units of “kg/mm²” as opposed to “kgf/mm²” as in the ’706 Patent, Kim ’761, and Wolski, a POSITA would have interpreted Cheng’s values as having units of “kgf/mm².” As discussed above, it is well-known that the units of tensile strength are force per area, not mass per area as suggest by “kg/mm².” But a POSITA would have well understood that with regard to force, 1 kg and 1kgf are equivalent. This is because, on planet earth, a 1 kg mass exerts a force of ~9.81 N (where N = Newtons = kg·m/s²), due to the relation: $f = m \cdot a$, where f is force, m is mass and a is acceleration (in this case the acceleration due to the gravitational force on Earth (a.k.a. “g”), which is

generally accepted to be *ca.* 9.81 m/s^2). Thus a POSITA would understand that the force a 1 kg mass (on Earth) exerts is equal to $\sim 9.81 \text{ N}$ (Newtons), a value which is equal to 1 kgf (on Earth). Thus, when experiments are conducted under the same gravitational force (i.e. the g force on planet Earth ($\sim 9.81 \text{ m/s}^2$)), the units kg/mm^2 and kgf/mm^2 are one and the same, and Cheng's tensile strength data are thus reported in the same units as those disclosed in the other publications (the '706 Patent, Wolski, and Kim '761). The kg/mm^2 unit is simply a holdover from the past, as historically, it was common to perform force-based tests, such as tensile tests using counter-balanced weights (or masses) instead of load cells and digital instrumentation, and so the tester would simply note the amount of weights (or masses), typically in kg (kilograms), that were needed to perform the test measurement of interest (e.g., in the case of tensile testing, to cause tensile failure of the associated sample). Thus, use of the unit " kg/mm^2 " has been typical when reporting tensile strength of electroplated materials (including foils) for decades. SOLUS-1039, 20 (Table 2).

[5]: The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has an elongation, measured at room temperature, of 3% or more.

97. Kim '761-Cheng-Wolski renders obvious a room-temperature elongation of 3% or more. The rationale here is generally similar to that provided

for [4] above. Although Kim '761 does not disclose elongation values, both Cheng and Wolski describe various room-temperature elongation values, all of which fall in the claimed range, as shown in the table below. SOLUS-1007, 6:64-7:4, Tables 3-4; SOLUS-1008, Table 2.

Claimed Elongation	Cheng Elongation	Wolski Elongation
3% or more	9.4 – 15.6 %	11.7 – 19.8 %

98. The elongation for each of Cheng's six Examples and for each of Wolski's four Examples is within the claimed range.

99. As an initial note, given the disclosure in many of the prior art documents I reviewed, an elongation of "3% or more" does not appear to be at all remarkable or to constitute an improvement to the prior art. For example, Cheng, Wolski, Tsai, Sano, Shinozaki '922, Chou, and Lee each disclose examples of elongation for copper foils, and **all** of the examples in these documents have an elongation of "3% or more" SOLUS-1007, 6:64-7:4, Tables 3-4; SOLUS-1008, Table 2; SOLUS-1023 Table 2; SOLUS-1024, Table 2; SOLUS-1016, [0042]-[0043], Table 1; SOLUS-1015, Table 1; SOLUS-Lee, Table 4. Elongations in this range are also disclosed in SOLUS-1039, published in 1974. SOLUS-1039, 20 (Table 2). Thus, it appears that the claimed range of elongation for the '706 Patent's claim 5 is not inventive.

100. That notwithstanding, first, given that the modified foil results from a combination of Kim '761, Cheng, and Wolski, the foil would be expected to have an elongation similar to those of Cheng and Wolski, for reasons similar to those I provided above for [4]. This expectation is strengthened by the fact that the electrolytic solutions and other process parameters used by Kim '761, Cheng, and Wolski are similar to one another (*see*, e.g., the discussions in Section VII.D above), and by the fact that the disclosed elongations of Cheng and Wolski are well beyond the claimed range minimum value of 3%, such that, even if the modified foil had a significantly lower elongation – for example, 50% lower – the modified foil would still satisfy claim 5. Based on this reasoning, the Kim '761-Cheng-Wolski foil renders obvious the claimed range by having a room temperature elongation within the claimed range.

101. Alternatively, claim 5 is obvious because it would have been obvious to optimize the foil to arrive at an elongation within the claimed range. Both Cheng and Wolski describe the desirability of a high elongation foil. SOLUS-1007, 3:13-19, 4:20-23; SOLUS-1008, 2:36-59, 5:55-65. Accordingly, a POSITA would have been highly motivated to obtain a high elongation, such as one within the claimed range.

102. And, for reasons similar to those discussed above with respect to [4], because the general conditions of claim 5 are disclosed in the prior art, it would

have been obvious to discover the optimum or workable ranges by routine experimentation. Here, both Cheng and Wolski disclose high elongations that easily satisfy the claimed range, such that the general conditions of the claim are satisfied by the prior art. And, as discussed above for [4], because of the art's detailed process disclosures, apparent robustness and predictability of obtaining high values of room temperature elongation, and disclosure of particular process parameters associated with high elongation, a POSITA would have had a reasonable expectation of success in achieving the claimed elongations by routine experimentation.

103. For at least the foregoing reasons, the claimed room-temperature elongations are obvious.

VIII. GROUND 1B: Claims 6 and 8 are obvious over Kim '761, Cheng, Wolski, and Kim '541

A. Kim '541

104. Kim '541 relates to a “copper foil for a current collector of a lithium secondary battery” having particular texture coefficients, surface roughness, weight deviation, tensile strength, elongation, and thickness. SOLUS-1009, Abstract. Inventor Dae-Young Kim is shared between Kim '541 and Kim '761.

105. Kim '541 describes that, when parameters including “weight deviation” are optimized, “the generation of wrinkles at a surface of the copper foil” can be “effectively decrease[d].” SOLUS-1009, 2:5-10. Specifically, Kim

'541 discloses that "[t]he 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.

106. To that end, Kim '541 provides process parameters (including electrolyte composition and electrolysis conditions) that can be used to fabricate copper foils having low weight deviation. For example, Kim '541 discloses that:

[] the copper foil [] according to the present invention is made by adding a small amount of organic additives to a copper sulfate solution containing copper sulfate, sulfuric acid and chlorine. Here, the additive may be a sulfonate based additive containing sulfide as a brightener to polish a plating surface and obtain a fine plating layer, gelatin having a low molecular weight of 1,000 to 100,000 as a leveler added to obtain a low roughness copper foil, or a cellulose based additive serving as a suppressor to realize a stable low roughness. As the process condition, copper is electrodeposited on a drum surface of a foil making machine with a current density of 30 to 80 ASD (A/dm^2) at a temperature of 30 to 60° C., and the surface of the copper foil is chromated to prevent corrosion. SOLUS-1009, 3:8-22.

107. Using these process parameters, Kim '541 discloses seven different copper foils, the weight deviations of which range from 0.4% to 2.6%:

	Examples						
	1	2	3	4	5	6	7
(220) ratio [%]	24	38	17	30	29	19	34
Tensile strength [kg/mm ²]	32.2	33.7	34.5	32.6	32.1	37.2	33.1
Weight deviation [%]	0.4	0.7	0.8	1.6	0.4	2.6	1.2
Number of wrinkles [ea]	0	0	0	0	0	0	0

Modified Table 1 of Kim '541

108. Based on my review of Kim '541 and the '706 Patent, the “weight deviation” of Kim '541 corresponds to the “lateral weight deviation” of the '706 Patent. For example, I have compared the descriptions provided with respect to these parameters in the two patents to determine that they correspond to one another to within the level of detail provided by the '706 Patent, as shown below. The two patents disclose exactly the same process, down to the same 5cm × 5cm portions into which the copper foil is cut. It appears very likely that this was a standard test process employed in a common research lab or firm, or for a common or standard test protocol, in which experiments for Kim '541 and the '706 Patent were carried out.

109. Note that, because Kim '541 describes measurement “along a width direction of the copper foil,” Kim '541’s weight deviations are “lateral” weight

deviations. SOLUS-1009, 4:33-34. *Cf.* the '706 Patent's description of a "sample cutting process in the lateral direction of the copper foil." SOLUS-1001, 5:37-38.

'706 Patent	Kim '541
"In the present disclosure, the lateral weight deviation of the electrolytic copper foil is realized by cutting a copper foil into an area of 5 cmx5 cm in order to manufacture a sample, measuring the weight of the sample, converting the measured weight of the sample into a weight value of the copper foil per unit area, repeatedly performing the sample cutting process in the lateral direction of the copper foil, measuring the copper foil weight value of each sample, and calculating the standard deviation." SOLUS-1001, 5:31-40.	"Here, the weight deviation is obtained by cutting a copper foil by an area of 5 cmx5 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-1009, 4:30-37.

B. Combination of Kim '761, Cheng, Wolski, and Kim '541 and analysis of [6].

[6]: The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has a lateral weight deviation of 5% or less.

110. The combination of Kim '761, Cheng, Wolski, and Kim '541 renders obvious the claimed lateral weight deviation. As discussed in Section VIII.A, Kim '541 establishes the importance of weight deviation and describes the desirability of having a low weight deviation, e.g., "3% or less" in order to avoid "property deviations [] which may increase the number of wrinkles." SOLUS-1009, 4:26-29.

Based on this disclosure, it would have been obvious, and within the skill of a POSITA, to optimize the manufacture of the foil of Kim '761, Cheng, and Wolski in order to obtain a weight deviation of 3% or less, necessarily satisfying claim 6's recitation of a lateral weight deviation of 5% or less.

111. A POSITA would have had a reasonable expectation of success in obtaining the low weight deviation. For example, Kim '541 discloses that low weight deviations can be obtained by using an electrolytic solution including "copper sulfate, sulfuric acid, [] chlorine," and "a small amount of organic additives" such as "a sulfonate based additive containing sulfide," "gelatin having a low molecular weight [], or a cellulose based additive." SOLUS-1009, 3:8-17. This clear guidance is similar to that in Kim '761, Cheng, and Wolski. For example, Kim '761 discloses an electrolytic solution having "copper ion" (which would have been obvious to provide using copper sulfate, as corroborated in many of the prior art documents discussed herein), "sulfuric acid," "chlorine ions," "hydroxyethyl cellulose," and "organic sulfide," the latter two of which are examples of Kim '541's "organic additives." SOLUS-1005, [0049]. In addition, Kim '761's use of "a current density of 10 to 80 A/dm² at 40 to 60°C" is in agreement with Kim '541's use of "a current density of 30 to 80 ASD (A/dm²) at a temperature of 30 to 60° C." SOLUS-1005, [0049]; SOLUS-1009, 3:19-21. And, as I discussed above in Section VII.D, the electrolytic solutions and process

parameters of Cheng and Wolski match or are similar to those of Kim '761 and, correspondingly, those of Kim '541 in association with the low weight deviation. As such a POSITA would have had a reasonable expectation of success in obtaining the low lateral weight deviation.

112. As a result, it would have been obvious to obtain the modified foil discussed in Section VII.D with a lateral weight deviation of 5% or less, e.g., using the combined fabrication process of Kim '761, Cheng, Wolski and Kim '541.

C. Analysis of [8]

113. The preamble of claim 8 recites “[t]he electrolytic copper foil of claim 1, wherein the electrolytic copper foil is manufactured by:”. This preamble establishes claim 8 as a product-by-process claim. I have been informed that, if the product in a product-by-process claim is the same as or obvious from a product of the prior art, the claim is unpatentable even if the prior product was made by a different process.

114. To investigate the obviousness of the product corresponding to claim 8's process, I consulted the '706 Patent to determine how various aspects of the process affect the final product. The '706 Patent describes that several parameters of the process claimed in claim 8 result in an improved product. However, as shown below, each of these improvements to the product itself is obvious over the combination of Kim '761, Cheng, Wolski, and Kim '541, such that claim 8 is also

obvious, even without an analysis of the obviousness of the recited process steps.

Claimed process step	Described product characteristics	Obviousness of product characteristics
buffing a surface of a rotary negative electrode drum using a brush having a grit of 500 # to 3000 #;	1. “the range of Rz/Ra of the S surface of the electrodeposited electrolytic copper foil is 5.1 to 6.8” SOLUS-1001, 6:31-39 2. “the peak density of the S surface [] is a relatively uniform value of 10 to 20 ea.” SOLUS-1001, 40-45	1. <i>See</i> [3] above 2. [see below]
electrodepositing the copper foil...; and	Results in manufacture of the foil	Obvious in view of disclosures of electrodeposited copper foils. That is, this process step results in the copper foil, a product which is obvious in view of the art’s many descriptions of a copper foil.
winding the electrodeposited copper foil,	[no disclosed product characteristics]	
wherein the electrolytic solution comprises 70 to 90 g/L of copper ions,	[no disclosed product characteristics]	

80 to 120 g/L of sulfuric acid,	[no disclosed product characteristics]	
10 to 20 ppm of chlorine ions,	[no disclosed product characteristics]	
3 to 12 ppm of a sulfide-based compound,	TC(220) in range from 0.4 to 1.32. SOLUS-1001, 4:9-21, 6:5-20.	<i>See</i> [1a] above
25 to 50 ppm of molybdenum (Mo),	1. $\Delta(R_z/R_a)$ less than 2.42. SOLUS-1001, 4:22-26; 6:55-57. 2. If Mo below this range, “locally nonuniform plating” and “M surface of the copper foil is stained or nonuniformly electroplated.” SOLUS-1001, 6:59-63.	1. <i>See</i> [1b] above 2. <i>See</i> [6] above, and corresponding discussion immediately below.
5 to 25 ppm of polyethylene glycol (PEG).	1. Small difference in the PD values between the M surface and the S surface. SOLUS-1001, 7:11-13. 2. R_z/R_a at M surface is at least 4.2. SOLUS-1001, 7:13-17.	1. <i>See</i> [1c] above 2. <i>See</i> [2] above

115. With reference to the '706 Patent's disclosure that Mo concentrations outside the recited range are associated with “locally nonuniform plating” and “M surface of the copper foil is stained or nonuniformly electroplated,” this product

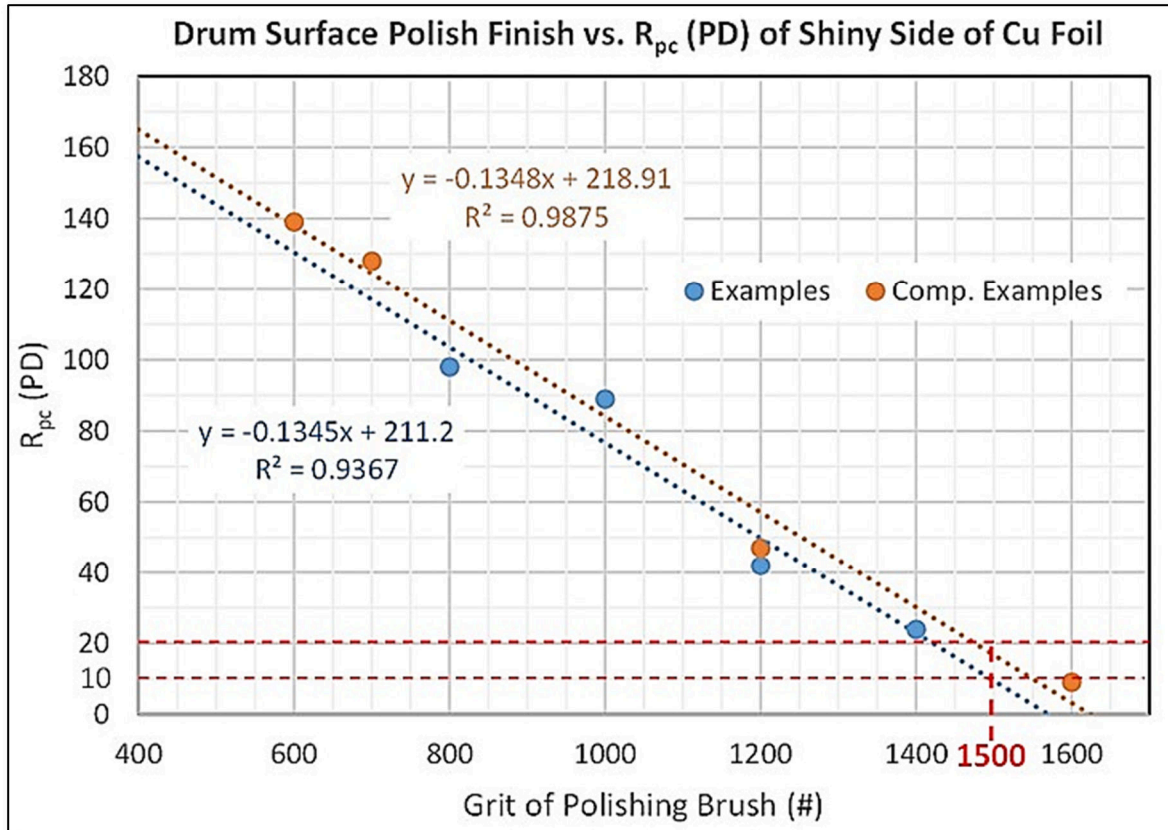
characteristic is obvious. The low weight deviation taught by Kim '541 corresponds to uniform plating, because nonuniform plating would express itself as a high weight deviation (including laterally along the width of the copper foil), with more copper deposited in some locations than in other locations. Also, none of Kim '761, Cheng, Wolski, or Kim '541 disclose a problem with “stain[ing],” from which I conclude that their foils are not stained. As such, the prior art teaches the product characteristics resulting from the claimed Mo concentrations.

116. With reference to the '706 Patent's disclosure that “the peak density of the S surface [] is a relatively uniform value of 10 to 20 ea” in association with the process element of “buffing,” this product characteristic is obvious. SOLUS-1001, 6:21-45. First, Kim '761 discloses that R_{pc} (PD) for the shiny side is in a range of 10 to 100, which overlaps and encompasses the 10 to 20 ea range associated with the recited Mo concentration and thereby renders the 10 to 20 ea range obvious. SOLUS-1005, [0042].

117. In addition, I note that the R_{pc} (PD) values disclosed for the shiny surfaces of Kim '761's examples are in a range from 24 to 98, outside the 10 to 20 ea range associated with the “buffing” process element. SOLUS-1005, Table 1. However, given Kim '761's focus on peak density as a parameter of interest, it would have been obvious to try smaller peak densities, including those within the 10 to 20 ea range, that would have been attainable with a high expectation of

success. Specifically, as I discussed above in Section V.E, a POSITA would have been able to tune the PD with a high degree of predictability by tuning the surface of the drum. As such, it would have been obvious for a POSITA to optimize the shiny side PD within the general conditions of the prior art, to obtain a shiny side PD in a range from 10 to 20 ea. For example, as a matter of routine experimentation based on Kim '761's focus on shiny side PD (R_{pc}) as a parameter of interest, it would have been obvious to use a slightly higher grit than the #1400 grit used for Kim '761's Example 2, so as to obtain a slightly smaller PD than the disclosed 24 ea, such that the modified and obvious resulting copper foil would have a shiny side PD in the range of 10 to 20 ea and within Kim '761's target range of 10 to 100 ea. SOLUS-1005, Table 1. This modification would have constituted no more than optimization of an art-recognized result effective variable (shiny side PD) with a reasonable expectation of success based on the art's recognition of the connection between roughness and polishing.

118. To show this, I have plotted the shiny side PD of the Examples and the Comparative Examples disclosed in Table 1 of Kim '761 below. Using simple linear regression it is evident from the figure that PD between 10 and 20 ea may be achieved with an approximately 1500 grit polish (which is a commonly available grit size) using either set of data (Example or Comparative Example) with a very high degree of confidence (i.e., $R^2 = 0.937$ and 0.988 respectively).



119. For the foregoing reasons, the product produced by the process of claim 8 is obvious. It follows that claim 8 is also obvious.

IX. GROUND 1C: Claim 7 is obvious over Kim '761, Cheng, Wolski, and Lee

A. Lee

120. Lee relates to “an electrodeposited copper foil” that has “low roughness[,] high strength[,] high elongation rate, and [] excellent glossiness, so that the electrodeposited copper foil may be used in a current collector of a [] battery.” SOLUS-1010, Abstract. Lee also discusses the importance and measurement of “corner curl angle” and “corner curl height.” *Id.*, [0052].

B. Combination of Kim '761, Cheng, Wolski, and Lee and analysis of [7].

[7]: The electrolytic copper foil according to claim 1, wherein an arithmetic mean of measured heights of corners of four protruding incision portions of the electrolytic copper foil, formed by incising electrolytic copper foil in a form of a cross having a size of 8 cm×8 cm so as to be vertically divided into two parts, is less than 10 mm.

121. The combination of Kim '761, Cheng, Wolski, and Lee renders obvious the claimed corner heights measured according to the recited process. Lee provides ample motivation for a POSITA to try to produce a copper foil having a low measured corner height (i.e., that lays flat and has little residual internal stress, at least in order to avoid wrinkles during processing), for example, disclosing that “when the corner curling phenomenon is generated, a plurality of defects, such as a torn corner, may be generated during a process, such as deposition, in a PCB process, and in a process of the lithium secondary battery, a corner may be torn or folded, or wrinkles may be generated during a coating of an active material.” SOLUS-1010, [0052]. As such, a smaller corner curl height is preferable. *Id.*, [0121].

122. Besides generally motivating a low corner height, Lee provides measured values for four examples of foils. *Id.*, [0120]. As shown in the annotated table below, of the four examples, two have a corner curl height in the claimed

range of “less than 10 mm,” while a third has a corner curl height of 12 mm, close to the claimed range. It would have been obvious to a POSITA to try to manufacture a copper foil having these low, attainable curl heights satisfying the range of claim 7.

TABLE 5		
	Corner curl angle (°)	Corner curl height (mm)
Example 1	5	4
Example 2	15	12
Example 3	8	6
Example 4	30	26
Comparative Example 1	52	48
Comparative Example 2	48	44
Comparative Example 3	46	43
Comparative Example 4	50	46

Annotated Lee Table 5

123. In addition to the foregoing description, Lee claims a range of curl height from 0 to 40 mm, a range which covers the entirety of claim 7 of the '706 Patent. SOLUS-1010, claims 11, 25, 37.

124. Lee also provides significant guidance to a POSITA as to how these small corner curl heights may be obtained. For example, Lee provides detailed electrolytic solution compositions for each of the examples and comparative examples, along with plating current and temperature. SOLUS-1010, [0091]-

[0096], Table 1. It would have been obvious to employ electrolytic solution compositions and plating conditions similar to those described for Examples 1-3, which have the lowest curl heights disclosed by Lee, in order to obtain low curl heights. For example, a POSITA would have naturally observed that Examples 1-3 were produced using various combinations and concentrations of additives as disclosed in Lee's Table 1, and would have concluded that the use of those same additives would likely provide foils with low corner curl heights. Further, Lee's electrolytic solution is similar to those of Kim '761, Cheng, and Wolski, including, for example, the same or similar concentrations of copper ions and sulfuric acid, a chlorine concentration within the range disclosed by Kim '761, and similar additives such as a thiourea-based compound and/or MPS. SOLUS-1005, [0049]; SOLUS-1006, 4:40-50 SOLUS-1008, 8:46-55, Table 1; SOLUS-1010, [0091]-[0097], Table 1. As such, any optimization based on Lee would have simply been optimization within the general conditions of the existing art, such that a POSITA would have had a reasonable expectation of success in optimizing the curl height.

125. Although claim 7 does not recite that the "measured heights" are "curl" heights, the '706 Patent makes clear that they are. For example, the '706 Patent describes the measurement of the heights in a section titled "Curls" and states that "the arithmetic mean of the measured heights was taken as the curl." SOLUS-1001, 8:46-55.

126. I have also compared the '706 Patent's measurement methods with the measurement method described by Lee. A table comparing these methods is shown below. As disclosed in the portions of the '706 Patent and Lee cited in the table, in each case, a portion of copper foil is cut with two intersecting cuts ("a cross" in the '706 Patent or "a shape of 'X'" in Lee). Further, in each case, heights of multiple corners formed by the cuts are measured. In addition, the lateral sizes relevant for the measurements are similar (8×8 cm for the '706 Patent and 10×10 cm for Lee). *Id.* Although claim 7 recites that the copper foil is "vertically divided into two parts," based on FIG. 3 of the '706 Patent, the copper foil is not actually separated into multiple pieces; rather, a cross-shaped cut is made in a cohesive portion of copper foil. SOLUS-1001, FIG. 3. This is consistent with the process described by Lee. Thus, the measurement method recited in claim 7 appears to match that of Lee, with two differences.

'706 Patent	Lee
"An incision was made in the shape of a cross having a size of 8 cm×8 cm at an arbitrary point on the M surface of each of the electrolytic copper foils manufactured according to Examples and Comparative Examples so as to be vertically divided into two parts in order to form four incision portions.	"Specimens having a width 10 cm × a length 10 cm were extracted from the electrodeposited copper foils obtained in Examples 1 to 4 and Comparative Examples 1 to 4, the extracted specimens were laid on a flat floor and were cut at an angle (corner curl angle), at which corner portions were

After incision, the heights of the corners of the four incision portions that protruded sharply were measured, and the arithmetic mean of the measured heights was taken as the curl.” SOLUS-1001, 8:46-55. “an arithmetic mean of measured heights of corners of four protruding incision portions of the electrolytic copper foil, formed by incising electrolytic copper foil in a form of a cross having a size of 8 cm×8 cm so as to be vertically divided into two parts” (claim 7).	bent and in a shape of ‘X’, and then heights (corner curl height), by which the cut portions were rolled up, were measured, and the measurement results are represented in Table 5 below.
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127. First, Lee does not explicitly describe that the multiple “heights” corresponding to the “corner portions” are averaged to obtain an “arithmetic mean.” However, the calculation and presentation of an average of multiple measured values is standard in experimental science generally and in copper foil research in particular. In nearly any measurement of physical parameters, the reported result will be some sort of averaged value. *See, e.g.*, SOLUS-1030, 13-15; SOLUS-1031, [0211], [0423]; SOLUS-1032, 2; SOLUS-1014, 6:11-12; SOLUS-1033, [0089], [0094]. For example, SOLUS-1030 describes that “intuitively [] it should be possible to obtain a more reliable result for the diameter by using the 10 measurements than by using only one measurement. [] The first procedure which obviously suggests itself is simply to take the *average*, or arithmetic *mean*. [] [I]n

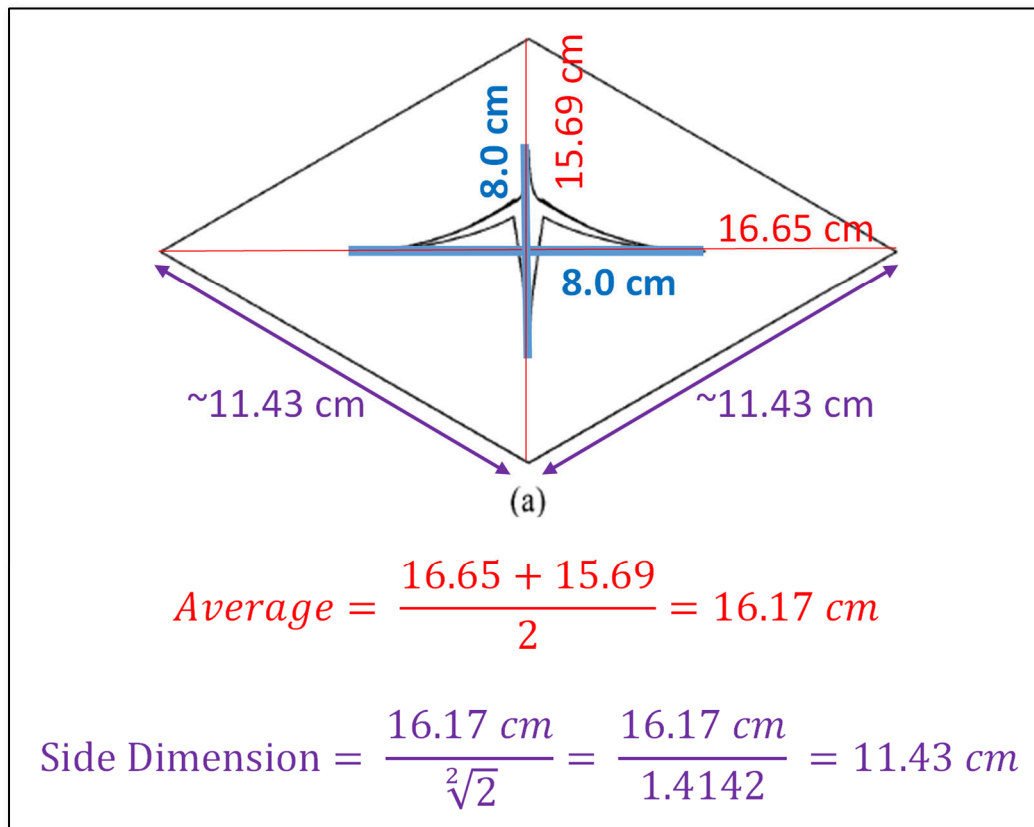
some important cases there is a good reason for regarding the *average* of a set of measurements as the *best* estimate of the true value of the quantity being measured.” SOLUS-1030, 13-14. As such, it would have been obvious to obtain the curl heights in Lee by taking the average of the heights of multiple corners.

128. Second, claim 7 recites that the cross-shaped cut has a “size of 8 cm×8 cm,” whereas Lee does not provide measurements for the cut size but notes that the portions of foil that are cut have “a width 10 cm × a length 10 cm.” SOLUS-1010, [0120].

129. I have conducted a detailed analysis of the ’706 Patent and Lee to conclude that the foil size used in the ’706 Patent was likely similar to the 10 cm × 10 cm size of Lee, and that Lee’s cut size was likely similar to the 8 cm × 8 cm size of the ’706 Patent. I understand that figures in patents do not have to be to scale. However, I understand that drawings in a patent can be relied on for what the drawings would teach a POSITA. FIG. 3 of the ’706 Patent is “a photograph” that was originally submitted in photographic form and later redrawn as a line drawing. SOLUS-1001, 3:4-6; SOLUS-1002, 804. Therefore, a POSITA would have found it reasonable to analyze the ’706 Patent’s FIG. 3 to determine accurate dimensional information. Further, the description of the curl test in the ’706 Patent, as detailed above (SOLUS-1001, 8:46-55), discloses at least the cut dimensions involved. Thus, it is my understanding that dimensional analysis of FIG. 3 of the ’706 Patent

is proper.

130. It is my understanding that FIG. 3 of the '706 Patent shows a picture of an example of a cut in a piece of foil for the curl test described therein. SOLUS-1001, 8:46-55. As disclosed in the '706 Patent, it is also my understanding that the cut dimension is 8 cm (SOLUS-1001, 8:46-55), from which I have measured in the drawing to calculate an estimated foil length and width of 11.43 cm as illustrated below. This length/width was calculated by first measuring the size of the diagonal of the foil using the known 8 cm length of the cut, and then by dividing by $\sqrt{2}$ (1.4142). 11.43 cm is relatively close to the 10 cm foil size used by Lee (i.e., within ~12.5%).



Annotated '706 Patent FIG. 3(b)

131. In addition, the '706 Patent discloses that “[a] current collector having a width of 10 cm was prepared using [] the electrolytic copper foils.” SOLUS-1001, 8:62-64. This further suggests that the '706 Patent was generally interested in and would have measured portions of foil having the 10 cm width used by Lee, or a width close to 10 cm (e.g., the 11.43 cm width measured above in FIG. 3).

132. With respect to the cut size used by Lee, the cut size (i) must be smaller than $(10 \text{ cm}) \times \sqrt{2} = 14.14 \text{ cm}$, in order to allow room for the cut in the foil, and (ii) must be larger than the 4.8 cm measured as Lee’s largest curl height, to allow the foil to bend 4.8 cm. SOLUS-1010, Table 5. This puts Lee’s cut size

between 4.8 cm and 14.1 cm, a range that includes and is overall close to the '706 Patent's 8 cm cut size. For example, the upper and lower bounds on the cut size average to 9.5 cm.

133. To summarize, the two measurements use similar-sized cuts, that are identical in shape, and use similar sized copper foil cutouts. I would not expect the corner curl heights obtained by Lee to change substantially if performed using the method of claim 7, and vice-versa, as the test formats and conditions are almost identical. As such, I assess that the differences in measurement method (if any) are not significant enough to lead to substantially different values in measured curl heights.

134. With respect to the obviousness of obtaining Lee's curl heights, a POSITA would have been motivated to do so, as Lee teaches that "the electrodeposited copper foil of the present invention exhibits high strength and a high elongation rate, and stress inside the electrodeposited copper foil is small, thereby preventing a corner curling phenomenon." *Id.*, [0016]. Further, Lee teaches the method through which corner curl is reduced, even while maintaining tensile strength: "In the case of the electrodeposited copper foil according to the present invention, impurities exist within a copper crystal, so that strength of the electrodeposited copper foil is high, and thus it is expected that a degree of corner curling is large, but impurities do not exist in a copper grain boundary, so that

internal stress is decreased and thus a degree of corner curl is decreased.” *Id.*, [0052]. And Lee teaches how to achieve these characteristics using minor additive additions, several which are common to those disclosed in the ’706 Patent, such as SPS (Bis-(3-sulfopropyl or sodium sulfopropyl)-disulfide), ZPS (3-(benzothiazolyl-2-mercapto)-propyl-sulfonate or sulfonic acid sodium salt), and PEG (polyethylene glycol)) as disclosed in Table 1 for at least Examples 1 and 3. SOLUS-1008, Table 1.

135. Accordingly, it would have been obvious for a POSITA to optimize the corner curl height of the Kim’761-Cheng-Wolski copper foil, as taught by Lee, to obtain corner heights having the values disclosed by Lee and satisfying claim 7.

X. GROUND 1D: Claims 8-10 are obvious over Kim ’761, Cheng, Wolski, Lee, and Shinozaki ’681

A. Shinozaki ’681

136. Shinozaki ’681 relates to electrodeposited copper foils and their production. SOLUS-1012, [0038]. Specifically, Shinozaki ’681 describes the finding that use of “an electrolyte solution with or without a prescribed organic additive and with the chloride ion concentration adjusted to a prescribed low concentration” produces copper foils having desirable properties. *Id.*, [0036]. Shinozaki ’681 also describes that it can be beneficial to use an electrolyte solution “obtained by mixing an aqueous solution of a metal salt of a metal that exists as an

oxide in a solution of pH 4 or lower and an aqueous copper sulfate solution.” *Id.*, [0036].

B. Combination of Kim '761, Cheng, Wolski, Lee, and Shinozaki '681

137. It would have been obvious to try manufacturing the copper foil of Kim '761, Wolski, and Lee using combinations of the electrolyte chemistries disclosed in those references, as well as in Lee and Shinozaki '681, in the amounts disclosed in those references.

138. The electrolyte solutions discussed here and in Sections XI and XIV would have been obvious to try. The prior art discusses a finite, relatively small number of possible additives known to provide benefits in the manufacture of copper foils. The prior art also discusses how those additives affect or correlate with properties of the resulting copper foils (i.e., a recognition of each of the solutes as result-effective). And the prior art further discloses amounts of the additives, thereby providing guidance that would lead one of ordinary skill in the art to have a reasonable expectation of success in combining the additives. This would have constituted no more than combining two compositions, both of which are used for electrolytic copper deposition, in order to form a third composition used for the same purpose.

139. In addition, as shown in the following Section X.C, the electrolyte solutions employed in each of these five references share the same two primary

components: copper ions (e.g., as provided by copper sulfate), and sulfuric acid.

The remaining constituents are additives that are added in smaller amounts to improve various properties of the foil, e.g., its roughness and mechanical characteristics. With the knowledge that the basic compositions of each disclosed solution are the same, it would have been obvious for a POSITA to try varying the additives and their amounts to improve foil properties. *See* Section V.F. for a brief overview of electrolyte additives.

140. Further, in reference to concentration, it would have been obvious to arrive at the additive amounts described by the '706 Patent as optimum and as claimed in claims 8-10. Because the prior art provides specific amounts that satisfy the claimed ranges and result in desirable copper foil characteristics, it would have been obvious to try using those amounts. I have been advised that optimization of a result-effective variable is obvious.

141. For these reasons, and for the reasons discussed below with respect to each claim element, it would have been obvious to manufacture the copper foil using an electrolytic solution that includes the additives and associated additive amounts that are disclosed by Kim '761, Cheng, Wolski, Lee, and Shinozaki '681.

C. Analysis of claims

[8pre]: The electrolytic copper foil of claim 1, wherein the electrolytic copper foil is manufactured by:

142. As discussed in Section VIII.C, claim 8, as a product-by-process claim, is obvious because the claimed process has not been demonstrated to result in a non-obvious product. Claim 8 is also obvious based on the analysis below.

[8a]: buffing a surface of a rotary negative electrode drum using a brush having a grit of 500 # to 3000 #;

143. Kim '761 discloses that “in order for the shiny surface 111a to have a peak count roughness R_{pc} of 10 to 100 and a ten-point mean roughness R_{z1S} of 2 μm or less, the surface of the rotational anode drum is **polished with a #800 to #1500 grit polishing brush.**”² SOLUS-1005, [0051]. Kim '761 also presents data showing how roughness values depend on the polishing grit, where specific disclosed examples of the grit include #1200, #1400, #800, and #1000. *Id.*, Table 1. All of these values fall within the claimed range.

144. Although Kim '761 discloses an “anode drum,” this reflects a clear and unambiguous error. A POSITA would have understood Kim '761 to actually be referring to a **cathode** drum. Copper electroplating is performed by immersing a cathode drum (typically titanium or similar) and an anode in an electrolytic solution. An electric current is passed between the anode and the cathode, and positively-charged copper ions in the solution are attracted to the negatively-charged cathode drum. As the copper reaches the drum, it forms a foil, and the

² Emphasis is added except where noted otherwise.

drum is rotated so that a wound roll of foil is produced. This process **requires that the drum be a cathode**: if the drum were an anode (i.e., positively charged), copper ions (also positively charged) would be repelled from, not attracted to, the drum, and the reduction of the copper cations to copper metal (and thus electrodeposition) would not occur. A POSITA would have immediately noticed the error in Kim '761 and understood its references to an 'anode drum' to instead be references to a cathode drum. Similarly, the POSITA would have understood Kim '761's references to a "cathode plate" to instead refer to an "anode plate."

145. Nevertheless, to the extent Kim '761 is not interpreted to explicitly disclose the use and buffing of a "cathode drum" (or, equivalently, a "negative drum"), each of Cheng, Wolski, and Lee explicitly disclose the use of such a drum, such that the use and buffing of such a drum would have been obvious as a simple substitution of one known element for another to obtain predictable results. SOLUS-1007, 3:56; SOLUS-1008, 1:25; SOLUS-1010, [0037].

[8b]: electrodepositing the copper foil on the buffed rotary negative electrode drum by applying electric current between a positive electrode plate and the buffed rotary negative electrode drum, wherein the positive electrode plate and the buffed rotary negative electrode drum are disposed in an electrolytic solution and spaced apart from each other; and

146. Both this element and the following [8c] element are fundamental to

the manufacture of electrolytic copper foils. This claim merely describes what any researcher in the field would have done on a daily basis to manufacture a copper foil.

147. Nevertheless, the prior art explicitly discloses this process. For example, Kim '761 describes that “there is provided a method of producing an electrolytic copper foil by allowing a current to flow between a cathode [understood as anode] plate and a rotational anode [understood as cathode] drum spaced apart from each other in an electrolytic solution so as to electrodeposit a copper on the rotational anode drum.” SOLUS-1005, [0018], as a POSITA would have understood.

[8c]: winding the electrodeposited copper foil,

148. A POSITA would have understood “winding the electrodeposited foil” to be implied by Kim '761’s disclosure that the “drum” on which the copper is “electrodeposit[ed]” is “**rotational**.” SOLUS-1005, [0018]. The drum rotates **so that** the copper foil can be wound, to produce a foil having substantial surface area. In addition, Cheng describes “continuously winding” the “electrolytic copper foil,” and Wolski describes “the copper foil is wound from a cathode drum.” SOLUS-1007, 1:58-59; SOLUS-1008, 5:38-40.

[8d]: wherein the electrolytic solution comprises 70 to 90 g/L of copper ions,

149. In view of the disclosed concentrations below and the reasoning in Section X.B, the claimed concentrations of copper ions are obvious. Each of the disclosed ranges encompasses or overlaps with the claimed range, and the two disclosed specific values are both within the claimed range. SOLUS-1005, [0049]; SOLUS-1007, 4:45; SOLUS-1008, 8:46; SOLUS-1010, [0085]; SOLUS-1012, [0077].

150. To calculate Cheng’s copper ion concentration from the disclosed “320 g/L of copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)” (SOLUS-1007, 4:45) (molecular weight = 249.56 g/mol), I used the molar masses of Cu (63.5 g/mol), S (32.06 g/mol), O (16.0 g/mol), and H (1.0 g/mol) to determine that copper represents ~25.4 % of the mass of copper sulfate. 25.4% of 320 g/L is 81.4 g/L.

Copper Ion Concentration (g/L)					
Claimed range	Kim ’761	Cheng	Wolski	Lee	Shinozaki ’681
70 – 90	50 – 100	81.4	90	60 – 180	50 – 90

[8e]: 80 to 120 g/L of sulfuric acid,

151. In view of the disclosed concentrations below and the reasoning in Section X.B, the claimed concentrations of sulfuric acid are obvious. Two of the three disclosed ranges overlap or encompass the claimed range, and the two disclosed specific values are both within the claimed range. SOLUS-1005, [0049];

SOLUS-1007, 4:45-46; SOLUS-1008, 8:46-47; SOLUS-1010, [0095]; SOLUS-1012, [0077].

Sulfuric Acid Concentration (g/L)					
Claimed range	Kim '761	Cheng	Wolski	Lee	Shinozaki '681
80 – 120	50 – 100	100	110	80 – 150	40 – 70

[8f]: 10 to 20 ppm of chlorine ions,

152. In view of the disclosures below and the reasoning in Section X.B, the claimed concentrations of chlorine ions are obvious. Kim '761 describes the use of “50 ppm or less of chlorine,” a range which encompasses the claimed range and renders obvious the disclosed range. SOLUS-1005, [0049]. Further, Lee discloses the desirability of between 1 and 40 ppm of chlorine ions, and specifically discloses the use of 20 ppm in the “Example” foils that outperform the “Comparative Example” foils manufactured using 35 or 40 ppm. SOLUS-1007, [0074], Table 1. This would have provided strong motivation for a POSITA to try using 20 ppm, which falls within the claimed range. For example, the POSITA would have noted Lee’s disclosure that the inclusion of chlorine with these concentrations provides desired tensile strength and roughness characteristics. SOLUS-1010, [0074].

153. Shinozaki '681, too, describes a solution that includes chlorine ions,

disclosing that “the [] foil of the present invention is formed [] from an electrolytic solution of sulfuric acid and copper sulfate with low chloride ion concentration []. Here, ‘low chloride ion concentration’ means that the amount of chloride ion in the electrolyte is 15 mg/L or less.” SOLUS-1012, [0049]. Specific disclosed ion concentrations include, among other values, 10 mg/L and 15 mg/L, both of which are within the claimed range. *Id.*, Table 1.

154. I note that mg/L would have been understood to be the same as ppm by a POSITA, as ppm represents 1 mg per kg and it is typical that the density of the plating solution would be estimated as the same as that of water (1 g/cm³, or 1000 g/L). Accordingly, it would have been typical and obvious to equate ppm with mg/L. More detailed calculations to account for deviations from this common heuristic would not substantively change the numerical values or reasoning herein.

155. Accordingly, the claimed range of chlorine ion concentration is obvious.

[8g]: 3 to 12 ppm of a sulfide-based compound,

156. In view of the disclosures below and the reasoning in Section X.B, the claimed concentrations of a “sulfide-based compound” are obvious.

157. The ’706 Patent describes that “the additive may include at least one sulfide-based compound selected from the group consisting of bis-(sodium sulfopropyl) disulfide (SPS), 3-mercapto 1-propane sulfonate (MPS), and 3-

(benzothiazolyl-2-mercapto)-propyl-sulfonate (ZPS).” SOLUS-1001, 6:7-11.

However, claim 8 does not limit the sulfide-based compounds to these specific compounds.

158. Kim ’761 describes that the solution includes “a small amount of organic additive such as [] organic sulfide.” SOLUS-1005, [0049]. A POSITA would have understood “organic sulfide” to be a “sulfide-based compound,” as organic sulfides are compounds that are a subset of sulfide-based compounds. Further, with the exception of sulfuric acid and copper sulfamate, all of the sulfide-based compounds disclosed in the ’706 Patent (i.e., SPS, MPS and ZPS) are organic sulfides. SOLUS-1001, 6:5-14. And the purpose of these sulfide-based compounds is to be used as electrolyte additive(s) in order to brighten, or level the electrodeposited copper. SOLUS-1001, 6:5-14. However, Kim ’761 does not explicitly disclose a specific concentration of the organic sulfide.

159. However, each of Cheng, Wolski, Lee, and Shinozaki ’761 disclose the inclusion of MPS or ZPS, which constitute two of the three specific examples of sulfide-based compounds disclosed in the ’706 Patent. SOLUS-1001, 6:5-14. For example, Lee discloses that the inclusion of “additive B,” a “sulfone acid of a compound including a sulfur atom or metallic salt thereof” such as “SPS,” “MPS,” or “ZPS,” can improve surface glossiness. SOLUS-1010, [0073]-[0075], [0081]. Lee describes that between 10 and 200 ppm of this additive should be included

and, as a specific example, reports that the use of 10 ppm of ZPS in “Example 2” provides desirable low surface roughness, high tensile strength, and high elongation. *Id.*, [0074], [0117], Table 1, Table 4. Based on these results, it would have been obvious for a POSITA to optimize within the disclosed range of 10 to 200 ppm and, for example, try using 10 ppm of ZPS as disclosed by Lee, thereby satisfying the claim’s requirement for “3 to 12 ppm of a sulfide-based compound.”

160. In addition, Shinozaki ’681 discloses that “the amount of organic additives [] is in the preferred range of 1 ppm to 20 ppm. More preferably, the amount [] is 1 ppm to 7 ppm.” SOLUS-1012, [0075]. Among the “organic additives” described by Shinozaki ’681 is MPS. *Id.*, [0066], [0091], Table 2. It would further have been obvious to optimize the MPS concentration within the range disclosed by Shinozaki ’681 to arrive at an MPS concentration within the claimed range, which is encompassed by Shinozaki ’681’s range.

[8h]: 25 to 50 ppm of molybdenum (Mo),

161. Shinozaki ’681 renders obvious the claimed concentration of Mo. Shinozaki ’681 describes that foils having “high conductivity, high tensile strength, and excellent heat resistance can be obtained by [] using an electrolytic solution obtained by mixing **an aqueous solution of a metal salt** [] and an aqueous copper sulfate solution, without or with a prescribed organic additive, and where the chloride ion concentration has been adjusted to a prescribed low concentration.”

SOLUS-1012, [0036]. More specifically, Shinozaki '681 describes that “the metal [] is preferably at least one of W, **Mo**, Ti, or Te.” *Id.*, [0039]. Mo is used in the electrolytic solution of Examples 8, 11, 17, and 18 in the form of sodium molybdate (IV) dihydrate. *Id.*, Tables 1-2. The disclosed concentrations of these metal salts are 40, 400, 80, and 100 mg/L, respectively, corresponding to concentrations of the molybdenum itself of **15.9, 159, 31.7, and 39.7 ppm, respectively.** *Id.*, Tables 1-2. That is, two out of the four molybdenum-incorporating solutions of Shinozaki '681 have a molybdenum concentration in the claimed range of 25 to 50 ppm. I arrived at these ppm values by calculating the mass% of molybdenum in sodium molybdate (IV) dihydrate, or $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$, (using 23.0 g/mol for Na, 96.0 g/mol for Mo, 16.0 g/mol for O, and 1.0 g/mol for H). As a result, Mo represents about 39.7% of the mass of that compound, based on which I calculated, for example, $0.397 \cdot (80 \text{ ppm of sodium molybdate (IV) dihydrate}) = 31.7 \text{ ppm Mo}$.

162. It would have been obvious for a POSITA to incorporate Mo into a modified electrolyte solution, employing the concentrations used by Shinozaki '681, in order to realize the “high conductivity, high tensile strength, and excellent heat resistance” disclosed by Shinozaki '681. SOLUS-1012, [0035], [0036], [0038]. This combination would have entailed nothing more than pursuing one of the finite number of identified, predictable additives disclosed by Shinozaki '681,

with the concentration disclosed by Shinozaki '681. Stated another way, the combination would have involved simply applying a technique known to improve the devices of Shinozaki '681 – the inclusion of molybdenum in the electrolyte solution, with particular concentrations – to the electrolyte solution of Kim '761, Cheng, Wolski, and Lee.

163. A POSITA would have had a reasonable expectation of success in making the modification. For example, the electrolytic solutions used by Shinozaki '681 include copper ions, sulfuric acid, chlorine ions, and an organic additive such as MPS. That is, these electrolytic solutions are quite similar to those described by 'Kim '761, Cheng, Wolski, and Lee, and similar to the proposed modified electrolytic solution discussed herein with respect to claim 8 of the '706 Patent. Based on these similarities, a POSITA would have had a reasonable expectation that molybdenum incorporated into the modified electrolytic solution would have a similar effect to molybdenum incorporated into Shinozaki '681's solutions.

164. For at least these reasons, the inclusion of molybdenum in the recited concentrations is obvious.

[8i]: and 5 to 25 ppm of polyethylene glycol (PEG).

165. Lee and Cheng render obvious the claimed concentration of PEG. Each of the four examples disclosed by Lee includes **20 ppm** of PEG, suggesting that PEG should be included in the electrolytic solution at this concentration

(within the claimed range) in order to obtain the high-quality copper foils produced by Lee, which have desirable mechanical properties, surface properties, and curl properties. SOLUS-1010, [0006], [0121], Table 1.

166. Cheng notes that “[t]raditionally, an organic additive, such as polyethylene glycol (PEG)” is added “in order to reduce the roughness of the M side of the electrolytic copper foil.” SOLUS-1007, 2:1-2, 3:65-4:1. Based on this teaching, it would have been obvious to a POSITA to try including PEG in the electrolytic solution, with the 20 ppm concentration disclosed by Lee, in order to tune matte-side surface roughness.

[9]: The electrolytic copper foil of claim 8, wherein the sulfide-based compound is selected from a group consisting of bis-(sodium sulfopropyl) disulfide (SPS), 3-mercapto 1-propane sulfonate (MPS), and 3-(benzothiazolyl-2-mercapto)-propyl-sulfonate (ZPS).

167. As discussed in reference to [8g] above, it would have been obvious to use SPS, MPS, or ZPS as the sulfide-based compound having concentration 3 to 12 ppm. For example, Lee describes the use of 10 ppm of ZPS. SOLUS-1010, Table 1.

[10]: The electrolytic copper foil of claim 8, wherein the sulfide-based compound is SPS.

168. In view of Lee, it would have been obvious to include SPS in the

electrolytic solution with a concentration of 3 to 12 ppm. As discussed above in reference to [8g], Lee discloses the use of 10 ppm of ZPS to improve surface glossiness. SOLUS-1010, [0074], [0117], Table 1, Table 4. As I discussed in Section V.F, ZPS is one of a class of sulfur-containing compounds (accelerators) that are often used interchangeably in electrolytic solutions for copper foil manufacture. As I detailed above, SPS and ZPS are both organic sulfonates, and are within a class of plating electrolyte additives or intermediates (commonly termed “accelerators” or “brighteners” or “grain refiners”) that are commonly used in copper electrodeposition, either interchangeably or in concert, in order to adjust one or more properties of the deposited copper. Indeed, Lee discloses that “the sulfone acid [additive B] may be one or more selected from the group consisting of [] SPS [] MPS [] DPS [] UPS [] OPX [] ZPS” and several others. SOLUS-1010, [0073], [0081]. Based on this and general knowledge in the art (*see* Section V.F.), a POSITA would have understood Lee to be describing that SPS, MPS, and ZPS, among other compounds, which are known to be accelerator additives, may be used substantially interchangeably, and as equivalents to one another, in order to maintain surface glossiness and obtain a desired matte side surface roughness. SOLUS-1010, [0077].

169. Based on this disclosure, it would have been obvious for a POSITA to try using SPS instead of ZPS, with the same 10 ppm concentration disclosed by

Lee. This would have been merely a matter of substituting, for one component (ZPS), another (SPS) that the art has recognized as equivalent for the same purpose (maintaining surface glossiness and obtaining a target matte side surface roughness).

XI. GROUND 1E: Claim 10 is obvious over Kim '761, Cheng, Wolski, Lee, Shinozaki '681, and Dobashi

A. Dobashi

170. Dobashi relates to “a surface-treated electro-deposited copper foil” having desirable surface characteristics. SOLUS-1014, Abstract. Among the surface parameters discussed is RSm, and Dobashi discloses that “RSm (JIS B 0601, 2001) obtained by using the stylus-type roughness meter can be adopted as the period of waviness, RSm can also be used as an indicator for judgment of the surface. The surface has small waviness and is smooth when RSm is large, and the surface has large waviness and is rough when RSm is small.” *Id.*, 6:24-29. Dobashi describes the desirability of performing copper deposition in an electrolytic solution that “preferably comprises at least one selected from MPS and SPS,” and that MPS and/or SPS can advantageously cause the matte side of the copper foil to be smooth. *Id.*, 11:60-12:13.

B. Combination of Kim '761, Cheng, Wolski, Shinozaki '681, Lee, and Dobashi and analysis of claim 10

[10]: The electrolytic copper foil of claim 8, wherein the sulfide-based compound is SPS.

171. Claim 10 is obvious in view of Lee, as discussed in Section X.C. To the extent Lee fails to disclose any specific examples in which SPS is used with a concentration from 3 and 12 ppm, Dobashi discloses the incorporation of SPS in that range. Dobashi recognizes the equivalence of **both** “MPS and/or SPS” for obtaining desired surface roughness. SOLUS-1014, 12:1-5. Dobashi further describes that the “MPS and/or SPS” should be included in a range from “0.5 ppm to 200 ppm” and “preferabl[y] [] 1 ppm to 20 ppm,” and provides examples of electrolytic solutions in which SPS is included with concentrations of 5 and 6 ppm. *Id.*, 11:65-67, Table 1. Accordingly, and for the reasons discussed in Section X.B, it would further have been obvious, in view of Dobashi, to use SPS as the sulfide-based compound having a concentration of 3 to 12 ppm.

XII. GROUND 2A: Claims 1-5 are obvious over Dobashi, Shinozaki '922, and Chou

A. Chou

172. Chou relates to an “electrodeposited copper foil” having certain crystal plane texture coefficients (TC). SOLUS-1016, Abstract. Those texture coefficients are associated with reduced nodule count, “excellent tensile strength and rate of elongation,” and desirable surface roughness. *Id.*, [0049].

B. Shinozaki '922

173. Shinozaki '922 relates to “an electrolytic copper foil” in which “the Rz difference between the front and back surfaces [is] within 3 μm and the Ra

differences between the front and back surfaces [is] within 0.3 μm .” SOLUS-1015, Abstract. These copper foils (including in the as-deposited form) have advantageous tensile strengths and elongations, and the small difference in roughness between their two sides is advantageous for subsequent treatment. *Id.*, [0049]-[0050].

C. Combination of Dobashi, Shinozaki '922, and Chou

174. It would have been obvious to a POSITA to apply the teachings of Shinozaki '922 and Chou to the copper foil of Dobashi (i.e., “Dobashi-Shinozaki '922-Chou”), to obtain modified copper foils having (i) the mean profile width R_{Sm} (and, correspondingly $|\Delta PD|$) of Dobashi, (ii) the R_z/R_a ratios of Shinozaki '922, and (iii) the (220) texture coefficients of Chou. The reasoning here is substantially similar to that provided in Section VII.D.

175. For example, the teachings of Dobashi, Shinozaki '922, and Chou would have been combinable with a reasonable expectation of success based on the overall similarities of the processes discussed in these documents. Each uses an electrolyte solution based primarily on copper ions and sulfuric acid, with similar concentrations. SOLUS-1014, 15:50-16:12; SOLUS-1015, [0088], Table 1; SOLUS-1016, [0035]. Further, the electrolysis temperatures and currents used are similar to one another. SOLUS-1014, 16:28-37; SOLUS-1015, Table 1; SOLUS-1016, [0035]. Also, several of the disclosed solution additives (e.g., chlorine and

MPS) are common to two or more of these references' manufacturing processes.

SOLUS-1014, Table 1; SOLUS-1015, Table 1; SOLUS-1016, [0035].

Accordingly, a POSITA would have had a reasonable expectation of success in optimizing foil properties by jointly applying the teachings of these three similar references.

1. Rz/Ra

176. Regarding Rz/Ra, Shinozaki '922 describes the desirability of having “the difference of roughening [roughness] between the two surfaces in the state of the untreated copper foil [be] small,” and Shinozaki '922 focuses specifically on Rz and Ra as the two roughness parameters of interest. SOLUS-1015, [0046], [0048]. For example, Shinozaki '922 describes that “untreated copper foil with roughnesses Rz of both surfaces [] of a low 0.8 μm to 2.0 μm is employed” and (in reference to treated foils “a difference of a roughness between the roughnesses Rz of the front and back surfaces being within 3 μm or a difference of a roughness between the roughnesses Ra of the front and back surface being within 0.3 μm .” *Id.*, [0035], [0054]. These characteristics are associated with improved battery performance. *Id.*, [0055]-[0056], [0074], [0116]. Further, Shinozaki '922 provides a clear roadmap for obtaining these Rz and Ra values, disclosing the electrolyte compositions and deposition conditions that produce copper foils with these parameters. *Id.*, [0088]-[0089], Table 1.

177. Accordingly, and for reasons similar to those discussed in Section VII.D and Section XII.C above, it would have been obvious for a POSITA to optimize Rz and Ra to have the values taught in Table 2 of Shinozaki '922, with a reasonable expectation of success. As a result, the POSITA would have also arrived at the Rz/Ra ratios taught by Shinozaki '922.

2. TC(220)

178. Regarding TC(220), Chou makes clear (i) that texture coefficients in general are important parameters for determining foil quality, and (ii) that the particular combinations of texture coefficients obtained for Chou's Examples 1-10 foils result in favorable roughness, mechanical, and nodule properties compared to foils having different texture coefficients. SOLUS-1016, [0049], Tables 1-2. As such, it would have been obvious for a POSITA to optimize the foil texture coefficients so as to attain a combination of texture coefficients matching that of Examples 1-10.

179. For example, a primary parameter of interest in Chou is the ratio of TC(200) to the sum of TC(111), TC(200), TC(220), and TC(311). SOLUS-1016, [0013]-[0014]. Particular ranges of this parameter are associated with improved surface characteristics. SOLUS-1016, [0034]. Optimization of this parameter would have necessarily involved interest in and modulation of TC(220) as part of the total expression. SOLUS-1016, [0034], Table 1. That is, optimization of the

quantity $\frac{TC(200)}{TC(111)+TC(200)+TC(220)+TC(311)}$ would have naturally involved consideration of and modulation of TC(220), which appears in the denominator of the quantity. For example, to achieve the target values of that quantity disclosed by Chou, the most natural route for a POSITA would have been to manufacture a foil having the TC(111), TC(200), TC(220), and TC(311) values disclosed by Chou, which are known to be achievable and to provide target values of the quantity as a whole.

180. To the extent these teachings were insufficient for a POSITA to recognize TC(220) as result-effective, the POSITA would have also been aware of disclosures in Cheng, Kim '541, and Song that more directly note the importance of TC(220) for foil quality. For example, Song describes that “(220)-oriented Cu foils possessed a superior combination of tensile strength and ductility.” SOLUS-1032, Abstract. As such, it would have been obvious for a POSITA to optimize TC(220) to have a value taught by Chou, e.g., any of the values of Examples 1-7 and 9-10, which satisfy the range of claim 1.

181. I further note that fourteen of the fifteen TC(220) values disclosed in Chou are within the claimed TC(220) range, including the five comparative examples. SOLUS-1016, [0048], Table 1, Table 2. This suggests that the TC(220) range of claim 1 can be achieved robustly over a wide range of deposition conditions, corroborating a POSITA's expectation of success in achieving a

TC(220) in the recited range. Indeed, the fifteenth TC(220) value, which is not within the claimed range and corresponds to Example 8, is close to the lower limit of the claimed range (0.33 vs. 0.4).

182. Like Shinozaki '922, Chou provides detailed electrolyte compositions and process parameters associated with the copper foils, such that a POSITA would have had a reasonable expectation of success in making this optimization. SOLUS-1016, [0035], Table 1.

183. Accordingly, and for reasons in Section XII.C above and similar to those provided in Section VII.D, the Dobashi-Shinozaki '922-Chou copper foil with the TC(220) values of Chou is obvious.

3. Analysis of RSm

184. Dobashi discusses the importance of "RSm" as defined in the JIS B 0601 (2001) standards. SOLUS-1014, 6:13-29. RSm is tightly linked to peak density PD. RSm is essentially a measure of the average spacing between peaks (or, equivalently, a measure of the average width of "profile elements"). SOLUS-1022, 14, FIG. 10. PD (or R_{pc} or P_c), on the other hand, tells us how many peaks exist per unit length. SOLUS-1017, 21. That is, RSm and PD contain the same information but express it inversely from one another.

185. Based on this recognition, I have converted the RSm values disclosed by Dobashi into PD values (over a 4 mm measurement length) that can be

compared directly to those of the '706 Patent. These conversions are shown in the table below. To calculate PD from RSm, I simply divided 4 by the RSm value. For example, if RSm is 0.5 mm (indicating a 0.5 mm spacing between peaks), then, over a 4 mm sampling length, we would measure $4/(0.5) = 8$ peaks, or PD = 8 ea.

Subject	PV (um)	Rsm (mm)	PD (calculated)	Default height discrimination (um)
Example 1	0.39	0.19	21.1	0.039
Example 2	0.48	0.16	25.0	0.048
Example 3	0.079	0.39	10.3	0.008
Example 4	0.3	0.18	22.2	0.030
Example 5	0.39	0.16	25.0	0.039
Example 6	0.44	0.22	18.2	0.044
Example 7	0.66	0.14	28.6	0.066

186. However, this calculation is complicated by the fact that Dobashi does not disclose the criteria lines associated with its RSm values. The JIS standard describes that “*RSm* [] require[s] height and spacing discrimination. If not otherwise specified, the default height discrimination shall be 10 % of [] *Rz*.” SOLUS-1022, 14. No “spacing discrimination” or equivalent quantity is disclosed in the '706 Patent. However, as discussed above in Section V.D, the '706 Patent measures PD using height criteria of $\pm 0.5 \mu\text{m}$. SOLUS-1001, 8:36-45. These criteria define whether a given surface irregularity is “counted” as a peak/profile element in calculating RSm and PD.

187. Although Dobashi does not explicitly disclose any such height discrimination, the JIS standard used for Dobashi’s RSm measurements describes the “default height discrimination” as being 10% of “*Rz*.” SOLUS-1022, 14. Here,

Rz is not the ten-point average roughness but the “maximum height of profile” or “sum of [the] height of the largest profile peak height Z_p and the largest profile valley depth Z_v within a sampling length.” *Id.*, 10. Dobashi discloses an equivalent quantity as PV, “the sum of the maximum peak height and maximum valley depth of the sample surface.” SOLUS-1014, 7:55-62. Accordingly, by multiplying PV by 0.1 (i.e., 10%) for each of Dobashi’s Example foils, one can derive a height discrimination that, according to the JIS standard cited by Dobashi, would have been used by “default” in the absence of an indication otherwise. *Id.*, 14. I have provided these default height discrimination values in the table above.

188. Notably, all of the default height discrimination values are quite small, generally on the order of several hundredths of a micron. These values are much smaller than the 0.5 μm used by the ’706 Patent. Assuming Dobashi’s RSm were indeed calculated using these default height discrimination values or a similar value, the same calculation using the ’706 Patent’s 0.5 μm would lead to a **higher RSm and lower PD**, because some peaks “counted” using the smaller discrimination criteria would not be counted using the 0.5 μm criteria.

189. As such, I have performed my subsequent analysis using the PD calculated directly from Dobashi’s RSm values. In fact, these PD values represent an **upper limit** on corresponding “PD calculated using 0.5 μm height discrimination” values. For example, as shown in the table above, Dobashi’s

Example 1 has PD = 21.1 using ambiguous discrimination criteria. If we were to apply the '706 Patent's height discrimination criteria, the resulting PD might be less than 21.1, but it would not be higher, according to the cited JIS standard.

D. Analysis of claims

[1pre]: An electrolytic copper foil having a first surface and a second surface, wherein

190. The modified Dobashi-Shinozaki'922-Chou copper foil discussed in Section XII.C satisfies or at least renders obvious an electrolytic copper foil having a first surface and a second surface. For example, Dobashi discloses an “electro-deposited copper foil” having a “shiny side” and a “deposit side.” SOLUS-1014, 3:34-47.

[1a]: a texture coefficient of (220) plane of the electrolytic copper foil defined by Equation 1 below is 0.4 to 1.32,

$$TC(220) = \frac{\frac{I(220)}{I_0(220)}}{\frac{1}{n} \sum \frac{I(hkl)}{I_0(hkl)}}$$

191. The Dobashi-Shinozaki'922-Chou foil, having TC(220) values such as those disclosed by Chou, satisfies or at least renders obvious a TC(220) of 0.4 to 1.32. Of Chou's ten examples, **nine** have a TC(220) within the claimed range; the TC(220) as a whole span a range of 0.33 to 0.7. SOLUS-1016, Table 1. Based on this disclosure, in which nearly all of the explicit values are in the recited range

and which corresponds to a range overlapping with the claimed range, it would have been obvious to make a copper foil having a TC(220) in the claimed range, for reasons discussed in Section XII.C and similar reasons to those provided in Sections VII.D and VII.E.

[1b]: a difference ($|\Delta(Rz/Ra)|$) between Rz/Ra at the first surface of the electrolytic copper foil and Rz/Ra at the second surface of the electrolytic copper foil is less than 2.42, and

192. The Dobashi-Shinozaki '922-Chou foil, having Rz and Ra values such as those disclosed by Shinozaki '922, satisfies or at least renders obvious a $|\Delta(Rz/Ra)|$ of less than 2.42. As shown in Shinozaki '922's Table 2 below, all manufactured foils have $|\Delta(Rz/Ra)|$ well below the claimed upper limit of 2.42. Based on this disclosure, it would have been obvious to make a copper foil having a $|\Delta(Rz/Ra)|$ in the claimed range, for reasons discussed in Section XII.C and similar reasons to those provided in Sections VII.D and VII.E.

Untreated		Ra (μm)		Rz (μm)		Δ(Rz/Ra)
copper foil	Thickness (μm)	S surface	M surface	S surface	M surface	
A1	10.0	0.27	0.28	1.5	1.3	0.91
A2	10.0	0.27	0.20	1.5	0.8	1.60
A3	10.0	0.27	0.30	1.5	2.0	1.10
B1	10.0	0.27	0.42	1.5	2.6	0.63
B2	10.0	0.27	0.30	1.5	1.9	0.78
B3	10.0	0.27	0.26	1.5	1.4	0.17

Modified Shinozaki '922 Table 2

[1c]: a difference ($|\Delta PD|$) between a peak density (PD) at the first surface of the electrolytic copper foil and a peak density (PD) at the second surface of the electrolytic copper foil is 96 ea or less.

193. The Dobashi-Shinozaki '922-Chou foil, having RSm values such as those disclosed by Dobashi, renders obvious a $\Delta(PD)$ of 96 ea or less. First, as discussed above in Section XII.C, I have performed calculations to convert Dobashi's matte side (deposit side) RSm into a matte side PD. The resulting PD values are shown in the modified Dobashi Table 2 below.

194. I also noted that Dobashi does not explicitly disclose discrimination lines to be used in RSm/PD calculation, while the '706 Patent describes using ± 0.5 μm. SOLUS-1001, 8:40. However, as discussed in Section XII.C, the JIS standard cited by Dobashi describes how to determine "default" discrimination criteria

using the equivalent of Dobashi's PV. SOLUS-1022, 10, 14. All of the calculated default discrimination criteria for RSm are much lower than the +/- 0.5 μm used in the '706 Patent. Assuming that the disclosed RSm were measured according to the cited standard (which would be the most obvious conclusion), it is apparent that the use of default discrimination lines (corresponding to much more stringent requirements on what constitutes a peak) would result in fewer peaks being measured, i.e., a **lower** PD. As such, I will treat the calculated matte side PD as upper bounds on the matte side PD obtained using $\pm 0.5 \mu\text{m}$ discrimination lines.

TABLE 2										
Deposit side of electro-deposited copper foil										
Copper foil	Three-dimensional surface structure analysis			Stylus-type roughness meter		Gloss Gs				
	thickness	Wmax	PV	Wmax/PV	Rzjis	RSm	(60°)		Deposit side PD	Default discrimination criteria (μm)
Subject	(μm)	(μm)	(μm)	(-)	(μm)	(mm)	TD	MD		
Example 1	15	0.37	0.39	0.949	0.32	0.19	659	665	21.1	0.039
Example 2	12	0.45	0.48	0.938	0.31	0.16	664	671	25.0	0.048
Example 3	70	0.065	0.079	0.823	0.17	0.39	691	686	10.3	0.008
Example 4	15	0.27	0.30	0.904	0.29	0.18	790	790	22.2	0.030
Example 5	15	0.36	0.39	0.943	0.31	0.16	775	773	25.0	0.039
Example 6	12	0.42	0.44	0.959	0.47	0.22	654	687	18.2	0.044
Example 7	12	0.58	0.66	0.869	0.71	0.14	608	640	28.6	0.066
Comparative Example	12	0.82	1.87	0.439	1.00	0.07	324	383		

Modified Dobashi Table 2

195. Although Dobashi effectively discloses matte side PD, Dobashi does not explicitly discuss the shiny side PD. However, it would have been obvious to

make the shiny side PD lower than or similar to the matte side PD, such that the difference between the PD would be 96 ea or less. Motivation for that configuration would have been provided at least by Shinozaki '922's disclosure that it is desirable for the "difference of roughening between the two surfaces in the state of the untreated copper foil [to be] made small." SOLUS-1015, [0048]. I noted above in Section VII.D.2 that various prior art documents attest to the desirability of having similar roughness between the two sides of the foil. Following this direction, it would have been obvious for a POSITA to make the shiny side with a PD equal to or less than the matte side PD, which would necessarily satisfy element [1c], because the PD for the matte side is less than 96 ea for all examples of Dobashi. That is, because PD is always positive, the difference between (i) the shiny side PD and (ii) a larger matte side PD that is less than 96, would necessarily be less than 96 if the shiny side PD were equal to or less than the matte side PD. And the recited range is also satisfied if the PD values are equal to one another, would be the most desirable outcome according to Shinozaki '922 and the prior art documents cited in Section VII.D.2.

196. The same motivation would have made it obvious to (if not make the shiny side with the same or a smaller PD) at least make the shiny side with a PD **close** to the matte side PD, e.g., in a range from 0 to 117 for Example 1, from 0 to 121 for Example 2, etc., ranges of values that would satisfy this element of claim 1.

197. Moreover, as discussed in Section V.E above, shiny side roughness characteristics can be tuned easily and arbitrarily by adjusting the surface of the cathode drum. Accordingly, it would have been well within the skill of a POSITA to make the shiny side PD less than or similar to the matte side PD, with a reasonable expectation of success, to arrive at a difference between the PD of 96 or less.

198. Finally, to the extent the foregoing discussion fails to demonstrate the obviousness of making the shiny side PD similar to the matte side PD to obtain a PD difference of 96 or less, this element would have been obvious in view of Kim '761's explicit teaching of this characteristic. *See* Section VII.E.

[2]: The electrolytic copper foil according to claim 1, wherein the second surface is an M surface, and R_z/R_a at the second surface is 4.2 to 9.0.

[3]: The electrolytic copper foil according to claim 2, wherein the first surface is an S surface, and R_z/R_a at the S surface of the electrolytic copper foil is 5.1 to 6.8.

199. The Dobashi-Shinozaki'922-Chou foil, having R_z and R_a values such as disclosed by Shinozaki '922, satisfies or at least renders obvious each of claims 2 and 3. As shown in the table below, of Shinozaki '922's six examples of foils, all satisfy the R_z/R_a range recited in claim 3, and all except one satisfy the R_z/R_a range recited in claim 2. The sole value not satisfying that range differs from it by

only 5%. For reasons discussed in Section XII.C and similar reasons to those provided in Sections VII.D and VII.E, it would have been obvious to make the Dobashi-Shinozaki '922-Chou foil with Rz/Ra ratios matching or similar to those of Shinozaki '922, thus rendering obvious claims 2 and 3.

200. As an additional note, the S surface Rz/Ra disclosed by Shinozaki match across all samples. This evinces the predictability and ease of achieving targeted Rz/Ra values for the S surface, because the S surface can be easily tuned as I discussed in Section V.E.

Untreated		Ra (μm)		Rz (μm)		M surface Rz/Ra	S surface Rz/Ra
copper foil	Thickness (μm)	S surface	M surface	S surface	M surface		
A1	10.0	0.27	0.28	1.5	1.3	4.6	5.6
A2	10.0	0.27	0.20	1.5	0.8	4.0	5.6
A3	10.0	0.27	0.30	1.5	2.0	6.7	5.6
B1	10.0	0.27	0.42	1.5	2.6	6.2	5.6
B2	10.0	0.27	0.30	1.5	1.9	6.3	5.6
B3	10.0	0.27	0.26	1.5	1.4	5.4	5.6

Modified Shinozaki '922 Table 2

[4]: The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has a tensile strength, measured at room temperature, of 30 to 65 kgf/mm².

[5]: The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has an elongation, measured at room temperature, of 3%

or more.

201. The Dobashi-Shinozaki '922-Chou combination renders obvious the tensile strength and elongation of claims 4 and 5. Shinozaki '922 and Chou disclose both of these parameters, measured at room temperature, for ten and six different examples of foils, respectively. SOLUS-1016, [0042]-[0043], Table 1; SOLUS-1015, Table 2. Across these two references together, all sixteen examples satisfy the recited ranges for both the tensile strength and the elongation. For reasons similar to those discussed with respect to [4] and [5] in Section VII.E, it would have been obvious for a POSITA to arrive at the recited values by routine experimentation and optimization based on the disclosures of Shinozaki '922 and Chou.

XIII. GROUNDS 2B and 2C: Claims 6 and 7 are obvious over Dobashi, Shinozaki '922, Chou, and Lee or Kim '541

A. Analysis of claims

[6]: The electrolytic copper foil according to claim 1, wherein the electrolytic copper foil has a lateral weight deviation of 5% or less.

[7]: The electrolytic copper foil according to claim 1, wherein an arithmetic mean of measured heights of corners of four protruding incision portions of the electrolytic copper foil, formed by incising electrolytic copper foil in a form of a cross having a size of 8 cm×8 cm so as to be vertically divided into two parts, is less than 10 mm.

202. For reasons similar to those provided in Sections VIII and IX, claim 6 is obvious over Dobashi-Shinozaki '922-Chou further in view of Kim '541, and claim 7 is obvious over Dobashi-Shinozaki '922-Chou further in view of Lee. As discussed for Grounds 1B-1C, Kim '541 and Lee provide detailed process parameters to be used for achieving lateral weight deviation and corner heights in the recited ranges respectively. Moreover, the general similarities between the processes and electrolytic solutions of Lee/Kim '541 and Dobashi, Shinozaki '922, and Chou would have provided a POSITA with a reasonable expectation of success in achieving the recited values.

XIV. GROUND 2D: Claims 8-10 are obvious over Dobashi, Shinozaki '922, Chou, Lee, and Shinozaki '681

A. Analysis of claims

203. For the reasons discussed in Section X.B, it would have been obvious to try using a modified electrolyte solution including combinations of the various chemistries described by the prior art, and with the concentrations described by the prior art, to obtain the advantageous copper foils produced by the prior art using those chemistries.

[8pre]: The electrolytic copper foil of claim 1, wherein the electrolytic copper foil is manufactured by:

[8a]: buffing a surface of a rotary negative electrode drum using a brush having a grit of 500 # to 3000 #;

204. At least Dobashi's disclosure that "[i]n preparation of an electro-deposited copper foil, electrolysis was performed by using a rotating cathode made of a titanium plate in which the surface was polished by #2000 emery paper" renders obvious these elements. SOLUS-1014, 16:28-31.

[8b]: electrodepositing the copper foil on the buffed rotary negative electrode drum by applying electric current between a positive electrode plate and the buffed rotary negative electrode drum, wherein the positive electrode plate and the buffed rotary negative electrode drum are disposed in an electrolytic solution and spaced apart from each other; and

[8c]: winding the electrodeposited copper foil,

205. These elements are obvious at least in view of Dobashi's disclosure that "a sulfuric acid base copper electrolytic solution is supplied to the gap between a drum-shaped rotating cathode and a lead base anode or dimensionally stable anode (DSA) located opposed along the shape of the rotating cathode. Copper is electro-deposited on the surface of the rotating cathode, and the deposited copper is continuously peeled off as a foil from the rotating cathode and wound." SOLUS-1014, 8:51-58.

[8d]: wherein the electrolytic solution comprises 70 to 90 g/L of copper ions,

206. The following disclosures render obvious this solute and range. SOLUS-1014, 16:5; SOLUS-1015, Table 1; SOLUS-1016, [0035]; SOLUS-1010,

[0085]; SOLUS-1012, [0077]. The Chou value was calculated using molar masses as discussed in Section X.C above.

Copper Ion Concentration (g/L)					
Claimed range	Dobashi	Shinozaki '922	Chou	Lee	Shinozaki '681
70 – 90	80	90	80	60 – 180	50 – 90

[8e]: 80 to 120 g/L of sulfuric acid,

207. The following disclosures render obvious this solute and range.
SOLUS-1014, 16:6; SOLUS -1015, Table 1; SOLUS -1016, [0035]; SOLUS -1010, [0095]; SOLUS -1012, [0077].

Sulfuric Acid Concentration (g/L)					
Claimed range	Dobashi	Shinozaki '922	Chou	Lee	Shinozaki '681
80 – 120	140	100	110	80 – 150	40 – 70

[8f]: 10 to 20 ppm of chlorine ions,

208. At least the following disclosures render obvious this additive and range.

209. Shinozaki '681 describes a solution that includes chlorine ions, disclosing that “the [] foil of the present invention is formed [] from an electrolytic

solution of sulfuric acid and copper sulfate with low chloride ion concentration []. Here, ‘low chloride ion concentration’ means that the amount of chloride ion in the electrolyte is 15 [ppm] or less.” SOLUS-1012, [0049]. Specific disclosed ion concentrations include, among other values, 10 ppm and 15 ppm, both of which are within the claimed range. *Id.*, Table 1. Here, I rely on noting (i) that a POSITA would have understood ppm and mg/L disclosures to be used interchangeably, and (ii) that a more precise ppm calculation would not significantly alter these values or reasoning.

210. Dobashi discloses various chlorine concentrations, including an example in which the concentration is 10 ppm. SOLUS-1014, Table 1.

[8g]: 3 to 12 ppm of a sulfide-based compound,

211. At least the following disclosures render obvious this solute and range.

212. Chou discloses that “[t]o every liter of the copper sulfate electrolyte [] 3 mg of [] MPS [] were added.” SOLUS-1016, [0035]. 3 mg/L corresponds to 3 ppm, as I discussed above in Section X.C. MPS is listed by the ’706 Patent as a sulfide-based compound. SOLUS-1001, 2:52-57.

213. Shinozaki ’922 discloses examples of MPS concentration of 3 ppm, 5 ppm, and 10 ppm. SOLUS-1015, Table 1.

214. Dobashi discloses that “[i]t is also preferable that the total concentration of MPS and/or SPS in the sulfuric acid base copper electrolytic solution is 0.5 ppm to 200 ppm.” SOLUS-1014, 4:22-24. Dobashi also discloses that “[t]he sulfuric acid base copper electrolytic solution more preferably comprises at least one selected from MPS and SPS []. In this case, the total concentration of MPS and/or SPS in the sulfuric acid base copper electrolytic solution is preferably 0.5 ppm to 200 ppm. A more preferable concentration range is 0.5 ppm to 50 ppm, and a further preferable concentration range is 1 ppm to 20 ppm.” *Id.*, 11:60-67.

[8h]: 25 to 50 ppm of molybdenum (Mo),

215. See discussion of Shinozaki '681 in [8h] in Section X.C.

[8i]: and 5 to 25 ppm of polyethylene glycol (PEG).

216. See discussion of Lee in [8i] in Section X.C.

[9]: The electrolytic copper foil of claim 8, wherein the sulfide-based compound is selected from a group consisting of bis-(sodium sulfopropyl) disulfide (SPS), 3-mercapto 1-propane sulfonate (MPS), and 3-(benzothiazolyl-2-mercapto)-propyl-sulfonate (ZPS).

217. See discussion of [9] in Section X.C.

[10]: The electrolytic copper foil of claim 8, wherein the sulfide-based compound is SPS.

218. See discussion of [10] in Sections X.C and XI.B.

XV. CLAIM INTERPRETATION

219. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted “using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 283(b)...” 37 C.F.R. § 42.100(b). In that regard, I 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.

XVI. LEGAL PRINCIPLES

A. Anticipation

220. 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

221. 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.

222. 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.

XVII.CONCLUSION

223. The findings and opinions set forth in this declaration are based on my work and examinations to date.

224. I may continue my examinations. I may also receive additional documentation and other factual evidence over the course of this IPR that will allow me to supplement and/or refine my opinions. I reserve the right to add to, alter, or delete my opinions and my declaration upon discovery of any additional information. I reserve the right to make such changes as may be deemed necessary.

225. In signing this declaration, I recognize that the declaration will be filed as evidence in an IPR before the PTAB. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

226. I hereby 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 are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 9/19/2024 By:



Dr. Michael Randall
Simpsonville, South Carolina

APPENDIX

Michael S. Randall

313 River Walk Drive
Simpsonville, SC 29681
Phone: 864-608-1047
Almegacy@gmail.com

SUMMARY: Seasoned technologist, inventor, subject matter expert, entrepreneur and economic development specialist with over 30 years of experience in R&D, product development, intellectual property, and business identification including design, materials, processing, analysis, testing and business development, having a record of taking ideas to profitable products. An experienced consultant having provided expert services in the areas of electronic materials, components and assemblies, intellectual property, product development, process optimization, market studies, and grants. Recognized technical expert in electronic components and certified Six Sigma Black Belt (DFSS). Award winning author, inventor, board member, subject matter expert, lecturer, adjunct professor, entrepreneur and technical consultant.

WORK EXPERIENCE:

9/03 to present	Almegacy LLC, President & CEO Consulting
10/08 to 1/17	Health Sciences South Carolina, Chief Economic Development Officer
11/99 to 8/08	KEMET Electronics, Director Advanced Technology
10/97 to 11/99	Ferro Corporation, Ferro Electronic Materials Division, Director of Research and Development
10/92 to 10/97	AVX Corporation, Advanced Products and Technology Center, Manager of Ceramic Capacitor Research and Development
3/97 to 10/97	Webster University, Myrtle Beach Metropolitan Campus, Adjunct Professor
12/91 to 10/92	Engineering Consulting Firm of Gould, Lewis, and Proctor, Engineering Consultant
5/85 to 12/91	University of Florida, Graduate Research Associate
7/83 to 1/84	National Bureau of Standards (NIST), Research Engineer (Cooperative Education Program with Alfred University)

EDUCATION:

Aug 1993	PhD Materials Science and Engineering, University of Florida (GPA: 3.96/4.00)
May 1985	MBA Business Management, Webster University (GPA: 4.00/4.00)
Aug 1987	MS Materials Science and Engineering, University of Florida (GPA: 3.95/4.00)
May 1985	BS Ceramic Engineering, NYSCC at Alfred University, Minors in Chemistry and Business Management (GPA: 3.85/4.00) magna cum laude

SPECIALIZED EXPERIENCE:

Electronic Materials and Processing, Ceramic Dielectric Materials, Processing and Analysis, Electronic Components and Assemblies, Surface Mount Technology, Invention and Ideation, Reliability Assessment, New Product Development, Business Development, Economic Development, Subject Matter Expert Witness and Support, Grants, Intellectual Property, Product Liability Technology Leader's Forum, DFSS/6 σ Black Belt, Leadership, TOPS, DOE, QOS, FMEA

PROFESSIONAL TRAINING:

AWARDS:

KEMET (Club of Excellence, ELT, Best & Brightest), InnoVision Winner and Runner Up, Best Paper, Distinguished Writer, Outstanding Student, Scholarship

SOCIETIES:

AcerS, SMTA, IMAPS, MRS, AESF, A Σ M, TBPI, Φ K Φ , $\Delta\Delta\Delta$

PUBLICATIONS/PRESENTATIONS:

More than 100, More than 20 Invited, 2 Best Paper awards

SUBJECT MATTER EXPERT:

Multiple cases (patents, NDAs, product liability (ITC, PTAB, District Courts, etc.))

PATENTS:

20 U.S. Patents Granted, 2 Chinese

GRANTS:

Managed DARPA grant, assisted NIH GO Grant, ARRA/ONC HITECH Grant, ARPA-eBEEST Program award, The Duke Endowment, SC-Israel Collaborative (>\$25M in grants total)

SESSION CHAIR/LECTURER:

5 Symposia, multiple lectures at undergraduate and graduate levels

PERSONAL:

US Citizen with active passport, married, 2 children

August, 2024

WORK EXPERIENCE:

9/03 to Present Almegacy LLC, Simpsonville, SC
President, Consulting

- Provides ideation, invention, selection, sourcing, design, materials, processing, analysis, technology, IP and expert services, as well as equipment selection for electronic components
 - Electronic device, assemblies and related materials consulting including design, formulation, processing and testing development
 - Electronic component design, characterization, selection, assembly and sourcing for projects (active and passive)
 - Capacitors (SLC, MLCC, GBLC, Film, Ta, AE, EDLC/Supercapacitors, Hybrid/Pseudocapacitors, others), resistors (thick and thin film), inductors and terminators, antennae, batteries (primary and secondary), oscillators, LEDs, integrated Circuits, microprocessors, transducers, power harvesters and sensors (mechanical and gas including smart sensors), thermoelectric devices, and other passive electronic components and chassis/hardware
 - Component performance and reliability assessment and modeling
 - Adhesive/coating/potting/encapsulation selection
 - Selection and management of PCB fabrication and assembly processes
 - Advisement on product compliance per specification, including RoHS and REACH
 - Electronic materials selection and sourcing including ceramics, metals, and organics
 - Device, materials, process development and analysis for materials and related electronic components
 - High temperature materials selection, evaluation, design and processing
 - High energy density storage materials and devices design and development assistance
 - Product development assistance including design, materials selection and sourcing, processing and related process equipment, test and analysis, packaging, intellectual property protection and marketing
- Technical marketing studies for emerging proprietary technologies, including devices, materials, test and measurement, and associated equipment, intellectual property and technologies
- Consulted on ARPA-e grant team BEEST Program Award Recapping, Inc.: High Energy Density Capacitors, program in coordination with Recapping (Khosla Ventures funded) and Pennsylvania State University
- Subject matter expert:
 - Expert support for USPTO PTAB ex partes reexaminations, inter partes reviews, post grant reviews, petitions, responses and other matters regarding patents:

▪ US 6,014,309	▪ US 6,661,639	▪ US 7,307,829
▪ US 6,144,547	▪ US 6,816,356	▪ US 8,536,496
▪ US 6,243,254	▪ US 6,992,879	▪ US 9,326,381
▪ US 6,266,229	▪ US 7,190,252	▪ US 9,475,086
▪ US 6,337,791	▪ US 7,361,869	▪ US 9,798,968
▪ US 6,377,439	▪ US 7,705,776	
 - Expert support for U.S. District Court for the Central District of California, case number 8:09-cv-01124, Murata Manufacturing Co Ltd. v. Samsung Electro Mechanics Co. Ltd., et al., Assisted successful defense against infringement claims regarding US Patents 6,014,309 6,243,254 6,266,229 6,377,439
 - Expert for ITC trial Investigation Number 337-TA-692, “In the Matter of Certain Ceramic Capacitors and Products Containing Same”, Murata v SEMCO. Assisted successful defense against infringement claims regarding US Patents 6,014,309 6,243,254 6,266,229 6,377,439
 - Expert support for ITC trial Investigation Number 337-TA-813, “Certain Electronic Devices With Graphics Data Processing Systems, Components Thereof, and Associated Software”, S3 Graphics v Apple. Assisted successful defense settlement against infringement claims regarding US Patent 5,581,279
 - Expert support for U.S. District Court for the Eastern District of Texas, case number 2:11-cv-00052, MicroUnity Systems Engineering, Inc. v. Apple, Inc., et al. Assisted successful defense settlement against infringement claims regarding US Patent 6,643,765

August, 2024

- Expert support for U.S. District Court for the Southern District of California, case number 3:14-cv-02061, Presidio Components, Inc. v. American Technical Ceramics Corp., Assisted successful prosecution of infringement on claims regarding US Patent 6,816,356
- Expert for U.S. District Court for the Eastern District of New York, case number 2:14-cv-06544, American Technical Ceramics Corp., and AVX Corporation vs. Presidio Components, Inc. regarding US Patents 6,144,547, 6,337,791, and 6,992,879
- Expert support for Cap-XX Ltd. vs. Maxwell Technologies, Inc., Case No. 19-1733 (CFC), US District Court, District of Delaware, regarding US Patents 6,920,034 and 7,382,600
- Expert support for Envirodigim, Inc. vs. Apple, Inc., Case No. 20CV373138, Superior Court of the State of California for the County of Santa Clara, including successful defense (summary judgement)
- Expert for Fourth Circuit Court, Duval County Florida, product liability case number 16-2010-CA-001815, Gentleman v Medtronic. Assisted successful settlement for client
- Technical and market development advisor to several startup businesses in the field of passive electronic components (high temperature, high energy density storage devices and materials, high temperature gas sensing systems, supercapacitors, hybrid supercapacitors, secondary batteries, including technical and strategic support for US patent 10,679,799)
- Instructor, seminar on patent portfolios and intellectual property at CARTS USA 2011
- Invited instructor, seminar on intellectual property at SmartState™ Council of Endowed Chairs, May 2013
- Invited speaker for ASM seminar (2014-2024)
- Invited lecturer for BioE 8600, Introduction to Common Machining/Manufacturing Techniques for Medical Devices, Good Manufacturing Practices, (October 2014)
- Invited lecturer for BioE 8600, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," November 2016
- Invited lecturer for BioE 8600, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," November 2018
- Invited lecturer for BioE 8600, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," November 2019
- Adjunct professor in Bioengineering, Clemson University
- Technical writer for Venkel, Ltd., technical reports and technical blog "The Circuit: A Blog for Engineers," (subject matter including capacitors, resistors, inductors, LEDs, etc.)
- Marketed IP rights to patent portfolio for emerging technology company
- Client base includes more than 40 clients, from "start up" to "Fortune 100"

10/08 to 1/17 Health Sciences South Carolina, Columbia SC

Chief Economic Development Officer

- Assisted economic and business development at HSSC and 12 sponsored Centers of Economic Excellence
- Intellectual property development, 7 Idea disclosures/applications, 2 US Patents granted, 1 technology license
- New Product Design, Development and New Business Development
- Strategic planning
- Selection and implementation of advanced, HSSC-wide, clinical analytics system
- Promoted networking between member organizations and external organizations to provide business, legal, information and government services needed by member organizations
- Assisted organizations in finding and developing relationships with allied organizations
- Assisted establishment of businesses in South Carolina, promoting quality job creation in South Carolina
- Team member of an ARRA Grand Opportunities ("GO") Grant (RFA OD 09-004. CFDA 93.701) to establish unique Research Permissions Management System, \$4.3M award
- Team member of an ARRA/ONC RC HITECH RC Grant (EP-HIT-09-003) to establish CITIA-SC, \$6.4M award
- Team member for The Duke Endowment Grant II to HSSC, \$11.25M award
- Team member for SC-Israel Collaborative Industry R&D Program Grant, \$1M Total budget

August, 2024

- Member of the Board of Directors, NXT Health
- Member of the Economic Advisory Board and the Board of Directors of Clemson University Department of Bioengineering
- Established EDAC (Economic Development Advisory Committee) for HSSC membership
- Established Vendor Selection Committee for CITIA-SC (South Carolina's REC) and managed and performed contract review and negotiations for EHR vendor and Analytics Software vendor selection activities
- Assisted development of statewide clinical trials and research system plan
- Established HEAL SC (Health Economy Advancement Legacy for South Carolina) symposium, South Carolina's first statewide health sciences related economic development summit
- Organized SC Collaborative at BIO International
- Represented HSSC at numerous meetings as a Panelist, Panel Leader or Information Conveyor

1/05 to 8/08 KEMET Electronics, Advanced Technology Group, Simpsonville, SC
Director, Advanced Technology

- Business identification, demand creation, invention and NPD for 7 new advanced products from ideation to pilot scale addressing more than \$450M in potential markets
 - D-Stick (low inductance feed through decoupling capacitor)
 - Controlled ESR D-Stick
 - D-Pack (ultra-low inductance feed through capacitor array)
 - L-CAP (low cost, two terminal low inductance capacitor)
 - Controlled ESR L-CAP
 - K-SIP (decoupling capacitor array interposer for SIP packaging)
 - V-Max (very high capacitance density hybrid (anodized Ta/BT sol-gel) dielectric capacitor system)
- Development of non-destructive screening method for enhancement of device reliability
- Intellectual property generation and searches for patentability and product clearance Internal expert for Ceramic Business Group NPD activities
- Technology assessment for due diligence for M&A efforts resulting in successful acquisition of Evox Rifa Oy
- Enhancement of customer relations through specialized designs and prototype evaluations
- Partnering and open innovation activities with customers, suppliers, universities, and government agencies
- Member of Extended Leadership Team (ELT)
- Member of the Club of Excellence (2007 and 2008)
- KEMET Special Recognition Award
- KEMET patent awards: More than 10 U.S. Patents granted U.S.
- Honorable mention in 10 press releases

4/03 to 1/05 KEMET Electronics, Technical Marketing and New Business Dev., Simpsonville, SC
Director of Ceramic Technical Marketing and New Business Development

- Quantification of \$17B Capacitor Market Landscape
- Identification of \$400M+ potential KEMET markets
- Produced and managed Advanced Products Portfolio
- Member of due diligence teams for 9 separate, investment/M and A opportunities
- Established business case and business risk assessment system
- Assisted Development of 4 new product lines
 - HV Commercial SMD MLCC
 - HV Leaded MLCC
 - Flex Robust MLCC
 - Open Mode, Soft Termination, Clip On Leadframe
 - Environmentally friendly, high CV COG MLCC

August, 2024

- Directed and managed technical support for all ceramic products
- Established highly effective system for competitor analyses/competitive intelligence

11/99 to 4/03 KEMET Electronics, Ceramic Technology, Ft Inn, SC

Director of Ceramic Technology

- Responsible for the direction of seven, process specific, functional teams, providing technology solutions for Multilayer Ceramic Capacitor (MLCC) development needs, including:
 - Mixing, Milling and Coating of Dielectric Tapes
 - Electrode Materials
 - Green Chip Processing
 - Thermal Processing and Corner Rounding
 - Termination Materials and Processing
 - Plating
 - Test and Failure Analysis
- Directed/Assisted Platform product development teams
 - COG, X5R and Y5V (PME and BME)
- Directed/Assisted non-platform development teams
 - Product performance improvement
 - Quality improvement
 - Cost and yield improvement
 - Employee and laboratory performance improvement
- KEMET university liaison for Ceramic Technology Department
- Directed or assisted/facilitated projects responsible for ~70% of ceramic capacitor new product sales

9/98 to 11/99 Ferro Corporation, Ferro Electronic Materials, CA (Formerly The Electronic Materials Division), San Marcos and Santa Barbara, CA

Director of Research and Development

- Responsible for planning, direction and oversight of all division level research and development and new product development, including the following product lines:
 - LTCC (Low Temperature Cofired Ceramic systems)
 - MMS (Multilayer Materials Systems)
 - OEM (Organic Electronic Materials systems)
 - PVS (Photovoltaic materials Systems)
 - RMS (Resistor Materials Systems)
 - TFS (Thick Film materials Systems)
- Directed new product development of more than 225 new line item products accounting for ~25% of FEM, CA FY99 total sales
- Established and managed an R&D/NPD group
- Established a comprehensive R&D information system
- Established and managed a process engineering group
- Established and managed a QA group
- Corporate level R&D interaction for division
- Division level interaction with external product development sources
- Managed divisional intellectual property
- Managed DARPA grant for high aspect ratio electrode printing on low loss dielectric packaging
- Member of Senior Management Committee

10/97 to 9/98 Ferro Corporation, Electronic Materials Division, San Marcos/Santa Barbara, CA
Manager of Research and Development

- Responsible for planning, management and oversight of all division level research and development and new product development including the product lines outlined above
- Managed new product development of more than 125 new line item products
- Responsible for all corporate level R&D interaction with division
- Established R&D new product development system
- Established R&D long term project portfolio

4/94 to 10/97 AVX Corporation, Advanced Products and Technology Center, Myrtle Beach, SC
Manager of Ceramic Capacitor Research and Development

- Responsible for planning and oversight of all multi-layered ceramic capacitor development
- Oversight of development of base metal, relaxor and conventional MLCC systems, high CV, low cost (Ni-metallurgy X7R and Y5V, Relaxor-based Y5V/Y5U)
 - For high frequency applications (Cu-metallurgy COG)
 - For harsh environments (X8R/other under-the-hood applications)
 - Assisted Integrated Passive Component development
- Member of AVX Development Council
- Member of AVX Dielectric Strategy Committee
- Oversight Committee for competitor benchmarking
- Interface and assist corporate MLCC development at satellite plants (Myrtle Beach, SC, Conway, SC, Raleigh, NC, Olean, NY, Vancouver, WA, Coleraine, Ireland, Kyocera (Japan and USA))
- Member of Environmental, Health and Safety Council
- AVX Representative to the American Ceramic Industries Association

10/92 to 4/94 AVX Corporation, Corporate Research Laboratory, Conway, SC
Principal Engineer

- Responsible for pilot scale actuator green fabrication and thermal processing
- Project leader for piezoelectric voltage generator development
- Project leader for voided piezoelectric sensor project
- Developed various piezoelectric and electrostrictive devices

3/97 to 10/97 Webster University, Myrtle Beach Metropolitan Campus, Myrtle Beach, SC
Adjunct Professor (part time (weekends) while working at AVX)

- Instructor for BUSN 6080: Management Information Systems
- Instructor for BUSN 6150: Business Communications and Technology
- Assisted establishment of computer/communications lab for new, state-of-the-art campus (LAN, ISP, presentation system, etc.)

12/91 to 10/92 The Engineering Consulting Firm of Gould, Lewis and Proctor, Gainesville, FL
Engineering Consultant

- Designed, built and maintained a direct tension, multi-station, hydraulic apparatus for investigation of and characterization of accelerated stress corrosion cracking and hydrogen embrittlement of high strength steel reinforcement wire used in pre-stressed concrete pipe.
 - Equipment payback achieved within 2 months of implementation. System proved highly reliable and highly profitable.
 - Received a bonus and a raise as reward for the uniqueness, functionality and profitability of the direct tension mechanical test system

5/85 to 12/91 University of Florida, Gainesville, FL**Graduate Research Assistant**

- Performed graduate level research in the areas of phase separation and crystallization in heavy metal fluoride glasses (Master's research) and in the area of low dielectric loss electronic packaging materials (Doctoral research)
- Designed and outfitted a general purpose research laboratory

7/83 to 1/84 National Bureau of Standards (now NIST), Gaithersburg, MD**Research Engineer** (Cooperative Education Program with Alfred University)

- Characterized the high TiO_2 end of the BaO/TiO_2 binary phase diagram via XRD on samples prepared via a drop-tube quench furnace
- Characterized the high Li_2O end of the $\text{Li}_2\text{O/Al}_2\text{O}_3$ binary phase diagram via XRD on samples heat treated in controlled atmosphere or microtorr furnaces
- Rebuilt/redesigned intermediate temperature, microtorr vacuum furnace
- Investigated PSZ/SiC(w) composite precursor powder-whiskers, produced via spray drying, using optical microscopy, SEM, ASEM, and LS particle size analysis
- Assisted set up of a powder processing/characterization laboratory

EDUCATION:**University of Florida, Gainesville, FL****Degree:** Ph.D. Materials Science and Engineering, August 1993**GPA:** 3.96/4.00**Dissertation:** Processing, Characterization and Modeling of Low Dielectric Constant, Low Dielectric Loss, Porous Composites for Use in High Frequency Applications**Candidacy Defense:** "SSACTECD: Smart-Switched, Actively Controlled Transmissive, Electrochromic Device"**Advisors:** Prof. J. H. Simmons, Prof. M. D. Sacks**Webster University, St. Louis, MO (Myrtle Beach, SC Campus)****Degree:** M.B.A. Business Management, May, 1995**GPA:** 4.00/4.00**Thesis:** Case Study: Kyocera Corporation**University of Florida, Gainesville, FL****Degree:** M.S. Materials Science and Engineering, August, 1987**GPA:** 3.95/4.00**Thesis:** Immiscibility and Crystallization in the Cadmium-Lithium-Aluminum-Lead Fluoride Glass System**Advisor:** Prof. J. H. Simmons**N.Y.S. College of Ceramics at Alfred University, Alfred, NY****Degree:** B.S. Ceramic Engineering, May, 1985**Minors:** Chemistry, Business Management**GPA:** 3.85/4.00, Magna Cum Laude**Thesis:** Characterization of PTCR Behavior in BaTiO_3 -Based Thermistors**Advisor:** Prof. V. R. W. Amarakoon

SPECIALIZED EXPERIENCE:

- Ideation and Invention: Inventor on more than 20 patents. Brainstorming Sessions, Options Selection and Projects Portfolio Establishment and Management
- Basic Design and Performance Modeling: Passive Electronic Components and Assemblies: Multilayer Devices (MLCC, Multilayer Arrays, Low ESL MLCC, Controlled ESR MLCC, Multilayer Piezo Devices, Film Capacitors, Electrolytic Capacitors, EDLC/Supercapacitors, Hybrid/Pseudocapacitors), Batteries, LEDs, Thick Film Devices, EMI Filters, LTCC
- Formulation: Dielectrics, Glasses, Thick Film Pastes, Organic Vehicles, Additives and Modifiers
- Synthesis: Ceramic (Barium Titanate, BCT, BCTZ, Calcium Titanate, Calcium Zirconate, PMN/PT, PZT, Glass), Organic (Uniform Polystyrene Latex Particles, Polymethylmethacrylate)
- Powder Processing and Characterization: Batching, Milling, Mixing, Dispersing, Classifying, Coating/Pressing, Surface Area, Particle Size Analyses, Microscopy, Bulk Chemistry, Surface Chemistry, Density (Tap, Pycnometer, Bulk), Porosity (Archimedes, Hg Porosimetry), X-Ray Diffraction, FTIR, ICP, Rheometry (Liquid Viscometry), Fraction Solids (Organic and Ceramic), Other
- Microscopy, Metrology, and Associated Analytical Techniques: Physical, Electrical, Optical, ASEM, ATEM, sample preparation techniques, analysis, and data interpretation
- Analytical Testing Techniques: ICP, LAMS, XRF, XRD, SAED, TGA/DTA, DSC, TMA
- Additive and subtractive manufacturing
- Thermal Processing: Low and High Temperature, Controlled Atmospheres (Vacuum, Inert and Reactive Atmospheres), Microwave Sintering
- Finishing: Corner Rounding, Thick Film Conductors, Plating (Electroless and Electrolytic), Anodizing
- Device Sorting, Testing and Packaging: Capacitance, Dissipation Factor, Dielectric Constant, Dielectric Withstanding Voltage, Dielectric Breakdown Strength, Insulation Resistance, Temperature Coefficient of Capacitance, Field Effect, Dielectric Aging, Tape and Reel, Other
- Battery analysis: ΔT vs. charge/discharge current, capacity vs. temperature, life cycle degradation, ESR, etc.
- Reliability Testing: Thermal Shock, Thermal Cycling, Highly Accelerated Life Test, Life Test, Temperature Humidity Bias Test, Non Destructive Test (CSAM and SLAM), Other
- Analysis and Failure Analysis
- Guidance of product performance vs. specification (Military, Aerospace, Automotive, other)
- Management of board builds including working with PWB fabricators and assemblers, conformal coating selection and RoHS advisement
- Mechanical Characterization: Tension, Torsion, Flexural, Wrap, Pull, and Microhardness/Nanohardness Indentation, Fatigue Acceleration, Lamination/Bond Strength
- Technology Management/Direction: Personnel/Group Management, Project Management, Technology Management, Strategic Analysis, Portfolio Management, Acquisition Analysis and Due Diligence, IP and IP Portfolio Management, Quality Management
- Market Analysis and Business Identification: Electronic Market Segments Analysis, Competitive Intelligence/Analysis, Product Portfolio Management, Roadmap Establishment and Management, Economic Analysis
- Ideation, Technical Author, Statistical Analysis, Lean Design, Design for Manufacturability, Process Design, Grant Writing, Grant Budgeting and Management,
- Subject Matter Expert: Expertise in Electronic Components such as Multilayer Capacitors, Resistors, Inductors, Batteries, LEDs, as well as Surface Mount Technology, Electronic Assemblies, and Related Design, Materials, Processing, Testing and Markets

PROFESSIONAL TRAINING AND CERTIFICATIONS:

- Team Oriented Problem Solving (TOPS II/TOPS III, Global 8D, Ford Sanctioned)
- Design of Experiments (DoE, StorageTek, KEMET, Minitab Sanctioned)
- Failure Modes and Effects Analysis (FMEA, Ford Sanctioned)

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- QV2000/Quality Operating System (QOS, AVX Sanctioned)
- A Leadership Course In: Effective Employee Motivation (Dun and Bradstreet)
- A Leadership Course in: Effective Time Management (Dun and Bradstreet)
- Making Managers Into Leaders (Enlightened Leadership International)
- Project Management Training (CareerTrack)
- Managing Multiple Projects and Priorities (Fred Pryor)
- The Seven Habits of Highly Successful People (Stephen Covey, Fred Prior Sanctioned)
- Personal Productivity (The Leadership Group Sanctioned)
- Effective Leadership Skills (The Leadership Group Sanctioned)
- Project Planning with Microsoft Project (Sam Brooks Associates, Microsoft sanctioned)
- Benchmarking: An Introduction (AVX sanctioned)
- Technology Forum (KEMET Sanctioned)
- Lean Six Sigma, Design for Six Sigma (Green Belt and Black Belt Trained and Certified)
- KEMET Technology Leadership Forums

AWARDS:

- Member, KEMET ELT (Extended Leadership Team, 2005-2008)
- Member, KEMET Club of Excellence 2007, 2008
- Noted as one of KEMET's Best and Brightest (KEM press release, December 19, 2006)
- Innovision Awards Finalist (D-Pack), 2006
- Innovision Awards Winner (Green BME COG), 2007
- KEMET Special Recognition Award, 2008
- KEMET Patent Awards, 2006, 2007, 2008
- John D. Moynihan Best Paper Award, CARTS USA 2003
- Distinguished Writer Award, AVX Corporation, Recipient (1995, 1996, 1997)
- University of Florida President's Recognition for Outstanding Students (1992)
- University of Florida Graduate Council Fellowship, Recipient (1985-1986)
- Alfred University Southern Tier Scholarship, Recipient (1981-1985)
- New York State Regents Scholarship, Recipient (1981-1985)

SOCIETIES:

ACerS Reviewer for Journal of the American Ceramic Society, 2011-Present, Director of History and Personnel, Electronics Division 2005, ACerS Director of Corporate Membership, Electronics Division 2006, ACIA Board Member, Session Chair, Committee Chair for Electronic Division History and Personnel Committee, ACerS (technical reader for Ceramic Transactions 19: Advanced Composite Materials 1988), Keramos (University of Florida Secondary Founder, Secretary, Treasurer 1986), MRS, ISHM/IMAPS (founded the University of Florida Chapter 1986, Board Member of So Cal IMAPS, Editor of So Cal IMAPS Newsletter 1997), SMTA, AESF, IEEE, Alpha Sigma Mu, Tau Beta Pi, Phi Kappa Phi, Alpha Lambda Delta

SELECT PUBLICATIONS, LECTURES, POSTERS AND PRESENTATIONS:

- M. Randall, "Anodizing," ASM International, Greenville Old South Chapter, February 2024
- M. Randall, "Thoughts and Considerations on Crossing MLCCs," Venkel Ltd., White Paper, November, 2022
- M. Randall, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," invited lecture, Clemson University Department of Bioengineering, BioE 8600: Biomedical Engineering Device Design Innovation, November 6, 2020
- M. Randall, "Ceramic Capacitors: The Smart Replacement for Electrolytic Capacitors," Venkel Ltd., Technical Paper, September 2020.
- M. Randall, "More About Circuits," article for Venkel technical blog, March, 2020.

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- M. Randall, "AC Series and Parallel Circuits: Inductors and Capacitors," article for Venkel technical blog, March, 2020.
- M. Randall, "Series and Parallel Circuits 3: Capacitors" article for Venkel technical blog, March, 2020.
- M. Randall, "Series and Parallel Circuits 2: Resistors," article for Venkel technical blog, March, 2020.
- M. Randall, "Series and Parallel Circuits 1: The Basics," article for Venkel technical blog, March, 2020.
- M. Randall, "LEDs: Data Sheets, Drivers and More Applications," article for Venkel technical blog, March, 2020.
- M. Randall, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," invited lecture, Clemson University Department of Bioengineering, BioE 8600: Biomedical Engineering Device Design Innovation, November 1, 2019
- M. Randall, "Materials Analysis: Examples Used in IP Litigation," invited talk ASM Greenville SC, January 10, 2019.
- M. Randall, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," invited lecture, Clemson University Department of Bioengineering, BioE 8600: Biomedical Engineering Device Design Innovation, November 9, 2018.
- M. Randall, "MELF Resistors: Applications," article for Venkel technical blog, August 2018.
- M. Randall, "MELF Resistors: Performance," article for Venkel technical blog, July 2018.
- M. Randall, "Welcome Back! MELF Resistors," article for Venkel technical blog, July 2018.
- M. Randall, "LED Applications," article for Venkel technical blog, August 2017.
- M. Randall, "Optical Properties of LEDs," article for Venkel technical blog, August 2017.
- M. Randall, "LEDs: How they are made," article for Venkel technical blog, July 2017.
- M. Randall, "A Brief Introduction to High Voltage Surface mount Capacitors," Venkel Ltd., Technical Paper, March 2017.
- M. Randall, "This Little Light of Mine: LED Basics," article for Venkel technical blog, March 2017.
- M. Randall, "Manufacturing Technology for Implantable Electronic Medical Devices: Processes, Verification, Validation and Scale-up," invited lecture, Clemson University Department of Bioengineering, BioE 8600: Biomedical Engineering Device Design Innovation, November 18, 2016.
- M. Randall, "Surface Mount Power Inductors," article for Venkel technical blog, December 2015.
- M. Randall, "The Definitive Guide to Surface Mount Resistor Selection," Venkel Ltd., Technical Paper, November 2015.
- M. Randall, "Part I: Introduction to Common Machining/Manufacturing Techniques for Medical Devices and Good Manufacturing Practices," invited lecture, Clemson University Department of Bioengineering, BioE 8600: Biomedical Engineering Device Design Innovation, October 23, 2015.
- M. Randall, "Chip Components and Surface Mounting," article for Venkel technical blog, February 2015.
- M. Randall, "Tin Whiskers and Chip Components," article for Venkel technical blog, February 2015.
- M. Randall, "SMT Chip Shelf Life: Solderability and IMC Considerations," article for Venkel technical blog, February 2015.
- M. Randall, "Chip Resistor Power Considerations," article for Venkel technical blog, December 2014.
- M. Randall, "Chip Resistors Part 3: Applications and Considerations," article for Venkel technical blog, November 2014.
- M. Randall, "Chip Resistors Part 2: Types," article for Venkel technical blog, October 2014.
- M. Randall, "Chip Resistors Part 1: The Basics," article for Venkel technical blog, October 2014.
- M. Randall, "High Voltage MLCCs: SHOCKING REVELATIONS! Part 3: It Ain't the Volts, It's the Amps: Some Applications and Considerations," article for Venkel technical blog, October 2014.

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- M. Randall, “High Voltage MLCCs: SHOCKING REVELATIONS! Part 2: Judging a Book by Its Cover: Don’t Forget the Outside,” article for Venkel technical blog, September 2014.
- M. Randall, “High Voltage MLCCs: SHOCKING REVELATIONS! Part 1: It’s What’s Inside that Counts,” article for Venkel technical blog, September 2014.
- M. Randall, “Capacitor ESR: It’s EaSiEr than you think!,” article for Venkel technical blog, August 2014.
- M. Randall, “Decoupling Part 2: Low ESL MLCCs,” article for Venkel technical blog, August 2014.
- M. Randall, “Decoupling Part 1: The Basics,” article for Venkel technical blog, July 2014.
- M. Randall, “Class 1 MLCC v. Film Capacitors: And the Winner Is...,” article for Venkel technical blog, July 2014.
- M. Randall, “Class 1 Ceramic Capacitors are First Class,” article for Venkel technical blog, July 2014.
- M. Randall, “Business Plans,” invited lecture, University of South Carolina Arnold School of Public Health, HSPM 791: Healthcare Innovations, June 22, 2015.
- M. Randall, “Deviant Behavior Part 3: Seen and Not Heard,” article for Venkel technical blog, June 2014.
- M. Randall, “A Farad on the Head of a Pin for Free,” invited talk ASM Greenville SC, October 23, 2014.
- M. Randall, “Deviant Behavior Part 2: Dude, Where’s My Capacitance?,” article for Venkel technical blog, June 2014.
- M. Randall, “Deviant Behavior Part 1: CRLZ Gone Wild,” article for Venkel technical blog, June 2014.
- M. Randall, “A Farad on the Head of a Pin for Free,” article for Venkel technical blog, May 2014.
- Invited panelist, Healthcare: IT-Ology Summit on Information Technology, Columbia SC April 23, 2014.
- N. Bailey and M. Randall, “Testing and Measurement Practices of High Capacitance Ceramic Capacitors,” Venkel, Ltd., Technical Paper, March 2014.
- Invited panelist (Moderator), Health IT: SCBIO Face to Face, Charleston, SC November 14, 2013.
- M. Randall, “Optimize and Protect Your Patent Portfolio,” invited talk, South Carolina SmartState™ Council of Chairs Meeting, Columbia SC, May 15, 2013.
- J. Gasque, M. Randall, W. Harrell, G. Alapatt, “Better Impedance Measurement Using Kelvin-Type Test Fixturing,” CARTS International 2012 Proceedings, Las Vegas, NV, pp. 157-185, March, 26-29, 2012.
- M. Randall, “Optimize and Protect Your Patent Portfolio,” invited instructor, for-free seminar,” CARTS USA 2011, Jacksonville, FL, 9:00am to Noon, March 28–30, 2011.
- M. Randall, “Electronic Health Records: Vendor Selection Process and Next Steps,” South Carolina Primary Health Care Association Annual Conference, Invited Talk, Myrtle Beach, SC, October 15-17, 2010.
- M. Randall, “SEMCO MLCC Tutorial Presentation,” Trial Investigation Number 337-TA-692, “In the Matter of Certain Ceramic Capacitors and Products Containing Same,” Presentation to the Court of the International Trade Commission, Washington D.C., July 21, 2010.
- M. Randall, “CITIA-SC Vendor Selection and Group Purchasing Committee Update,” SCORH Rural Health Clinic Meeting, Invited talk, Columbia, SC, June 9, 2010.
- M. Randall, “Vendor Selection and Group Purchasing Committee Update,” HIT SC Summit #8, Invited talk, April 22, 2010.
- M. Randall, “A Statewide Clinical Trials System,” Invited talk, 2nd Annual South Carolina Human Research Conference, Greenville, SC, November 13, 2009.
- J. Prymak, M. Randall, P. Blais, B. Long, P. Staubli, E. Chen, “Why 47 μ F Capacitor Drops to 37 μ F, 30 μ F, and Lower,” CARTS Europe 2008 Proceedings, Helsinki, Finland, October 20-23, 2008.
- J. Prymak, E. Reed, R. Hahn, M. Randall, P. Blais, B. Long, “Decoupling Solutions,” CARTS USA 2008 Proceedings, Newport Beach, CA, March 18–20, 2008.
- J. Prymak, M. Randall, P. Blais, B. Long, “Why That 47 μ F Capacitor Drops to 37 μ F, 30 μ F, or Lower,” CARTS USA 2008 Proceedings, Newport Beach, CA, March 18–20, 2008.

- J. Prymak, E. Reed, M. Randall, P. Blais, B. Long, "Decoupling Solutions," PCI (Passive Components Industry) Magazine, pp. 8-13, January-February, 2008.
- M. Randall, T. Kinard, J. Qazi, R. Hahn, P. Lessner, A. Tajuddin, S. Troler-McKinstry, S. Ko, T. Dechakupt, C. Randall, E. Dickey, "Hybrid Dielectric," 13th US-Japan Seminar on Dielectric and Piezoelectric Ceramics, pp. 315-18, Hyogo, Japan, November 4-7, 2007.
- M. Randall, J. Prymak, M. Laps, G. Renner, E. Chen, K. Lai, "D-Pack 3D Interposer Decoupling System", CARTS Asia 2007 Proceedings, Taipei, Taiwan, October 9 – 13, 2007.
- R. Hahn, M. Randall, J. Paulsen, "The Battle for Maximum Volumetric Efficiency – Part 1: When Technologies Compete, Customers Win," CARTS Europe 2007 Proceedings, pp. 63-73, Barcelona, Spain, October 29 – November 1, 2007.
- M. Randall, T. Kinard, J. Qazi, R. Hahn, P. Lessner, S. Troler – McKinstry, S. Ko, S. Lu, T. Dechakupt, C. Randall, E. Dickey, "The Battle for Maximum Volumetric Efficiency – Part 2: Advancements in Solid Electrolyte Capacitors," CARTS Europe 2007 Proceedings, pp. 25-36, Barcelona, Spain, October 29 – November 1, 2007.
- M. Randall, J. Prymak, M. Laps, G. Renner, P. Blais, P. Staubli, A. Tajuddin, "D-Pack 3D Interposer Decoupling System," CARTS Europe 2007 Proceedings, pp. 147-161, Barcelona, Spain, October 29 – November 1, 2007.
- X. Xu, A. Gurav, M. Randall, J. Magee, M. Laps, A. Tajuddin, "BME COG MLCC: The High Capacitance Class - I Solution," CARTS Europe 2007 Proceedings, pp. 277-284, Barcelona, Spain, October 29 – November 1, 2007.
- P. Blais, M. Carter-Berrios, M. Randall, B. Sloka, M. Laps, G. Renner, J. Prymak, A. Tajuddin, "Decoupling Solutions," Automotive Electronics Council, Component Technical Committee Proceedings, May 22-24, 2007.
- X. Xu, P. Pinceloup, A. Gurav, M. Randall, A. Tajuddin, "High Reliability, Thin Layer BME X7R Dielectric with only a Few Core-Shell Grains," Proceedings of the 15th IEEE International Symposium on the Applications of Ferroelectrics, ISAF 2006, pp. 17-20, 2007.
- S. Ko, H. Nagata, E. Hong, S. Troler-McKinstry, C.A. Randall, P. Pinceloup, M. Randall, A. Tajuddin, "Micro-Contact Printed Thin Film Capacitors," IEEE International Symposium on the Applications of Ferroelectrics, Poster, ISAF 006.
- B. Sloka, D. Skamser, R. Philips, A. Hill, M. Laps, R. Grace., J. Prymak, M. Randall, A. Tajuddin, "Flexure Robust Capacitors," CARTS USA 2007, The 27th Symposium for Passive Electronic Components, pp. 125-40, Albuquerque, NM, March, 2007.
- X. Xu, P. Pinceloup, A. Gurav, M. Randall, A. Tajuddin, "High VC BME COG MLCC, CARTS USA 2007, The 27th Symposium for Passive Electronic Components, pp. 179-88, Albuquerque, NM, March 26-29, 2007.
- M. Laps, R. Grace, J. Prymak, X. Xu, P. Pinceloup, A. Gurav, M. Randall, P. Lessner, A. Tajuddin, "Capacitors for Reduced Microphonics and Sound Emission," CARTS USA 2007, The 27th Symposium for Passive Electronic Components, pp. 207-15, Albuquerque, NM, March 26-29, 2007.
- M. Randall, B. Sloka, M. Laps, G. Renner, J. Prymak, P. Blais, A. Tajuddin, "Decoupling Solutions," CARTS USA 2007, The 27th Symposium for Passive Electronic Components, pp. 217-32, Albuquerque, NM, March 26-29, 2007.
- M. Randall, D. Skamser, T. Kinard, J. Qazi, A. Tajuddin, "Thin Film MLCC," CARTS USA 2007, The 27th Symposium for Passive Electronic Components, pp. 403-15, Albuquerque, NM, March 26-29, 2007. This paper won the CARTS USA 2008 John D. Moynihan Award for Best Paper at the 2007 CARTS USA symposium.
- H. Nagata, S. Ko, E. Hong, C. Randall, S. Troler-McKinstry, P. Pinceloup, D. Skamser, M. Randall, A. Tajuddin, "Micro-Contact Printed BaTiO₃ and LaNiO₃ Thin Films for Capacitors," J. Am. Ceram. Soc., 89, [9], pp. 2816-2821, 2006.
- M. Randall, "Piezoelectric Materials," Invited talk, Michelin Americas Research Center (MARC), May 22, 2006.
- P. Pinceloup, M. Randall, A Gurav, "BME-COG MLCC with Ni Electrodes and the Role of Mn in CaZrO₃-Based Dielectric," CARTS US 26th Symposium for Passive Electronic Components, Orlando FL, pp. 459-66, 2006.
- M. Randall, P. Blais, J. Prymak, M. Prevallet, D. Skamser, A. Gurav, P. Pinceloup, X. Xu, A. Tajuddin, P. Lessner, T. Ashburn, "Capacitor Considerations for Power Management," CARTS US 26th Symposium for Passive Electronic Components, Orlando FL, pp. 97-111, 2006.

- Y. Fang, M. Lanagan, D. Agrawal, G. Yang, C. Randall, T. Shrout, A. Henderson, M. Randall, A. Tajuddin, "An Investigation Demonstrating the Feasibility of Microwave Sintering of Base-Metal-Electrode Multilayer Capacitors," *Journal of Electroceramics*, 15, pp. 13-19, 2005.
- H. Nagata, S. Ko, S. Trolrier-McKinstry, C. Randall, P. Pinceloup, J. Beeson, D. Skamser, M. Randall, A. Tajuddin, "Microcontact Printed Thin Film Capacitors," 12th US Japan Seminar on Dielectric and Piezoelectric Ceramics Nov. 6-9, Annapolis, MD, pp. 297-300, 2005.
- P. Pinceloup, A. Gurav, M. Randall, "Effect of Manganese Distribution on Properties of CaZrO₃ - Based Ceramics," 12th US Japan Seminar on Dielectric and Piezoelectric Ceramics Nov. 6-9, Annapolis, MD, pp. 293-296, 2005.
- M. Prevallet, S. Bagdy, J. Prymak, M. Randall, "High Voltage Considerations with MLCCs," IEEE International Power Modulator Symposium and High Voltage Workshop, San Francisco, (2004).
- L. Mann, M. Randall, D. Barber, P. Pinceloupe, J. Beeson, G. Yang, C. Randall, "Is Core-Shell Grain Structure Required for Reliable, High VE, B-Type, BME MLCC?" 11th US-Japan Seminar on Dielectric and Piezoelectric Ceramics, Sapporo, Japan, (9-12, 2003).
- M. Randall, "High Volumetric Efficiency MLCC," Plenary Lecture, 11th US-Japan Seminar on Dielectric and Piezoelectric Ceramics," Sapporo, Japan, (September 9-12, 2003).
- G. Yang, E. Dickey, C. Randall, M. Randall, "Modulated and Ordered Defect Structures in Electrically Degraded Ni-BaTiO₃ Multilayer Ceramic Capacitors," *J. App. Physics*, 94 (9) 5990-5996.
- Y. Fang, H. Peng, D. Agrawal, M. Lanagan, M. Randall, "Rapid Sintering of Base-Metal-Electrode Multilayer Capacitors Using Microwave Technology," *Sintering 2003: An International Conference on the Science, Technology and Applications of Sintering*, Session 9, Electronics and Technical Ceramics, Session Chair T. Kimura, Penn State University, (September 15-17, 2003).
- Y. Fang, D. Agrawal, M. Lanagan, T. Shrout, C. Randall, M. Randall, A. Henderson, "Microwave Cofiring of Base Metal Electrode Capacitors." *Ceramic Transactions*, Vol. 150, Ceramic Materials and Multilayer Electronic Devices, pp. 359-366, Editors: K.M. Nair, A.S. Bhalla, S.-I. Hirano, D. Suvorov, W. Zhu, R. Schwartz, pp. 359-366 (2004), The American Ceramic Society, 2003.
- Y. Fang, H. Peng, D. Agrawal, M. Lanagan, M. Randall, "Microwave Cofiring of Base-Metal-Electroded Ceramic Capacitors," ACerS 105th Annual Meeting and Exposition, Nashville, TN, AM-S19-49-2003, (April 27-30, 2003).
- M. Randall, A. Gurav, L. Mann, J. Beeson, "Thin Layer BME MLCC Technology," Invited talk, ACerS (The American Ceramic Society) 105th Annual Meeting and Exposition, Nashville, TN, AM-S19-96-2003, (April 27-30, 2003).
- M. Randall, A. Gurav, D. Skamser, J. Beeson, "Lifetime Modeling of Sub 2 Micron Dielectric Thickness BME MLCC, CARTS 2003," pp. 134-140, (March 31-April 3, 2003).
- M. Randall, "Multilayer Capacitor Materials and Devices," Invited talk, the 27th Annual Cocoa Beach Conference and Exposition on Advanced Ceramics and Composites (Held in conjunction with the Electronics Division of the American Ceramic Society), ECD-S3-39-2003, (January 26-31, 2003).
- M. Randall, "Precious and Base Metal Powders: Application in the Manufacture of Multilayer Ceramic Capacitors," Invited talk, Clarkson Center for Advanced Materials Processing (CAMP) Meeting, Saratoga Springs, NY, (May 13-15, 2002).
- M. Randall, "High Volumetric Efficiency MLCC Components," Invited talk, Penn State University Center for Dielectric Studies (CDS), State College, PA, (April 22-23, 2002).
- Gurav, M. Randall, L. Mann, "Selection of Nickel Powders for Base Metal Electrodes in MLCC," CARTS 2002, St. Petersburg, FL, pp. 81-88, (March 25-29, 2002).
- L. Mann, J. Beeson, M. Randall, J. Paulsen, E. Reed, "Reliability of Base Metal Electrode Multilayer Ceramic Capacitors," The tenth US-Japan Seminar on Dielectric and Piezoelectric Ceramics, Providence, RI, pp. 39-42, (September 26-29, 2001).
- M. Randall, "A Case for Integrated MLCCs: The Effect of Design Factors on Maximum Capacitance and Volumetric Efficiency," CARTS 2000, Huntington Beach, CA, pp. 195-203, (March 6-10, 2000).
- K. McVicker, G. Gunter, B. Fu, G., Sabo, M. Randall, "Organic Systems for Base Metal Multilayer Ceramic Capacitors," CARTS 2000, Huntington Beach, CA, pp. 116-119, (March 6-10, 2000).

- U. Kumar, G. Gunter, M. Randall, "Low Temperature Firing Platable Silver Termination for Capacitors," CARTS 2000, Huntington Beach, CA, pp. 234-239, (March 6-10, 2000).
- L. Chai, M. Randall, S. Turvey, "Ferro LTCC Systems for Wireless Packaging Applications," IWPC Wireless Symposium/Portable by Design Conference & Exhibition at PCS'99, New Orleans, LA, (Sept. 21-24, 1999).
- L. Chai, M. Randall, "Novel Manufacturing Techniques in LTCC Technology," IMAPS, Chicago-Milwaukee Meeting, (April 28, 1999).
- S. Turvey, M. Randall, "Ferro LTCC Systems—An Update," IWPC Joint International Conference, Vancouver, Canada, (Feb. 21-23, 1999).
- M. Randall, S. Turvey, "Low Temperature Cofired Ceramic Tape Systems in Sensor Applications," IMAPS Advanced Technology Workshop on Sensor Packaging, Ojai, CA, (Jan. 26-28, 1998).
- U. Kumar, J. Hock, B. Rawal, M. Randall, "Dielectric Properties of PMN Based Ceramic Under D.C. and A.C. Fields," The Eighth US-Japan Seminar on Dielectric and Piezoelectric Ceramics, Plymouth, MA, pp. 193-196, (October 15-18, 1997).
- U. Kumar, H. Pak, B. Rawal, M. Randall, "High Capacitance Value Multilayer Ceramic Capacitors from PMN Based Dielectrics," CARTS 97: 17th Capacitor and Resistor Technology Symposium, pp. 286-291, (March 24-27, 1997).
- U. Kumar, M. Randall, A. Ritter, "Actuator Miniaturization," Invited Paper, Symposium on Micro-Integrated Smart Materials and Structures, Society for Experimental Mechanics, Williamsburg, VA, (Oct. 11-12, 1995).
- U. Kumar, M. Randall, J. Hock, A. Ritter, "Reliability Studies on Electrostrictive Actuators," Journal of Intelligent Material Systems and Structures, Vol. 5, No. 6, pp. 802-809, (1994).
- M. S. Randall, "Low-Loss Cofirable Ceramic Materials for High Frequency Applications," presented at KII 5 (Kyocera International Incorporated Annual Technical Conference), Vancouver, WA, (May 13-14, 1994).
- M. S. Randall, "Optimization of Actuator Burnout: Application of Controlled Rate of Weight Loss Thermal Treatment Schedules," KII 4 (Kyocera International Incorporated Technical Conference), Myrtle Beach, SC, (April 16-17, 1993).
- M. D. Sacks, M. S. Randall, G. W. Scheiffele, R. Raghunathan, J. H. Simmons, "Processing of Silicate Glass/Silicon Nitride Composites with Controlled Microporosity," Ceramic Transactions, 19, The American Ceramic Society, Inc., Westerville, OH, pp. 407-420, (1991).
- M. S. Randall, M. D. Sacks, J. H. Simmons, "Processing of Borosilicate Glass/Silicon Nitride Composites Containing Controlled Porosity," presented at the Second International Ceramic Science and Technology Congress and Electronics Division Meeting, American Ceramic Society, Orlando, FL, (Nov. 12-15, 1990).
- M. S. Randall, J. H. Simmons, O. H. El-Bayoumi, "Primary and Secondary Phase Separation in CdF₂-LiF-AlF₃-PbF₂ Glasses," J. Am. Cer. Soc., 71, [12], pp. 1134-41, (1988).
- M. S. Randall, C. J. Simmons, "Crystallization from Liquid-Liquid Immiscibility in Mixed Cadmium-Lead Fluoride Glasses," presented at the ACerS Annual Glass Division Meeting, Bedford, PA, (Sept. 30-Oct. 2, 1987).
- M. S. Randall, J. H. Simmons, "Primary and Secondary Phase Separation in Mixed Cadmium Lead Fluoride Glasses," presented at the ACerS Annual Glass Division Meeting, Bedford, PA, (Sept. 30-Oct. 2, 1987).
- More than 25 Technical Posts for Venkel, Ltd. "The Circuit: A Blog for Engineers," covering the subjects of Capacitors, Ceramic Capacitors, High Voltage Capacitors, Decoupling, ESR, Resistors, MELF Resistors, Inductors, Light Emitting Diodes, Tin Whiskers, Surface Mounting of Chip Components, etc.

PATENTS:

- 6,162,849, "Thermally Conductive Thermoplastic," Q. Zhuo, R. M. Harris, D.C. Skovran, L.F. Lightner, M.S. Randall, V. E. Stygar.
- 6,906,907, "Monolithic Multi-Layer Capacitor with Improved Lead-Out Structure," J. D. Prymak, M.S. Randall.
- 7,054,137, "Refractory Metal Nickel Electrodes for Capacitors," D.E. Barber, A. Wang, M.S. Randall, A. Tajuddin.
- 7,211,740, "Valve Metal Electromagnetic Interference Filter," M.S. Randall.
- 7,277,269, "Refractory Metal Nickel Electrodes for Capacitors," D.E. Barber, A. Wang, M.S. Randall, A. Tajuddin.
- 7,280,342, "Low Inductance, High ESR Capacitor," M.S. Randall, A. Hill, P. Blais, G. Renner, R. Vaughan, A. Tajuddin.
- 7,292,429, "Low Inductance Capacitor," M.S. Randall, J. Prymak, A. Tajuddin.

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- 7,545,623 and WO2008067300, "Interposer Decoupling Array Having Reduced Electrical Shorts," M. Randall, G. Renner.
- 7,670,981 and CN101456731, "COG multi-layered ceramic capacitor," M.S. Randall, C. Antoniadis, D.E. Barber, X. Xu, J. Beeson, P. Pinceloup, A. Gurav, T. Poole, A. Tajuddin, I. Burn.
- 7,916,451 and CN101456731, "COG multi-layered ceramic capacitor," M.S. Randall, C. Antoniadis, D.E. Barber, X. Xu, J. Beeson, P. Pinceloup, A. Gurav, T. Poole, A. Tajuddin, I. Burn.
- 7,923,395 and CN101456731, "COG multi-layered ceramic capacitor," M.S. Randall, C. Antoniadis, D.E. Barber, X. Xu, J. Beeson, P. Pinceloup, A. Gurav, T. Poole, A. Tajuddin, I. Burn.
- 7,958,627, "Method of attaching an electronic device to an MLCC having a curved surface," M.S. Randall, C. Wayne, J. McConnell.
- 8,111,524 and CN101632173, "Electronic Passive Device," M. Randall, G. Renner, J. Prymak, A. Tajuddin.
- 8,293,323 "Thin Metal Film Conductors and Their Manufacture," S. Troler-McKinstry, C.A. Randall, S.W. Ho, M.S. Randall.
- 8,414,962, "Microcontact Printed Thin Film Capacitors," S. Troler-McKinstry, C.A. Randall, H. Nagata, P. I. Pinceloupe, J.J. Beeson, D.J. Skamser, M.S. Randall, A. Tajuddin.
- 8,717,774, "Electronic Passive Device," M.S. Randall, G. Renner, J.D. Prymak, A. Tajuddin.
- 8,828,480, "Microcontact Printed Thin Film Capacitors," S. Troler-McKinstry, C.A. Randall, H. Nagata, P. I. Pinceloup, J.J. Beeson, D.J. Skamser, M.S. Randall, A. Tajuddin.
- 8,895,940, "Switch Sanitizing Device," J. Moskowitz, M. Randall.
- 8,910,356, "Method of attaching an electronic device to an MLCC having a curved surface," M.S. Randall, C. Wayne, J. McConnell.
- 10,231,581, "Touch point area disposable contamination barrier dispensing device," J. Moskowitz, M. Randall.

SESSION CHAIR:

- Workshop Facilitator for the High Volume MLCC Components Session of the Spring 2002 Meeting of the Center for Dielectric Studies, State College, PA, April 23-24, 2002.
- Session Chair for the Microwave and LTCC Materials Session of the 27th Annual Cocoa Beach Conference and Exposition on Advanced Ceramics and Composites, Cocoa Beach, FL, January 26-31, 2003.
- Session Chair for the BME Session of the Spring, 2003 Meeting of the Center for Dielectric Studies, State College, PA, April 24-25, 2003.
- Panel Leader for Face to Face Health Information Technology Breakout Panel, November, 2013.

COMMUNITY SERVICE:

- United Way
 - Executive Director, KEMET Corporate Campaign: Team raised over \$250K, a new record for KEMET
 - Assistant Director, KEMET Corporate Campaign
 - Member Palmetto Society
- CROP WALK
 - Manager for Eastminster Presbyterian Church
 - Team secured Pledges in Excess of \$250K
 - Board Member, CROP Walk Greenville, SC
 - CROPWALK Participant
- Eastminster Presbyterian Church, Elder and Stewardship Committee
 - Team secured ~\$1M in Pledges
- Golden Strip YMCA, Board of Directors, Property Team Director
 - Hollingsworth property development plan and approval
 - Golden Strip YMCA Improvement Plan, author and champion
 - Golden Strip YMCA, Board of Directors
- Habitat for Humanity, Habitat Partner's Council

August, 2024

- Trees for the Future donor (providing funding to enable the planting of >500,000 trees)
- FLL: First Lego League team captain for Sterling School (Charles Townes Center)
- Junior Achievement Instructor (JA Economics, JA Interpersonal Skills, JA Our World Economics, JA Business Structure, JA Our Cities)
- Blood Donor, 3 Galloneer

PERSONAL:

- Married (Dr. Sara Pittman Elder Randall, Ph.D. Metallurgy, University of Florida, 1990)
- Two children
- U.S. Citizen with active passport

REFERENCES: Available upon request