

Attorney Docket No. 2189.006

Patent 10,329,653

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:
Doud, et al.

Attorney Docket No.
2189.006

U.S. Patent. No.: 10,329,653

Issued: June 25, 2019

Assignee: Terves, LLC

Mail Stop Ex Parte Reexam
Central Reexamination Unit Commissioner for Patents
United States Patent and Trademark Office P.O. Box 1450
Alexandria, VA 22313-1450

**DECLARATION OF DANA J. MEDLIN, PH.D., P.E., FASM UNDER 37 C.F.R. § 1.68 IN
SUPPORT OF REQUEST FOR *EX PARTE* REEXAMINATION OF U.S. PATENT NO.
10,329,653**

I. INTRODUCTION AND SUMMARY OF OPINIONS

1. My name is Dana J. Medlin. I submit this declaration on behalf of Petitioner Ecometal, Inc., which I understand is challenging the validity of claims 1–5, 7–9, 11–16, 18–21, 23–50, 52–62, 64, 66, 67, and 69–76 (Challenged Claims) of U.S. Patent No. 10,329,653 (the ‘653 patent/‘653 Patent) in a request for *ex parte* reexamination before the United States Patent and Trademark Office.

2. I have been asked to provide an opinion on the validity of the Challenged Claims. I previously submitted a substantially similar declaration in an *inter partes* review proceeding, IPR2020-1620, challenging the validity of some of the Challenged Claims. While my analysis there and here does not address every single one of the Challenged Claims, my analysis, below, covers each limitation of all of the Challenged Claims.

3. My opinions are based, at least in part, on the following references, as well as my understanding as to the general knowledge of a person of skill in the art at the time of the provisional application (i.e. April 18, 2014) to which the ‘653 Patent claims priority:

<u>REFERENCE</u>	<u>DATE OF PUBLIC AVAILABILITY</u>
A Certified English Language Translation of the Chinese Pat. Pub. No. CN 103343271 (Xiao) (Xiao)	October 9, 2013
Hassan, S.F., Gupta, M. Development of high strength magnesium based composites using elemental nickel particulates as reinforcement. <i>Journal of Materials Science</i> 37, 2467–2474 (2002). (Hassan)	June 2002

4. As detailed below, I conclude that the Challenged Claims are either anticipated by Xiao and/or obvious over the combination of Xiao and Hassan.

5. With respect to the Challenged Claims, and as I discuss further in the following three paragraphs, each of the claims appears to be a reorganization of several basic claim limitations.

6. In particular, each of the Challenged Claims of the '653 patent claim a magnesium [alloy] composite¹ that includes *in situ* precipitates of galvanically-active intermetallic phase(s)/particle(s) that allegedly enable "controlled dissolution"² of the magnesium [alloy] composite³ -- i.e., at "a dissolution rate of at least⁴ 5 mg/cm²/hr. in 3 wt.% KCl water mixture at 90°C."⁵

7. In each of the Challenged Claims, the magnesium [alloy] composite comprises:

A. magnesium (Mg) or a magnesium alloy; and

B. an "additive material"⁶ or "secondary metal."⁷

With respect to this "B" limitation, I collectively consider it an "added metal" limitation because in all of the Challenged Claims reciting an "additive material" each claim further requires that the

¹ Challenged Claims **25** (bolded claim numbers indicate an independent claim), **29**, **33**, **37**, **41**, **45**, **70**, **73** and **74** explicitly note that the magnesium [alloy] composite is for use in oil well drilling tool components (e.g. frac balls).

² The claimed property of "controlled dissolution" is also referred to in some Challenged Claims as "corrosion."

³ For example, this limitation, in particular, is represented by the language "in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite" in Challenged Claims **1**, **4**, **5**, **7**, **8**, **11**, **12**, **13**, **49**, **55**, **69**, **70**, **71**, **73** and **74** and by the language "a secondary metal to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite" in Challenged Claims **25**, **29**, **33**, **37**, **41**, **43**, and **45**. Challenged Claim **1** also explicitly states the "additive material forming precipitant in said magnesium composite."

⁴ Challenged Claims **49** and **73** actually recite "at least at least [sic] 5 mg/cm²/hr." which I have interpreted to mean simply "at least 5 mg/cm²/hr."

⁵ Instead of "at least 5 mg/cm²/hr.," the value recited in Challenged Claim **74** is "84-325 mg/cm²/hr" using the same KCl water mixture at 90°C.

⁶ Challenged Claims **1**, **4**, **5**, **7**, **8**, **11**, **12**, **13**, **49**, **55**, **69**, **70**, **71**, **73**, and **74**.

⁷ Challenged Claims **25**, **29**, **33**, **37**, **41**, **43**, and **45**.

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“additive material includes one or more metals selected from the group consisting of” copper, nickel, and cobalt. In most of the Challenged Claims iron is part of the “one or more metals,” in some claims titanium is included, and in one claim silicon is included.⁸ The Challenged Claims reciting the “secondary metal” similarly require that the “secondary metal [includes] one or more metals selected from the group consisting of copper, nickel, [and] cobalt” with Challenged Claims 25, 29, 33, and 37 also reciting “titanium and iron” among their group’s members.

8. The claimed magnesium [alloy] composites contain the following explicit weight percentage composition limitations for the:

- magnesium
 - “[greater than/over] 50wt%”
 - “at least 85 wt%”
 - “60-95 wt%”
- “added metal”
 - “additive material constituting about 0.05 wt.%-45 wt.% of” the mixture/composite
 - “additive material includes...said [additive material] constitutes about 0.05 wt.%-35 wt.% of” said magnesium composite
 - “about 0.05-45 wt.% of a secondary metal”
 - “additive material constituting about [0.05/0.1] wt.% of said mixture”⁹
- magnesium alloying elements
 - “one or more metals selected from the group consisting of 0.5-10wt.% aluminum, 0.05-6wt.% zinc, 0.01-3wt.% zirconium, and 0.15-2wt.% manganese
 - “0.01-1wt.% zirconium”
 - “0.5-10wt.% aluminum; 0.05-6wt.% zinc; 0.15-2wt.% manganese”
 - “0.05-6wt.% zinc; 0.01-1wt.% zirconium”

⁸ A few of the Challenged Claims also include one or more limitations directed to the melting point of the additive material: “said additive material having a greater melting point temperature than a solidus temperature of said magnesium” (Challenged Claims 1, 12, and 13) and “said additive material having a melting point temperature that is 100°C. greater than a melting temperature of said magnesium or magnesium alloy” (Challenged Claims 12 and 69).

⁹ Challenged Claims 1, 12, 49, 73 and 74 specify that the “mixture” is “a mixture of magnesium or a magnesium alloy and an additive material.”

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- “one or more metals selected from the group consisting of 0.5-10wt.% aluminum, 0.1-2wt.% zinc, 0.01-1wt.% zirconium, and 0.15-2wt.% manganese”
- “one or more metals selected from the group consisting of 0.1-3wt.% zinc, 0.01-1wt.% zirconium, 0.05-1wt.% manganese, 0.0002-0.04wt.% boron, and 0.4-0.7wt.% bismuth”

Some of the Challenged Claims expressly require that some of the additive material (or a portion of the additive material¹⁰) remains unalloyed and this unalloyed material “forms [the] galvanically-active in situ precipitate in said magnesium composite.”¹¹ The Challenged Claims (73 and 74) allege that the galvanically-active in situ precipitate provides the claimed improved dissolution/corrosion properties of the magnesium [alloy] composite. Two of the Challenged Claims (49 and 73) explicitly attribute the alleged improved dissolution/corrosion properties of the composition to the “additive material located in sufficient quantities in said galvanically-active intermetallic phases so as to obtain a composition and morphology of said galvanically-active intermetallic phases such that a galvanic corrosion rate along said galvanically-active intermetallic phases.”

9. With respect to my opinion that certain Challenged Claims are obvious over the combination of Xiao in view of Hassan, I believe that it would have been obvious for a person having ordinary skill in the art in April 2014 to combine the described and disclosed alloying mixtures, melting practices, and thermal-mechanical processing techniques described by Hassan

¹⁰ For example, Challenged Claims 4 and 43 require “wherein said [additive material/secondary metal] includes nickel, . . . said nickel forms galvanically-active in situ precipitate in said magnesium composite.” Challenged Claim 3 presents similarly with copper.

¹¹ “. . . at least a portion of said additive material remaining *unalloyed additive material*, said magnesium composite including in situ precipitation of *galvanically-active intermetallic phases that includes said unalloyed additive material*” (Challenged Claim 12 (emphasis added); see also Challenged Claim 71); “said additive material located in sufficient quantities in said galvanically-active intermetallic phases so as to obtain a composition and morphology of said galvanically-active intermetallic phases such that a galvanic corrosion rate along said galvanically-active intermetallic phases causes [the claimed dissolution rate]” (Challenged Claim 49).

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and the similar alloying mixtures, melting practices, and thermal-mechanical processing techniques described and disclosed by Xiao to form galvanically-active particles in a magnesium alloy for enhanced dissolution by controlled corrosion processes.

II. QUALIFICATION AND BACKGROUND

10. I have over 30 years of experience leading multidisciplinary failure analysis and design projects in metallurgical and materials science engineering, corrosion engineering, materials joining and welding, and biomedical engineering for a variety of companies and firms. My qualifications are detailed in my *curriculum vitae*, attached hereto as Ex. A.

11. In 1988, I earned a B.S. in Mechanical Engineering (Metallurgy Option) from the University of Nebraska at Lincoln. In 1990, I received an M.S. in Mechanical Engineering (Metallurgy Option) from University of Nebraska at Lincoln. In 1993, I earned a Ph.D. in Materials Science Engineering by the University of Nebraska at Lincoln. My doctoral dissertation was entitled "Metallurgical Phase Transformations in the Case Layer of a Carburized Bearing Steel Due to Rolling Contact Fatigue."

12. From 1993 to 1997, I served as a Research Assistant Professor at the Colorado School of Mines, in Golden, Colorado, where I conducted research, taught graduate and undergraduate courses in metallurgical and materials science engineering, supervised and managed graduate and undergraduate student research projects, presented and published technical research results, and conducted failure analysis, engineering design and maintenance metallurgy for several companies and firms.

13. From 1997 to 1998, I worked as a Materials Specialist and Supervisor of the Analytical Services Group at LTV Steel Company, a producer of flat-rolled and coated sheet steels. In that capacity, I supervised personnel and analytical research equipment including a complete

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metallurgical laboratory, two scanning electron microscopes, FTIR, x-ray diffraction, laser surface profilometer, numerous hardness testers, and corrosion testing. I also evaluated metallurgy quality problems with sheet steel and coatings, conducted mechanical property and fatigue evaluations, performed corrosion testing and failure analysis.

14. From 1998 to 2000, I was a Specialist and Principal Engineer for the Timken Company, an alloy steel and bearing manufacturing company. In those roles, I participated in the microstructural design of debris resistant bearings and heat treatment processing, performed basic static and dynamic mechanical testing on standard test samples and prototype components, managed all metallurgical and heat-treat quality issues, supervised validations and documentation for production derivatives, and recommended potential design options. I was also involved with failure analysis of returned products and issues involving potential product liability litigation.

15. From 2000 to 2005, I was the Global Metallurgy and Materials Leader and Principal Engineer for Zimmer, Inc., a manufacturer of orthopedic, spinal, and dental medical devices. I coordinated materials research efforts between branches of the company, including eliminating research redundancies, resolving systemic manufacturing issues, prioritizing research projects, and developing best practice recommendations. I was the team leader and obtained three patents in developing a process for metallurgically attaching trabecular metal (tantalum foam) to titanium substrates. I was a key member of the project team that was responsible for metallurgically attaching trabecular metal coating to new products. I managed the corrosion laboratory, where I performed and directed corrosion tests and analysis including long-term immersion testing and potentiodynamic anodic polarization (PAP) testing. I was also the project manager for the development of a surface carburization heat treatment for austenitic stainless-steel trauma products. Further, I designed test protocols for new product static and dynamic testing, including

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bending fatigue, uniaxial fatigue, shear, tensile, fracture toughness, coating adhesion, corrosion testing, residual stress, chemical analysis, and microstructural characterization.

16. From 2005 to 2011, I was the NUCOR Professor of Metallurgy at the South Dakota School of Mines and Technology. In that capacity, I taught graduate and undergraduate courses in materials and metallurgical engineering and developed a research program in physical and mechanical metallurgy. From 2010 to 2011, served as the Director of the Biomedical Engineering Graduate Program.

17. Also from 2005 to 2011, I formed Medlin Engineering Services and served as a private engineering consultant, where I conducted forensic engineering investigations, failure analysis, undertook engineering design, and maintenance metallurgical engineering problems for several companies and firms.

18. From 2011 to 2015, I was a senior managing consultant for Engineering Systems, Inc., a consulting engineering and investigation company in Omaha, Nebraska. I conducted forensic engineering investigations, failure analysis, engineering design, and provided expert testimony and maintenance metallurgical engineering problem solving for a number of companies and firms.

19. Also, from 2011 to 2015, I served as an adjunct professor at the South Dakota School of Mines and Technology where I provided graduate student guidance and served as a graduate student committee member and an advisor in the Metallurgical Engineering and Biomedical Engineering program.

20. From 2015 to May 2021, I was a senior managing consultant for EAG Laboratories, where I have conducted engineering investigations, failure analysis, engineering design, expert testimony and maintenance metallurgical engineering problem solving, and served as a technical

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expert in litigation involving failure analysis, materials and metallurgical engineering, biomedical engineering, corrosion engineering, design and safety issues, and manufacturing problems. In June 2021 I became the Vice President for EAG Laboratories where I continue to conduct engineering investigations, failure analysis, engineering design, expert testimony and maintenance metallurgical engineering problem solving, and served as a technical expert in litigation involving failure analysis, materials and metallurgical engineering, biomedical engineering, corrosion engineering, design and safety issues, and manufacturing problems. In addition, I also have responsibility for managing the failure analysis business and personnel aspects for the company.

21. From 2019 to May 2021, I was the Kielhorn Professor in the Department of Materials Joining & Welding Engineering at LeTourneau University in Longview, Texas. In that role, I taught graduate and undergraduate courses in materials and metallurgical engineering, materials and joining welding engineering, as well as developed a research program in welding related metallurgy.

22. I have authored or co-authored more than 40 peer-reviewed papers in materials and metallurgical engineering. I have given more than 100 presentations. I am a Licensed Professional Engineer in Ohio, Nebraska, and Texas. I am a member of the American Society for Materials International; Failure Analysis Society, ASM International; International Metallographic Society; American Society for Testing Materials; The Metallurgical Society; the Professional Engineering Examination Board; the Professional Engineering Examination Review Committee; Society for Biomaterials; Society for Automotive Engineers; the Iron & Steel Society; and the National Association of Corrosion Engineers. I have been honored as a Fellow of Alpha Sigma Mu, an International Professional Honor Society for Materials Science and Engineering; awarded tenure

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and professorship at the South Dakota School of Mines & Technology; honored as the NUCOR Professor at the South Dakota School of Mines & Technology; and honored as a fellow of ASM.

23. I am a named inventor on five U.S. patents and two U.S. patent applications. Those patents and patent applications are listed in my attached C.V.

III. UNDERSTANDING OF PATENT LAW

24. I am not an attorney. I have been provided with an understanding of the patent law relevant to conducting the analysis given in this report. The following represents a summary of my understanding of these issues.

25. I understand the patent-at-issue is the '653 Patent and that prior art to the '653 Patent includes patents and printed publications in the relevant art that predate the alleged priority date of the '653 Patent, which I have been told to assume is April 18, 2014.

26. I understand that a patent claim is “anticipated,” and thus invalid, if each and every element of that claim is disclosed expressly, implicitly, and/or inherently in a single prior art reference, arranged in the prior art reference as arranged in the claim. I have also been told that even if a reference does not expressly spell out all the limitations arranged or combined as in the claim, the reference may still anticipate the claim if a person having ordinary skill in the art (POSITA), reading the reference, would “at once envisage” the claimed arrangement or combination.

27. With respect to claimed compounds or compositions, I understand that anticipation only requires disclosure of the claimed compound or composition, not its properties or use. In other words, if the claimed composition is identical to a composition disclosed by a prior art reference, it does not matter for purposes of anticipation that the Patentee recognized additional properties of that composition.

28. I also understand that when, as by a recitation of ranges or otherwise, a claim covers several compositions, the claim is anticipated if even just one of them is in the prior art. I have also been told that when the prior art discloses a range of values which touches or overlaps the claimed range, even if no specific examples falling within the claimed range are disclosed in the prior art reference, that reference still anticipates the claim if the claimed subject matter is disclosed in the reference with "sufficient specificity."

29. I further understand for a disclosure to be implicit or inherent it must be a necessary feature or result of an embodiment sufficiently described and enabled in the prior art reference. In other words, that a certain result or characteristic *may occur or be present* in the prior art reference is not enough; that a certain result or characteristic must always occur (or be present) for the result or characteristic to be implicit or inherently disclosed. However, it is not necessary that a POSITA would have recognized that implicit or inherent disclosure at the time of invention.

30. I understand that a patent claim is invalid as "obvious" if the differences between the prior art and the claimed invention are such that they would have been "obvious" to a POSITA before the effective filing date of the claimed invention (i.e., April 18, 2014).

31. I also understand that a patent claim can be obvious in light of a single prior art reference if it would have been obvious to modify that single reference to arrive at the patented invention.

32. I have been further informed that obviousness does not require that a single reference disclose all of the requirements of the claim. Rather, two or more references can be combined if a POSITA would have combined such references.

33. In reaching a conclusion on whether references would have been combined by POSITAs at the time of the invention, I have been informed that I may consider, among other

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things: 1) whether the change was merely the predictable result of using prior art elements according to their own functions; 2) whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; 3) whether the innovation applies unknown technique that had been used to improve a similar device or method in a similar way; and 4) whether the claimed invention would have been obvious to try, meaning that the claimed and innovation was one of a relatively small number of possible approaches to the problem with a reasonable expectation of success by those having ordinary skill in the art.

34. I further understand if a POSITA can implement a predictable variation, obviousness bars its patentability. For the same reason, if a technique has been used to improve one device and a POSITA would recognize that it would improve similar devices in the same way, using the technique is obvious.

35. I understand that a claim may be obvious if common sense directs one to combine multiple prior art references or add missing features to reproduce the alleged invention recited in the claims.

36. Furthermore, I also have been informed that factors, such as a long felt need for the solution provided by the claimed invention, unsuccessful attempts by others to find the solution provided by the claimed invention, unexpected and superior results from the claimed invention, and other evidence tending to show obviousness or nonobviousness, are a consideration.

37. I understand that a POSITA is determined by considering: 1) the education level of the inventor; 2) the type of problems encountered in the art; 3) prior art solutions to these problems; 4) the rapidity with which innovations are made; 5) the sophistication of the technology; and 6) education level of active workers in the field.

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38. Based on these factors and my review of the '653 Patent (as set forth below) I have determined that a POSITA at the time of invention of the '653 Patent (i.e. April 18, 2014), would have had at least a bachelor's degree in metallurgical, materials, or mechanical engineering, or the equivalent, and at least five years of experience in metallurgical and materials engineering, or an equivalent amount of relevant work and/or educational experience.

39. Based on my level of education and experience, I am familiar with the level of knowledge that a POSITA would have possessed at the time of the invention, i.e., April 18, 2014, and by then, I was a POSITA.

IV. DESCRIPTION OF THE TECHNOLOGY AND OVERVIEW OF THE '653 PATENT

40. The '653 Patent ('653 Patent) is entitled "Galvanically-Active in Situ Formed Particles for Controlled Rate Dissolving Tools."

41. The application for the '653 Patent (U.S. Patent Application No. 15/641,439) was filed July 5, 2017. '653 Patent, front page.

42. I understand the '653 Patent is a "division" of the patent application that became U.S. Patent No. 9,903,010, which was filed on April 17, 2015. '653 Patent, second page.

43. I also understand that the '653 Patent relates to U.S. Provisional Patent Application No. 61/981,425, filed on April 18, 2014. '653 Patent, second page.

44. Therefore, I have been told that the '653 Patent has a "priority date" of April 18, 2014.

45. In its "Background of the Invention," the '653 Patent notes that the "ability to control the dissolution of a down hole [oil] well component in a variety of solutions is very important to the utilization of non-drillable completion tools, such as sleeves, frac balls, hydraulic

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actuating tooling, and the like.” ‘653 Patent at 1:16–21. And that “[r]eactive materials for this application, which dissolve or corrode when exposed to acid, salt, and/or other wellbore conditions, have been proposed for some time. Generally, these components consist of materials that are engineered to dissolve or corrode.” *Id.* at 1:21–26.

46. The ‘653 Patent continues on to describe alleged problems with the prior art, as follows:

While the prior art well drill components have enjoyed modest success in reducing well completion costs, their consistency and ability to specifically control dissolution rates in specific solutions, as well as other drawbacks such as limited strength and poor reliability, have impacted their ubiquitous adoption.

‘653 Patent at 1:31–36.

47. The ‘653 Patent then provides an overall direction of its solution to these alleged problems noting that:

Ideally, these components would be manufactured by a process that is low cost, scalable, and produces a controlled corrosion rate having similar or increased strength as compared to traditional engineering alloys such as aluminum, magnesium, and iron.

‘653 Patent at 1:36–40.

A. Basic Knowledge of a POSITA in April 2014

48. Having read the ‘653 Patent and the references discussed below, I believe the following information is useful to explain what certain disclosures would have meant to a POSITA (with respect to the subject matter of this patent in April 2014) and how a POSITA would have understood the terminology and basic chemical/materials/metallurgical scientific concepts underlying the ‘653 Patent and the references relied on below:

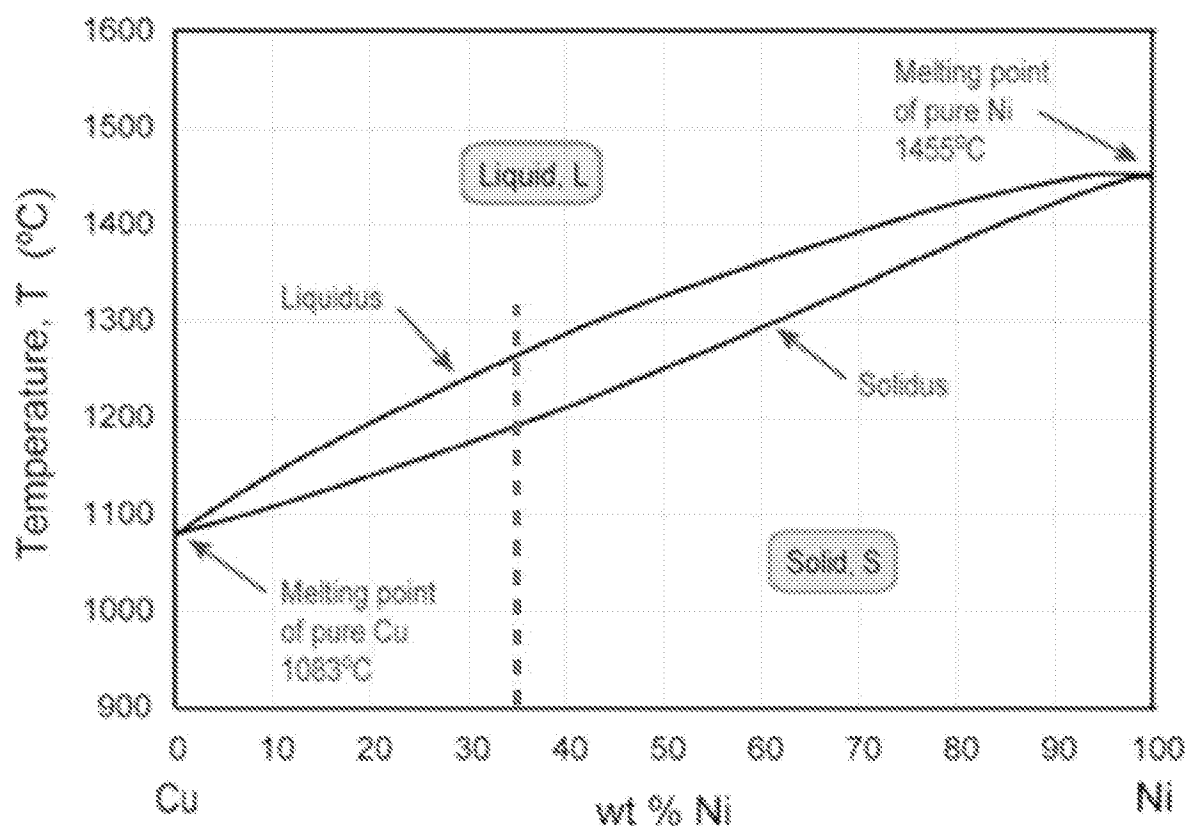
49. A POSTIA would have understood in April 2014, that an “alloy” is a metal made by combining two or more metallic elements (e.g., combinations of Au (gold) and Ag (silver)).

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The physical properties of an alloy are determined in great part by the phases present, and those phases depend on the alloy composition and the thermal and mechanical treatment to which the alloy has been exposed.

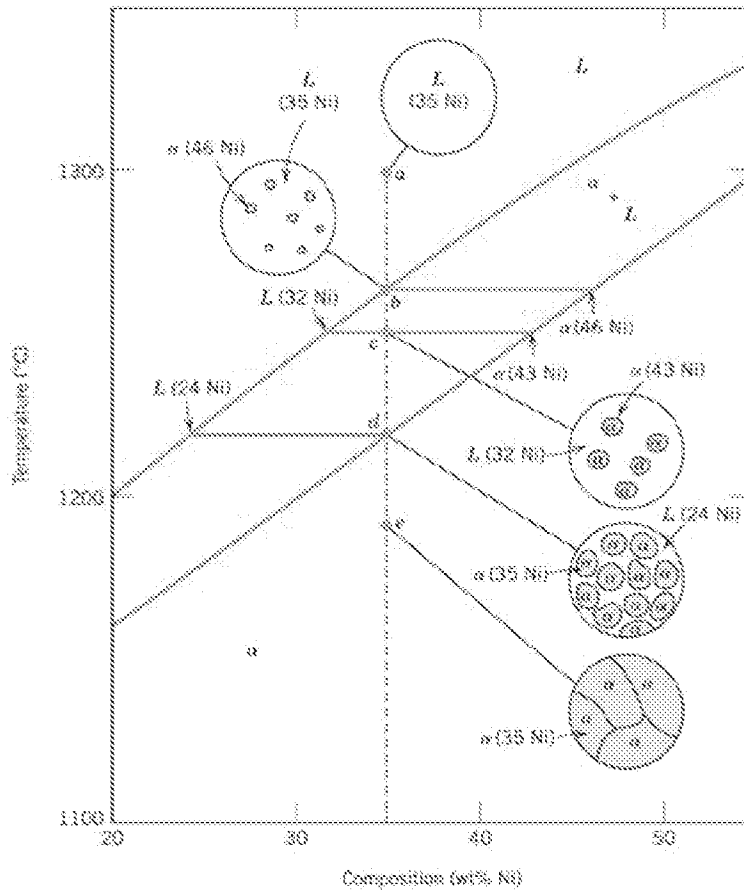
50. A POSITA in (and well-before) April 2014 would have routinely referenced “phase diagrams” to reliably predict under what conditions phase changes will occur in an alloy system, even the brief description of FIG. 4 in the ‘653 Patent acknowledged that phase diagrams are “typical.” ‘653 Patent at 15:49. In particular, a “phase diagram” is a graphical representation of the phases present in a particular alloy determined by experimental observations under selected conditions of temperature, pressure, and composition when the system is in thermodynamic equilibrium, and thus provides fundamental physical information about the equilibrium microstructures present in the alloy. Within an alloy system, POSITAs would have understood in (and well-before) April 2014 that one, two, or more different phases can be present at the same time. In a simple two-component, or binary system, where the components have total solubility in each other, the components form a single “solid solution.” For these systems, the phase diagram is especially simple, since only one phase exists in the solid state.

51. The following graph (taken from “Teach Yourself Phase Diagrams and Phase Transformations” Professor Mike Ashby, 5th Edition, March 2009 Cambridge) is an illustrative phase diagram for copper-nickel (aka cupronickel) alloys that vary in only two dimensions: temperature and alloy composition. With respect to the alloy composition, the x-axis begins at the left with pure copper (Cu) and ends on the right with pure nickel (Ni). This illustrative phase diagram for Cu-Ni shows three phases: liquid, solid, and slurry (i.e., a mixture of solid and liquid).

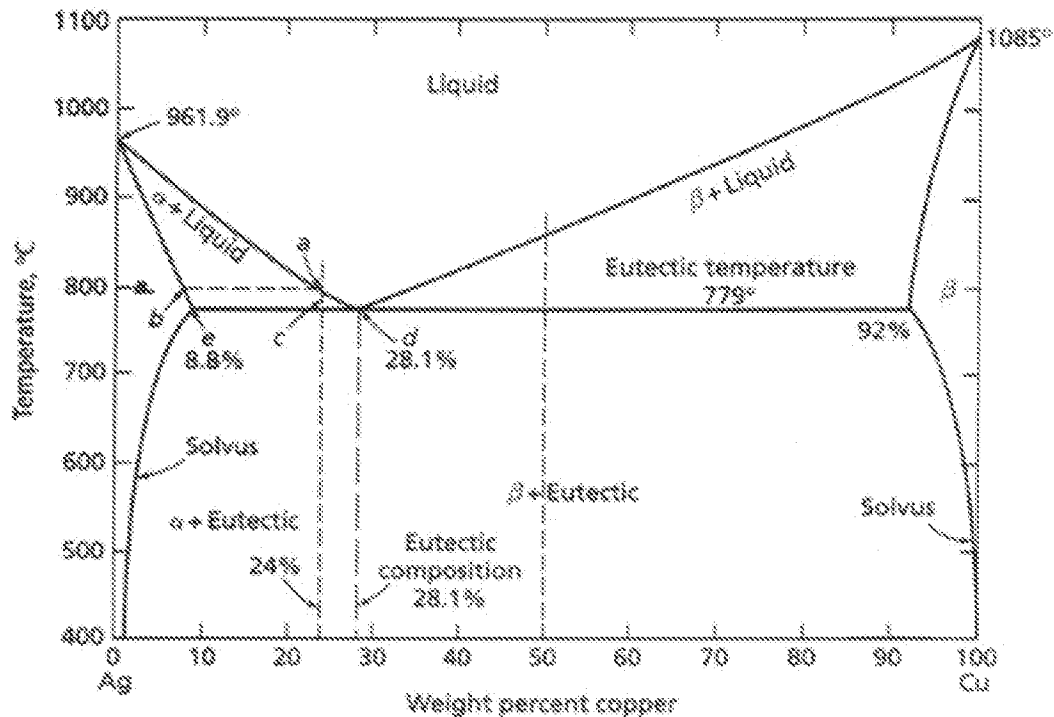


Above the “Liquidus” curve in a phase diagram, all of the alloy is in the molten or liquid phase or state. Below the “Solidus” curve in a phase diagram, all of the alloy is in the solid phase or state. (The liquid state is also sometimes referred to by POSITAs as being a “melt” and the process of changing from a solid state into a liquid state is referred to by POSITAs as “melting.”) For example, based on this phase diagram a POSITA in (and well-before) April 2014 would have understood that a mixture of 35 wt% Ni and 65 wt% Cu at 1300°C is entirely liquid at equilibrium, even though Ni by itself does not melt until 1455°C. The POSITAs would have similarly understood if 35 kg of solid Ni at 1300°C is added to 65 kg of molten Cu at 1300°C, the 35 kg of nickel will dissolve over a period of time into the already melted Cu forming a homogeneous mixture (once equilibrium is reached) even though the Ni added was not in a molten state.

52. An illustrated portion of the Cu-Ni phase diagram (below) (taken from “Materials Science and Engineering, 6th Edition by Callister and Rethwisch, 2003) shows only a limited range of Ni from 20% to 55%. If the same 35/65 wt% mixture is then cooled from 1300 °C to about 1240°C, a portion of the mixture begins to precipitate out of “the melt.” As would have been understood by a POSITA using this phase diagram, the initial precipitate formed contains about 46 wt% Ni (i.e., the point where the solidus curve intersects a horizontal line from the (35% Ni, 1240°C) position on the diagram). Upon further cooling, the composition of material solidifying follows the solidus curve, depleting the melt of nickel (i.e. the liquid phase will contain less nickel while the solid phase contains more nickel). Between 1240°C and about 1215°C, the material is a mixture of molten and solid alloy, and below the solidus curve, the alloy is completely solid.



53. A POSITA in (and well-before) April 2014, would have understood that in a phase diagram for a system having components only partially soluble in the solid state, two solid phases will co-exist, making the phase diagram more complex. One special case of this type of system is called eutectic. “Eutectic” means that when the two components are mixed, the melting point is lower than the melting temperatures of the two components separately. An illustrative example of a eutectic phase diagram is the Ag-Cu binary phase diagram (taken from Taylor, Shannon submitted to the Dept. of Materials Science and Engineering in partial fulfillment of the Requirements for the Degree of B.S. at the Massachusetts Institute of Technology (June 2013), citing McGraw-Hill Book Co. Inc. 1958 *Constitution of Binary Alloys*, Hansen, M. and K. Anderko) is shown below:

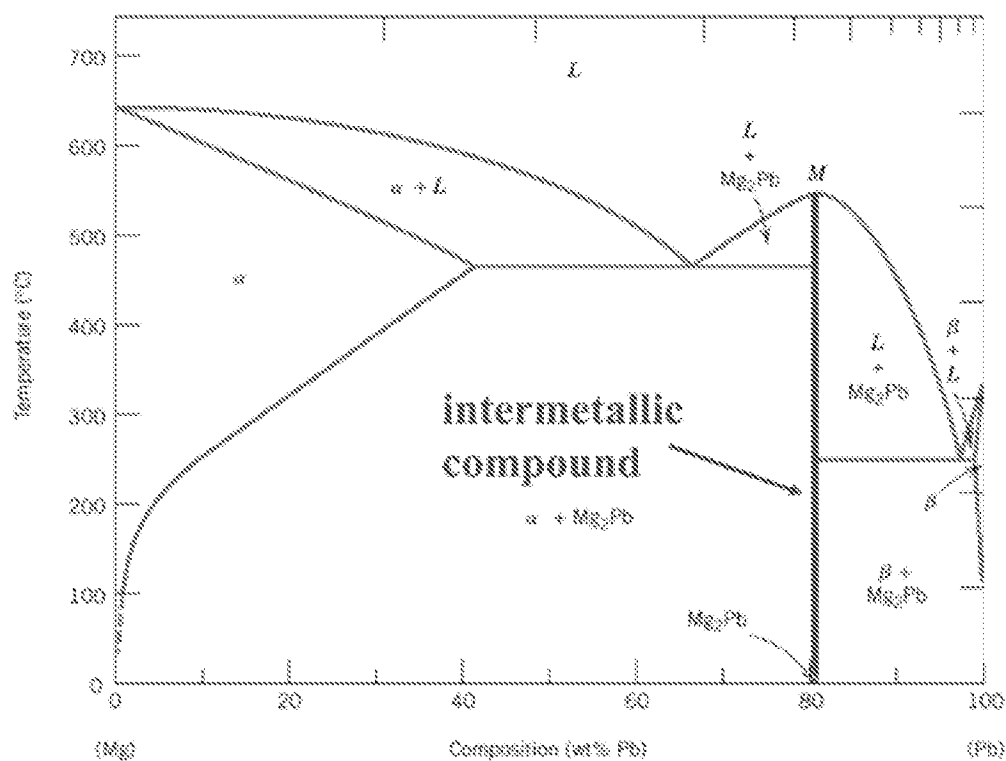


54. As would have been understood by a POSITA in (and well-before) April 2014 using the foregoing phase diagram, upon cooling to 800°C, an alloy melt of 24 wt% Cu and 76 wt% Ag begins to solidify as it crosses the liquidus line at point “a.” The initial solid precipitating out has the composition designated on the solidus curve at point “b” and is typically referred to as an “ α phase.” The α phase—in this phase diagram—is primarily Ag with a small amount of Cu in solid solution. This is analogous to the β phase on the right side of this phase diagram (which constitutes primarily Cu with small amounts of Ag in solid solution). Upon further cooling of the 24 wt% Cu and 76 wt% Ag composition to the eutectic temperature of 779°C, the remaining molten material solidifies as eutectic phase, the eutectic composition indicated by point “d.” At point d, the eutectic reaction $L \rightarrow \alpha + \beta$ occurs. The resulting solid alloy is, thus, a mixture of α phase “grains” and eutectic grains wherein the eutectic grains have a lamellar structure of mixed α and β phases. (To a POSITA in (and well-before) April 2014, “grain” refers to a 3-dimensional crystallite.

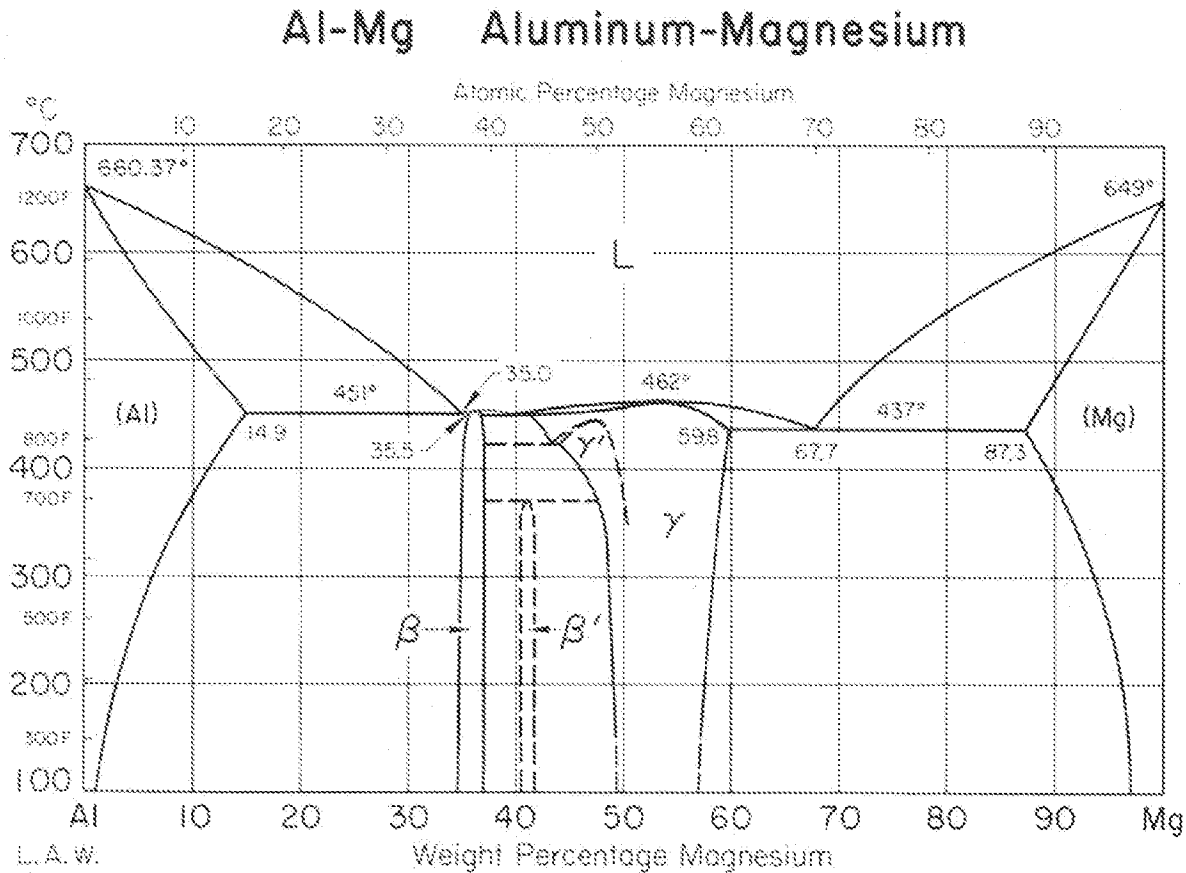
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Grains/crystallites form in alloys during cooling. And the areas where crystallites meet are called a “grain boundary.”)

55. A POSITA in (and well-before) April 2014 would have been aware that many metal alloy systems form intermediate compounds as temperature and other conditions are varied including, for example, CuAl_2 , Al_3Ni and Fe_3C . If the components of a precipitated intermediate compound are both metallic, it would have been and still is called an “intermetallic compound” by POSITAs. As a single phase of fixed composition or stoichiometry, intermediate phases have unique melting points and, thus, appear as a vertical line on a phase diagram. For example, the Mg-Pb phase diagram below (taken from MSE 2090: Introduction to Materials Science Chapter 9, Phase Diagrams; adapted from Phase Diagrams of Binary Magnesium Alloys, A.A. Nayeb-Hashemi and J.B. Clark (Editors), 1988 (with annotations added)) can be thought of as two joined eutectic diagrams, one for Mg-Mg₂Pb and the other for Mg₂Pb-Pb. The intermetallic compound M (Mg₂Pb) is a vertical line at approximately 80% Pb on the phase diagram.



56. In another example phase diagram for Al-Mg shown below (taken from the ASM Metals Handbook, 8th Edition, Vol. 8, Metallography, Structures and Phase Diagrams, 1973).



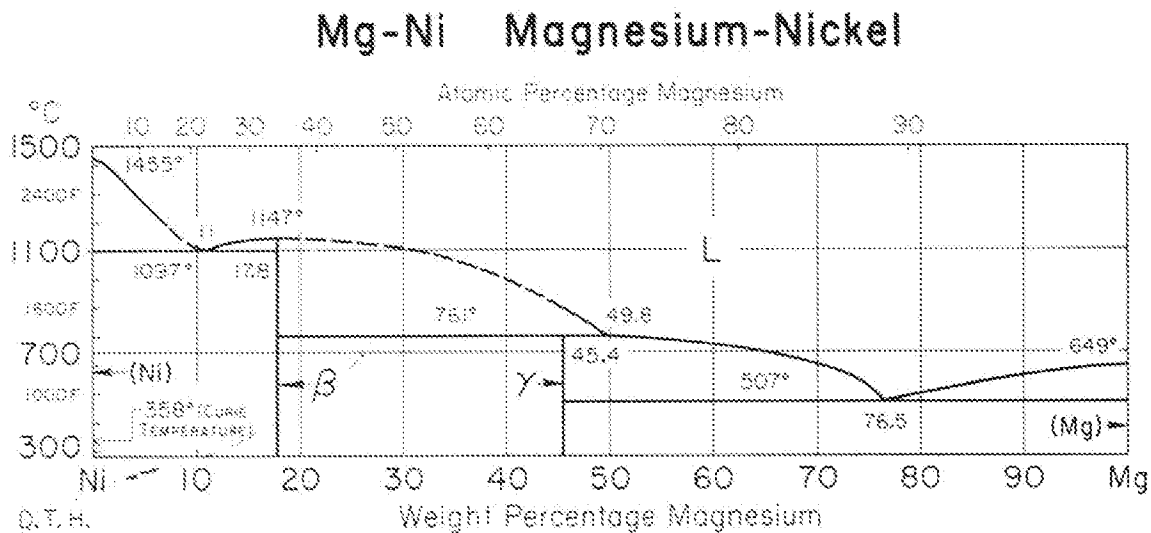
In this example, the (Mg) matrix at the right side of the phase diagram is the same as the α phase or anode phase mentioned in ¶ 0026 of Xiao Xiao (discussed below). The intermediate γ phase in the above diagram equates to the cathode phase as well as the β phase referred to in ¶ 0026 of Xiao. In this example, the intermediate phases (γ and β) have very narrow ranges of alloy contents that are near the stoichiometric chemistries which is typical for some phase systems.

57. A POSITA would have understood in (and well-before) April 2014 that these phase diagrams represent equilibrium conditions. Thus, a POSITA in April 2014 would have understood that additions of higher melting point elements that would completely dissolve (“melt”) in a molten alloy if the mixture was given time to reach equilibrium for the given temperature and composition of the constituents, would also have understood if not given that sufficient time to reach

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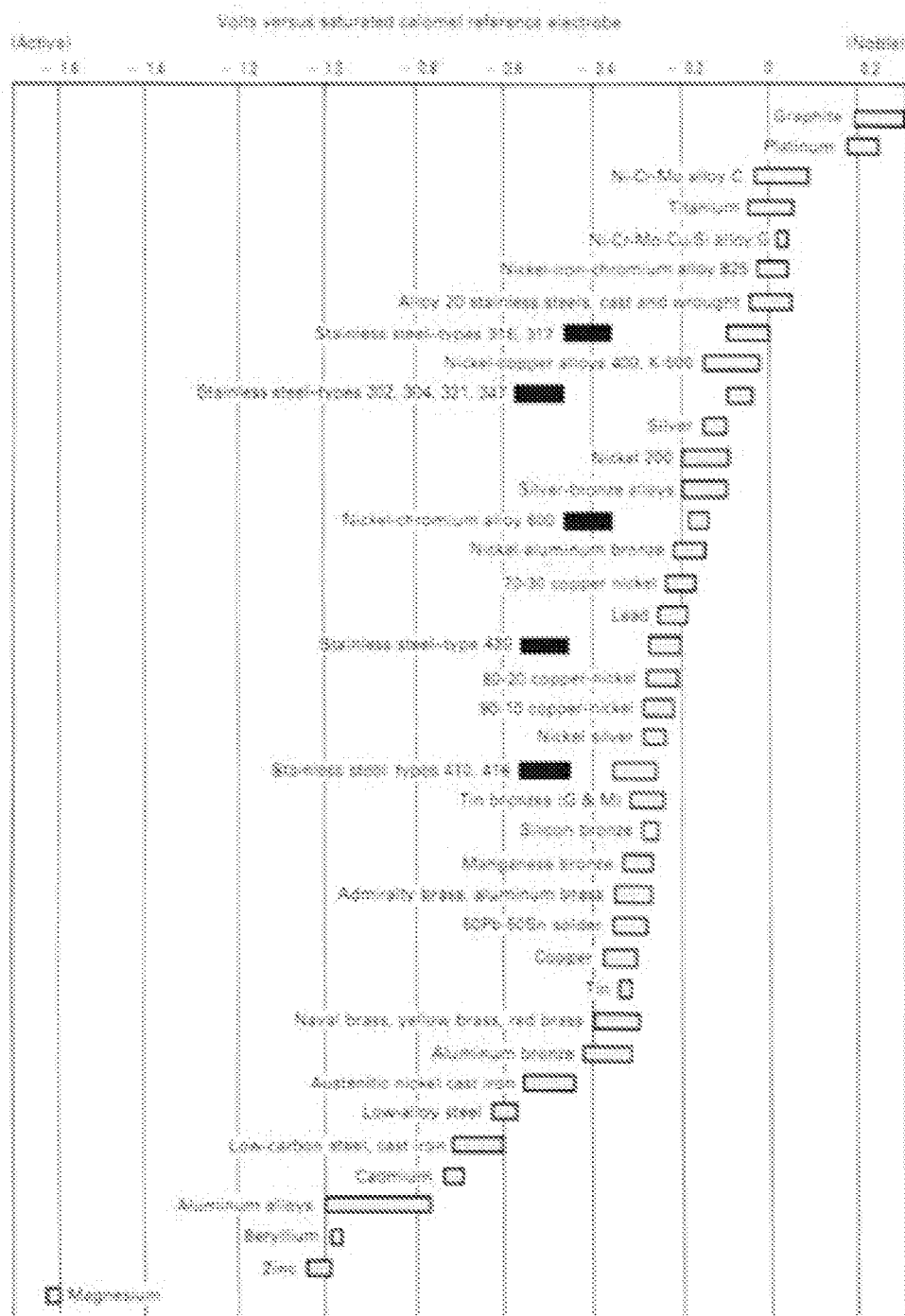
equilibrium before the mixture is cooled then the added higher melting point elements would not be completely dissolved prior to solidification of the alloy. Thus, a POSITA in April 2014 would have understood that a controlled cooling rate of the alloy would have limited the extent of dissolution of the higher melting point element in the mixture. Further, a POSITA in April 2014 would have understood that if the higher melting point element were added as particles at a specific wt%, smaller size particles would have greater surface area and would therefore dissolve faster than larger particles.

58. Intermetallic particles -- A POSITA would have already known well before April 2014 that Cu, Ni, and Fe, among other metallic elements, form intermetallic compounds with magnesium. This pre-invention knowledge is evidenced by the diagram below taken from the ASM Metals Handbook, 8th Edition, Vol. 8, Metallography, Structures and Phase Diagrams, 1973.



59. Galvanic Corrosion - A POSITA in (and well-before) April 2014 would have known that when two dissimilar metals or alloys are coupled together in a corrosive environment, one of the alloys will preferentially corrode while the other is protected from corrosion. The table

below is referred to by POSITAs as “the Galvanic Series,” which lists the corrosion potential of common metals and alloys.



Principles and Prevention of Corrosion, 2nd Ed., D.A. Jones, 1996, p 170.

The table is arranged to illustrate that an alloy or metallic element will preferentially corrode when coupled to another alloy or metallic element with a more positive or noble potential on the Galvanic Series. In other words, when coupled together, the alloy listed lower on the Galvanic Series will corrode and the alloy listed higher on the Galvanic Series will not corrode. In addition, the farther away the coupled alloys are on the list from one another, the higher driving force for corrosion.

60. As shown above, for example, magnesium is at the bottom of the Galvanic Series, and when coupled with other metals that contain elements such as aluminum, copper, zinc, silver, iron, and titanium, the magnesium will corrode, and the other elements will be protected from corrosion. In this sense, the magnesium when combined with other metals acts like a battery with an anode, a cathode, and “an electrolyte.” When the ends of the battery are connected through an electrical circuit, the anode inside the battery will corrode developing an electrical current to energize the circuit. When the anode is fully consumed, the battery is dead.

61. The intermetallics in a magnesium alloy mixture typically act as cathodes and the matrix material typically acts as an anode. When the magnesium alloy is exposed to a conductive solution (such as potassium chloride), the alloy will corrode as discussed above in conjunction with the Galvanic Series. Specific types and amounts of particular intermetallics will be more cathodic to the magnesium than other intermetallics and, thus, will cause the alloy to corrode at faster rates.

62. Alloy Processing - A POSITA in April 2014 would have understood that a key microstructural parameter in an alloy is the grain size, that grain size and shape describe the morphology of a grain, and that the morphology is determined in large part by the mixing prior to solidification and by any post-solidification heat treatment and/or deformation processing. A POSITA in April 2014 would have known that grain size of these alloys can be controlled by solute

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alloying, heat treatments, and forming the metals at ambient and elevated temperatures. With specific heat treatment processing and forming conditions, the grain size of a magnesium alloy can be controlled which in turn changes the mechanical performance of the alloy depending upon the application. Additionally, a POSITA in April 2014 would have understood that the rate of an electrochemical reaction is dependent on surface area which in turn depends on particle or grain size of the reactants. These principles were well known to a POSITA prior to April 2014 and common knowledge in the technical literature. In addition, it was also well known how each alloying element affects the mechanical properties as well as the corrosion resistance of this alloy group.

B. Alleged Invention of the '653 Patent

63. The '653 Patent's purported solution to its alleged problem¹² is a "magnesium composite for use as a dissolvable component in oil drilling" such as "a ball or other tool component in a well drilling or completion operation such as, but not limited to, a component that is seated in a hydraulic operation that can be dissolved away after use so that no drilling or removal of the component is necessary." '653 Patent at 1:53--59. The '653 Patent describes the purportedly inventive magnesium composite as being used to form a "castable, moldable, or extrudable component." *Id.* at 2:18--20.

64. The purportedly inventive magnesium composite would include "at least 50 wt.% magnesium" with "one or more additives added to a magnesium or magnesium alloy to form the

¹² As I already noted above, the '653 Patent described the problem as follows: "While the prior art well drill components have enjoyed modest success in reducing well completion costs, their consistency and ability to specifically control dissolution rates in specific solutions, as well as other drawbacks such as limited strength and poor reliability, have impacted their ubiquitous adoption."

'653 Patent ('653 Patent) at 1:31--36.

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novel magnesium composite.” *Id.* at 2:20–24. The “one or more additives can be selected and used in quantities so that galvanically-active intermetallic or insoluble precipitates form in the magnesium or magnesium alloy while the magnesium or magnesium alloy is in a molten state and/or during the cooling of the melt.” ‘653 Patent *Id.* at 2:24-29.

65. The ‘653 Patent further describes that the “one or more additives can be added to the molten magnesium or magnesium alloy at a temperature that is greater than the melting point of the one or more additives.” *Id.* at 2:53–56. “Generally, the temperature of the molten magnesium or magnesium alloy is at least about 10°C. less than the melting point of the additive added to the molten magnesium or magnesium alloy during the addition and mixing process, typically at least about 100°C. less than the melting point of the additive added to the molten magnesium or magnesium alloy during the addition and mixing process.” *Id.* at 3:2–8. According to the ‘653 Patent, the result of this process is that it “can be used to achieve a specific galvanic corrosion rate in the entire magnesium composite and/or along the grain boundaries of the magnesium composite.” *Id.* at 3:16–18.

66. The ‘653 Patent specifically notes that the “invention adopts a feature that is usually a negative in traditional casting practices wherein a particle is formed during the melt processing that corrodes the alloy when exposed to conductive fields and is imbedded in eutectic phases, the grain boundaries, and/or even within grains with precipitation hardening.” *Id.* at 3:19–24.

67. This purportedly “results in the ability to control where the galvanically-active phases are located in the final casting, as well as the surface area ratio of the *in situ* phase to the matrix phase, which enables the use of lower cathode phase loadings as compared to a powder metallurgical or alloyed composite to achieve the same dissolution rates.” *Id.* at 3:34–30. According to the ‘653 Patent, the *in situ* formed galvanic additives can be used to improve certain

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mechanical properties of the magnesium composite, including ductility, tensile strength, and/or shear strength. *'653 Patent Id.* at 3:24–30.

68. The '653 Patent further explains that in one non-limiting embodiment the present invention is directed to:

a ball or other tool component in a well drilling or completion operation such as, but not limited to, a component that is seated in a hydraulic operation that can be dissolved away after use so that no drilling or removal of the component is necessary. Tubes, valves, valve components, plugs, frac balls, and other shapes and components can also be formed of the novel magnesium composite of the present invention.

Id. at 1:51–59.

69. The '653 Patent goes on to describe many “non-limiting aspects” of the alleged invention. For example, the '653 Patent explains that the “magnesium composite is used to form a castable, moldable, or extrudable component.” *Id.* at 2:17–18. In this example, the magnesium composite would include at least 50 wt % magnesium with one or more “additives” added to the magnesium or magnesium alloy. *Id.* at 2:17–22. The “additives” are added in a weight percent that is less than the weight percent of the magnesium or magnesium alloy. *Id.* at 2:28–30. The one or more additives are typically added to the magnesium or magnesium alloy while it is in a molten state at a temperature that is less than the melting point of the one or more additives. *Id.* at 2:37–40. During mixing of the one of the one or more additives to the molten magnesium or magnesium alloy, the one or more additives are typically not caused to fully melt. *Id.* at 2:49–53.

70. In forming a composite with the magnesium or magnesium alloy, the one or more additives form “secondary metallic alloys with the magnesium and/or other metals in the magnesium alloy.” *Id.* at 2:56–61. According to the '653 Patent, as the molten metal cools, the

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newly formed secondary metallic alloys precipitate out of the molten metal and form the in situ phase to the matrix phase in the cooled and solid magnesium composite. *Id.* at 2:62–65.

71. After mixing, the molten magnesium or magnesium alloy and the one or more additives are cooled to form a solid component. *Id.* at 2:65–3:2. Generally, the temperature of the molten magnesium or magnesium alloy is about 10°C less than the melting point of the one or more additives added during the addition and mixing process. *Id.* at 3:2–13.

72. The '653 Patent refers to the particles that do not melt and/or newly formed “secondary metallic alloys” as “in situ particle formation.” *Id.* at 3:13–15.

C. Aspects of the Prosecution History of the '653 Patent Relevant to my Opinions

73. The application that became the '653 Patent was filed on July 5, 2017. '653 Prosecution History, at pp. 1306–55.

74. On September 20, 2017, Patent Owner disclosed to the Patent Office twenty-six (26) U.S. Patents, thirty-four (34) U.S. Patent Publications, fifteen (15) Foreign Patent Documents, and thirteen (13) Non-Patent Literature Documents. *Id.* at 864–872. The fifteen (15) Foreign Patent Documents included Chinese Patent Publication No. CN103343271A (in Chinese) accompanied by an English language abstract (hereinafter referred to as “Chinese-language Xiao”). '653 Prosecution History at 1274-75.

75. On November 21, 2018, the Patent Office issued a communication rejecting some of the pending claims as anticipated by, or obvious over, JP2013-019030 (Tashiharu). Other pending claims were rejected solely as being obvious over Tashiharu JP'030. *Id.* at 624-633.

76. Patent Owner responded to these anticipation and obviousness rejections over JP'030 (Tashiharu) that they were moot in view of Patent Owner's contemporaneous amendments to the claims and, with respect to a newly added claim, argued that the CaMgSi phase in the

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magnesium alloy of JP'030 is likely not galvanically-active and would not corrode in the presence of a KCL water mixture because it discloses a magnesium alloy which is usable in “transport-airplane machines” and other materials of an automobile, an airplane and a rail car, a machine part, and a robot part article and that *“a person having ordinary skill in the art would understand that the magnesium alloys . . . either improve corrosion resistance or are corrosion resistant.”* *Id.* at 606–07 (emphasis added).

77. The Examiner issued a Notice of Allowance on March 27, 2019, stating that claims were allowable because “the closest prior art of record,” JP2013-019030 (Tashiharu) does not teach or suggest the additive including copper, nickel, titanium, iron, or cobalt, or mixtures thereof. *Id.* at 90–91. The ‘653 Patent issued soon thereafter.

V. CLAIM CONSTRUCTIONS

78. I have been told in the related district court litigation that Patent Owner proposed construing the various claim terms of the ‘653 Patent either using their plain and ordinary meaning to a POSITA except with respect to the following claim terms where Patent Owner has proposed (sometimes in the alternative) the following constructions (some of which were also agreed upon with the Petitioner):

<u>Claim Term</u>	<u>Definition</u>
Additive material	a material that is added
Composite	a material having two or more different elements
Controlled dissolving	dissolving a substance in a controlled manner
Forming precipitant	“forming” = “coming into existence” “precipitant” = “something having a new phase different from what existed before”

Galvanically-active	allowing for an electrochemical reaction
in situ	in place
Intermetallic phase	Compound that has two or more metals.
melting point temperature	temperature at which liquid is formed
morphology of said galvanically-active intermetallic phases	shape of said galvanically-active intermetallic phases
Precipitation/precipitate	something having a new phase different from what existed before
Secondary metal	an additional metal that is added
Sufficient quantities in said galvanically-active intermetallic phases	"sufficient quantities" = "Enough additive material" "galvanically-active" = "allowing for an electrochemical reaction" "intermetallic phases" = "Compound that has two or more metals"
Unalloyed additive material	portion of the additive material that does not form a new compound

79. I understand that during reexamination of an unexpired patent, the USPTO's Patent and Trial Appeal Board will apply the broadest reasonable interpretation consistent with the specification standard. I also understand that the district court in the related litigation has issued a claim construction. Although I do not necessarily agree that a POSITA in April 2014 would

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construe any of the foregoing claim terms from the '653 Patent in the manner proposed by the Patent Owner (as set forth above), for purposes of the present declaration I adopt Patent Owner's proposed constructions (where presented) or the broadest reasonable interpretation (where no proposal has been offered by Patent Owner) in offering my opinions below. It is my opinion that under any of these claim constructions or standards, and certainly "broadest reasonable interpretation," the Challenged Claims are invalid for the reasons set forth below.

VI. OVERVIEW OF THE PRIMARY PRIOR ART

A. Certified English-language translation of Chinese Patent Publication No. CN 103343271A to Xiao *et al.* ("Xiao")

80. I was provided with a copy of Chinese-language Patent Publication No. CN103343271A accompanied by an English language abstract (hereinafter referred to as "Chinese-language Xiao"). I noted above that Chinese-language Xiao was provided to the patent examiner during the prosecution of the '653 Patent.

81. I do not read, speak, or understand the Chinese language.

82. I was also provided with Xiao, a certified English translation of the Chinese-language Xiao, that I was told Petitioner commissioned ("Xiao"). I base my opinions regarding the disclosure of the Xiao reference on this certified English translation, which I exclusively reference below.

83. Xiao was filed on July 8, 2013, is titled "Light and pressure-proof fast-decomposed cast magnesium alloy," and was published on October 9, 2013. Xiao (cover page). Because Xiao was published prior to the effective filing date of the invention of the '653 Patent, i.e. April 18, 2014, I have been told that Xiao is prior art.

84. According to the translation, Xiao discloses a "light and pressure-proof fast-decomposed cast magnesium alloy, which can be used as a tripping ball material for a multi-stage

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sliding sleeve staged-fracturing technique, and belonging to the technical field of magnesium alloy preparation.” Xiao, ¶ 0001. Xiao explains that “[i]n recent years, the United States has made breakthroughs in the technologies of shale gas exploration and development, and the output has grown rapidly,” and that “[t]he multi-stage sliding sleeve staged fracturing technology is a new oil and gas reservoir reconstruction technology developed in recent years in the area of oil and gas well engineering technology.” *Id.* at ¶ 0002.

85. Xiao continues: “One of the key parts of this technique is the tripping ball. The tripping ball has two main functions: 1) to open the sliding sleeve to fracturing the formation rock; and 2) to separate from the fracturing fluid and pressure.” *Id.* “After the completion of all rock fracturing, it is necessary to depressurize the well tubing to facilitate the later production of the oil and gas well. In the past, the conventional method is to use the low-layer pressure to push the ball back to the well opening, or use a drilling tool to drill the sliding sleeve ball seat and the tripping ball, so as to destroy them.” *Id.*

86. Xiao identifies shortcomings of the traditional methods, i.e. the possibility that the tripping ball is stuck, delay in construction, and increase in construction costs and risks, and the need for an alternative: “the development of a tripping ball that can withstand the high pressure of fracturing construction and the high temperature at the bottom of the well, and has the feature of self-decomposition in the fluid environment of a well, can effectively reduce the construction risk and improve the construction efficiency.” *Id.*

87. Xiao sought to solve this problem by proposing a “method for preparing a light and pressure-proof fast-decomposed cast magnesium alloy by means of optimizing the alloy composition design using a self-made flux containing a rare earth element and adopting a smelting casting method.” Xiao at ¶ 0004. To do so, Xiao discloses a “magnesium alloy with a high

aluminum content (13 to 25% by weight) and a high zinc content (2 to 10% by weight), and further adds elements of Fe, Cu, Ni and Ag which can enhance the corrosion performance of the magnesium alloy, and at the same time adds Zr, Ti element as grain refiners to improve the compressive strength of the formed material, in which the purpose of adding the high content of aluminum content is to produce a large amount of cathode phase, the β ($\text{Mg}_{17}\text{Al}_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy, and the magnesium matrix α phase functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

88. Xiao explains the purpose of adding other materials to the magnesium alloy: “Elements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* Thus, Xiao—unlike the prior art JP’030 (Tashiharu) reference focused on by the patent examiner—views an increased dissolution (i.e., decomposition) rate as an improvement.

89. Xiao further notes there were orders of magnitude increases in the dissolution/decomposition rate promoted by the addition of those materials (e.g. Fe, Cu, Ni, Ag, etc.) to the magnesium of: “60 to 200 times of that of the existing AZ91D magnesium alloy [at 70°C in a 3% KCl solution], and . . . 50 to 200 times [at 93°C in a 3% KCl solution] of that of the existing AZ91D magnesium alloy.” Xiao at ¶ 0026.

90. Xiao then discloses a “comparative example alloy [that] is AZ91D magnesium alloy,” *id.* at ¶¶ 0030–0032, and seven additional examples containing not only magnesium,

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aluminum, and zinc, but also Iron (Fe), Copper (Cu), Nickel (Ni), Silver (Ag), or and Titanium (Ti), *id.* at ¶¶ 0033–0060.

91. We compared the English-language abstract provided to the patent examiner with the “Abstract of the Disclosures” section of the Certified English-language translation of Xiao using the compare feature of MS Word. In my opinion, the comparison made it easier to confirm that the abstracts would have been considered practically identical from the standpoint of a POSITA in April 2014.

92. Most importantly, however, those Abstracts (Xiao) failed to disclose the truly important aspects of the subject matter of the Xiao reference. In particular, the Abstracts say nothing about galvanic-activity, corrosion, or accelerating the dissolution rate of magnesium. Rather, the Abstracts specifically state that “the alloy decomposition performance exceeds that of a traditional cast magnesium alloy.” See, Xiao. This portion of the final sentence of the Xiao Abstract likely led the patent examiner to incorrectly believe that Xiao--like much of the magnesium alloy prior art (see, e.g., ‘653 Patent, 3:19-24) including Tashiharu JP’030 considered by the patent examiner to be the closest prior art reference--disclosed, in the words of Patent Owner, “magnesium alloys [that] either improve corrosion resistance or are corrosion resistant.” (Prosecution History) at 606–07.

B. “Development of high strength magnesium based composites using elemental nickel particulates as reinforcement,” Printed Publication by S.F. Hassan and M. Gupta (“Hassan”)

93. Hassan, was first published in the June 2002 issue of the Journal of Materials Science, resulting in the following citation: Hassan, S.F., Gupta, M., Development of high strength magnesium based composites using elemental nickel particulates as reinforcement. *Journal of Materials Science* 37, 2467–2474 (2002). Hassan, cover page. Journal of Materials Science was

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before then and is still now considered a reputable, widely known scientific journal that has been readily accessible to POSITAs well before April 2014 (there are even issues of this Journal readily available from before 1970).

94. Hassan bears a copyright date of 2002. *Id.* Moreover, Hassan was marked “Received 14 June 2001 and accepted 12 February 2002” by its then publishing company, Kluwer Academic Publishers. Hassan, cover page and p. 2474. Volume 37, which contained Hassan, was assigned journal ISSN number (0022-2461) and a DOI number (Digital Object Identifier used for publications) “<https://doi.org/10.1023/A:1015475103720>”. *Id.* Hassan was also cited by others skilled in the art prior to April 18, 2014. (See Hai, at 18; Hemanth at 11.)” Because Hassan was published prior to the effective filing date of the invention of the ’653 Patent, i.e. April 18, 2014, I have been told that Hassan is prior art.

95. Hassan recognized that “[m]agnesium based materials due to their inherently low density and ensuing potential to exhibit high specific mechanical properties are actively sought for weight-critical structural application” and that “[t]he increasing hostile service conditions that the modern engineering devices have to withstand have led the materials scientist across the globe to create new materials with enhanced properties when compared to the conventional materials. One way to improve the properties of conventional metallic materials is to reinforce them judiciously keeping the end application in mind. Among the reinforced metallic materials, magnesium based composites are becoming the strong candidates for lightweight structural application due to their superior specific mechanical properties.” Hassan at 2467.

96. Hassan discloses the “synthesis of monolithic and nickel reinforced magnesium composites (Mg/Nip),” including “superheating the magnesium turnings with reinforcement

particulates (placed in multi-layer sandwich form) to 750°C” and stirring the “molten slurry.” *Id.* at 2468.

97. Hassan describes its study as “magnesium turnings of 99.9+% purity . . . were used as the base material and elemental nickel particulates of 99.9% purity (Johnson Matthey, MA, USA) with an average size of $29 \pm 19 \mu\text{m}$ were used as reinforcement phase.” *Id.* at 2468.

98. Hassan further discloses the results for the study revealed “[s]evere reaction between magnesium melt and nickel particulates during DMD processing led to the reduction of the particulate size and formation of Mg_2Ni intermetallics. The results of quantitative determination of unreacted nickel (see Table I), microstructural characterization illustrating the presence of reaction products (see Fig. 1) and XRD results (see Table II) showing the presence of Mg_2Ni supports the experimental observations.” *Id.* at 2472.

TABLE 1 Results of density and porosity measurements

Material	Reinforcement in composites			Size ^c	Density (g/cm^3)
	(wt%)	(vol%) ^a	(vol%) ^b		
Mg	—	—	—	—	1.7395 ± 0.0005
Mg/7.3Ni _p	7.3	1.5	0.1	2.7 ± 0.6	1.9046 ± 0.0038
Mg/14.0Ni _p	14.0	3.1	1.3	2.5 ± 0.4	2.0677 ± 0.0002
Mg/24.9Ni _p	24.9	6.1	4.3	9.0 ± 4.6	2.3834 ± 0.0092

^aComputed by using the total amount of Ni retained in composite samples.

^bIndicates the amount of Ni in the unreacted form present in composite samples.

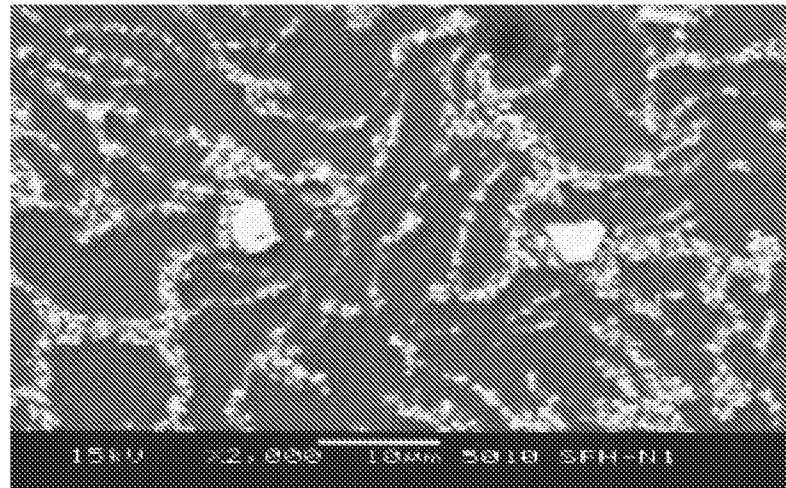
^cResult of cumulative image analysis conducted on fifteen representative SEM micrographs for each composite.

TABLE II Results of X-ray diffraction studies and coefficient of thermal expansion analysis

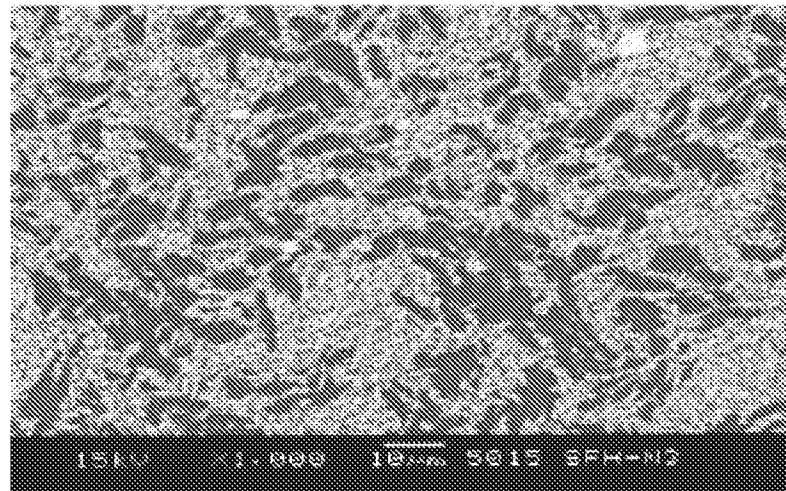
Materials	Number of matching peaks					CTE ($\times 10^{-6}/^{\circ}\text{C}$)
	Mg	Ni	Mg ₂ Ni	NiO	Ni ₂ O ₃	
Mg	9 [3]	—	—	—	—	28.60 ± 0.07
Mg/7.3Ni _p	6 [3]	—	6 [2]	—	—	27.54 ± 0.26
Mg/14.0Ni _p	5 [3]	—	8 [2]	—	—	26.35 ± 0.09
Mg/24.9Ni _p	6 [3]	2 [1]	16 [2]	1 [1]	1	20.75 ± 0.56

[] indicates the number of main peaks matched.

99. Figure 1 of Hassan demonstrates “representative SEM micrographs showing distribution of nickel and its reaction product in: (a) Mg/7.3Ni_p, (b) Mg/14.0Ni_p and (c) Mg/24.9Ni_p matrices.”



(a)



(b)



(c)

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100. Hassan was not considered by the patent examiner during the prosecution of the '653 Patent.

VII. SPECIFIC GROUNDS FOR PETITION

101. Below I provide my analysis of the foregoing prior art as compared to various claims of the '653 Patent. For the convenience of the Board, I have color-coded specific disclosures in the prior art to corresponding limitations or requirements of the claims of the '653 Patent.

102. In particular I have concluded there are three bases for invalidating the Challenged Claims of the '653 Patent. Ground I: Claims **1**,¹³ **4**, **5**, **11**, **13**, **29**, **37**, **41**, **43**, **45**, **49**, **69**, **70**, and **73** are anticipated by Xiao. Ground II: Claims **8**, **25**, **33**, **55**, and **74** are anticipated, or at least made obvious, by Xiao. And Ground III: Claims **7**, **12**, **13**, and **71** are obvious over Xiao in view of Hassan.

A. Ground I: Claims **1, **4**, **5**, **11**, **13**, **29**, **37**, **41**, **43**, **45**, **49**, **69**, **70**, **71**, and **73** are Anticipated by Xiao**

103. It is my opinion that Xiao anticipates Claims **1**, **4**, **5**, **11**, **12**, **13**, **29**, **33**, **37**, **41**, **43**, **45**, **49**, **69**, **70**, **71**, and **73** of the '653 Patent.

1. Independent Claim 1

a. "A magnesium composite"

104. Xiao discloses a "magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy..." Xiao at ¶ 0026, ll. 1–9.

¹³ I have tried to indicate which Challenged Claims are independent throughout my declaration by indicating them in bold font.

105. Thus, Xiao's disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of "a magnesium composite."

b. **"[magnesium composite] that includes in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite,"**

106. Xiao discloses that its invention adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes "the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy," and "the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy." *Id.* at ¶ 0026.

107. Xiao further discloses that "[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy." Xiao at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood this disclosure of "intermetallic composite micro-particles" to be a reference to intermetallic precipitate.

108. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases ("micro-batteries") are naturally and necessarily generated by the *in situ* reaction between magnesium and any and all of the disclosed

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metal additives forming *in situ* precipitate. Thus, all of the limitations of this claim element are disclosed by Xiao.

c. “said magnesium composite comprising a mixture of magnesium or a magnesium alloy and an additive material,”

109. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace . . . , next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022.

110. Xiao discloses that these “intermediate alloys” are Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti, which are heated to dry and then added to the magnesium-aluminum alloy melt.” Xiao at ¶ 0023. These intermediate alloys meet Patent Owner’s proposed definition of “additive material,” i.e. “a material that is added.”

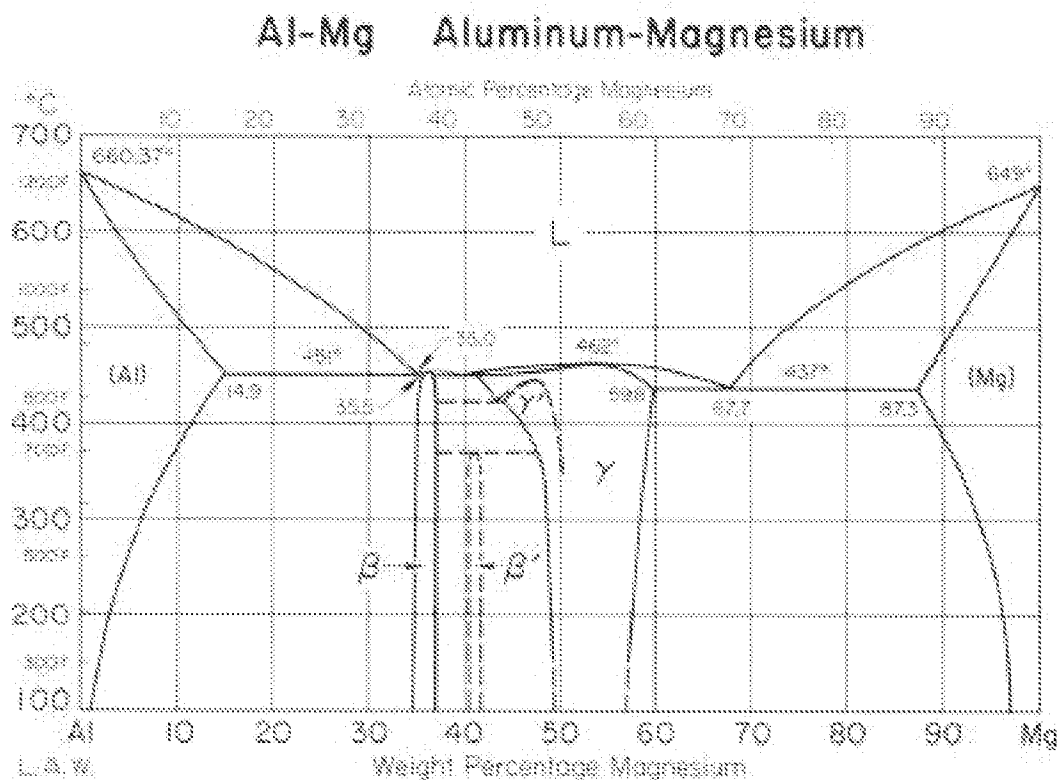
111. The addition of one or more of these intermediate alloys to the melted magnesium alloy necessarily results in a mixture of magnesium or magnesium alloy and the additive material. Thus, Xiao discloses all of the limitations of this claim element.

d. “said additive material having a greater melting point temperature than a solidus temperature of said magnesium, [. . . said additive material includes one or more metals selected from the group consisting of copper, nickel, iron, and cobalt]”

112. All of the prior elements of Independent Claim 1 had referred to “magnesium composite” rather than just “magnesium,” which the claim defined as comprising “a mixture of magnesium or magnesium alloy (and an additive material).” It is my opinion that a POSITA would have understood the reference to “magnesium” in this claim element as reference to the previous limitation of “magnesium or magnesium alloy.”

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113. Using a typical phase diagram, a POSITA in April 2014 would have readily determined that the solidus temperature of magnesium is the temperature at which a metal first begins to melt during heating and not necessarily when the metal is completely liquidus.



The POSITA would also use this phase diagram to find the solidus temperature of the magnesium-aluminum alloy disclosed in Xiao to be in a range of 650°C for pure magnesium and down to 437°C for aluminum additions up to 40wt%. The solidus temperature is 437°C for the magnesium-aluminum alloys disclosed in Xiao having in the range of 13 wt% to 25 wt% aluminum.

114. The additive materials disclosed in Xiao that were noted above are one or more of the intermediate alloys: Al-Fe, Al-Ni, Al-Co, Al-Ag, Al-Zr, Al-Ti. Xiao at ¶ 0023. Patent Owner has taken the position that “melting point temperature” would have meant “temperature at which liquid is formed” to a POSITA in April 2014.

115. The POSITA using typical phase diagrams for each of the additive materials (here the “intermediate alloys” disclosed in Xiao) would be able to readily determine the melting point temperature for each intermediate alloy. For example, the Al-Fe phase diagram shows a variable melting point temperature ranging from 1538°C (pure iron) down to 655°C for a eutectic temperature between about 63 wt% aluminum to near 99 wt% aluminum. The Al-Ni phase diagram shows a variable melting point temperature that ranges from 1640°C down to 640°C depending upon the alloy content. The Al-Cu phase diagram shows a variable melting point temperature ranging from 548°C up to 1084°C depending upon the alloy mixture. A POSITA in April 2014 would have readily determined the specific melting temperature of a specific alloy mixture based on these phase diagrams.

116. Xiao discloses a variety of Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti alloy mixtures with a variety of constituencies. For instance, Xiao specifically teaches in Example 7 that:

The composition of the alloy and the respective percentages by weight are as follows: 25% Al-10% Zn-1% Fe-0.5% Ni-0.1% Cu-0.5% Ti-0.05% Zr, and the remainder is Mg.

Xiao at ¶ 0059. Xiao teaches that the magnesium alloy of Example 7, as a whole, ends up with the maximum amount of aluminum (i.e. 25 wt%) taught as being within the invention of Xiao (see, Xiao ¶ 0026). Xiao specifically discloses--with respect to Example 7--that portions of that aluminum content are added into a magnesium-aluminum melt as an Al-Fe intermediate alloy, an Al-Ni intermediate alloy, an Al-Cu intermediate alloy, an Al-Ag intermediate alloy, an Al-Zr intermediate alloy, and an Al-Ti intermediate alloy. Xiao at ¶ 0060. Thus, it is necessary to prepare mass balance calculations to determine the relative concentrations of the pure magnesium

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and pure aluminum initially loaded into the smelting furnace in order to determine its solidus temperature.

117. First, a POSITA in April 2014, would have converted the weight percentages to grams to perform mass balances. As a result, a POSITA would have understood in April 2014 that Example 7 of Xiao includes 62.85 grams of magnesium (i.e., 100 grams - 37.15 grams (i.e., 25 grams (Al) - 10 grams (Zn) - 1 gram (Fe) - 0.5 grams (Ni) - 0.1 gram (Cu) - 0.5 grams (Ti) - 0.05 grams (Zr))).

118. The following intermediate alloy compositions were chosen for the initial mass balance calculations: Al-Fe (30 wt% Fe), Al-Ni (45 wt% Ni), Al-Cu (40 wt% Cu), Al-Ti (10 wt% Ti), Al-Zr (20 wt% Zr) alloy mixtures.

119. As would a POSITA in April 2014, (using the weight percentages-to-grams conversion noted above) I performed the initial mass balances.

120. Thus, using the initially selected Al-30Fe, Al-45Ni, Al-40Cu, Al-10Ti, and Al-20Zr alloys would have resulted in 7.79 grams of Aluminum being added to the overall alloy as components of the intermediate alloys (as opposed to the aluminum introduced into the ultimate alloy of Example 7 in the initial melt). Since Example 7 of Xiao calls for a total of 25 grams (i.e. 25 wt%) of Aluminum, 17.21 grams of Aluminum would have had to have been initially loaded into the smelting furnace in Example 7 along with the 62.85 grams of magnesium (see calculation above). Thus, the initial melt of Example 7 (using the intermediate alloys selected) would have had a composition of 78.5 wt% Mg and 21.5 wt% Al.

121. Next, a POSITA would have consulted the Mg-Al phase diagram to determine that the solidus temperature of the initial magnesium alloy (i.e. 78.5 wt% Mg and 21.5 wt% Al) of Example 7 of Xiao to be 437 °C.

122. A POSITA would also consult the relevant phase diagram to determine the melting point temperature of the various additive materials disclosed in Xiao. An aluminum-iron alloy with 30 wt% iron would have a melting point temperature of 655 °C, an aluminum-nickel alloy with 45 wt% Ni would have a melting point temperature of 854 °C, an aluminum-copper alloy with 40 wt% Cu would have a melting point temperature of 548°C, an aluminum-titanium alloy with 10 wt% Ti would have a melting point temperature of 665°C, and an aluminum-zirconium alloy with 20 wt% Zr would have a melting point temperature of 661°C. Thus, each of these additive materials from Example 7 of Xiao (with the constituencies selected above) would have had a greater melting point temperature than the solidus temperature of magnesium or the magnesium-aluminum alloy (i.e. 437°C) corresponding to 21.5 wt% aluminum which is the calculated amount of pure aluminum in pure magnesium initially loaded into the smelting furnace in Example 7. A POSITA in April 2014 would have also recognized that other compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in ~~Al-Fe, Al-Ni, and Al-Cu intermediate alloys~~ having greater melting point temperatures than the solidus temperature of initial magnesium alloy loaded in the various Examples of Xiao. Thus, Xiao discloses all of the limitations of this claim element.

- e. **“said additive material constituting about 0.05 wt %-45 wt % of said mixture, [... said additive material includes one or more metals selected from the group consisting of copper, nickel, iron, and cobalt]”**

123. Claim 1 of Xiao discloses: a “magnesium alloy, comprising the components at the weight percentages as follows: **Al: 13 to 25%, Zn: 2 to 15%**, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 discloses: a “magnesium alloy, according to Claim 1, further comprising the trace elements at the weight

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percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2.

124. These metallic elements are found in the additive materials generally disclosed by Xiao (*i.e.*, intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ti) (Xiao at ¶ 0023) and particularly described in association with Example 7 of Xiao (*Id.* at ¶¶ 0057 - 0060) for which I have already calculated (and set forth above) the specific weight percentage (ranges) of each additive material (which has been defined by the Patent Owner as “a material that is added” (see Paragraph 78 of my Declaration)) set forth in Example 7 of Xiao (*i.e.* Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc).

125. In particular, the additive materials aluminum-iron with 30 wt% iron, aluminum-nickel with 45 wt% nickel, and aluminum-copper with 40 wt% copper, which each have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao, also fall well within the range of about 0.05 wt% to 45 wt% of the mixture. For example, the aluminum-iron additive constitutes 3.3 wt% of the mixture (*i.e.*, 1%/0.30); the aluminum-nickel additive constitutes 1.1 wt% of the mixture (*i.e.*, 0.5%/0.45); and the aluminum-copper additive constitutes 0.25 wt% of the mixture (*i.e.*, 0.1%/0.40). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, **and** Al-Cu intermediate alloys constituting about 0.05 wt% to 45 wt% of the mixture. Accordingly, this element of the claim is disclosed by Xiao.

f. “said additive material forming precipitant in said magnesium composite,”

126. Xiao discloses that constituents of the additive materials disclosed in Xiao (and particularly disclosed in Example 7, thereof) form precipitant: “Elements such as Fe, Cu, Ni, Ag,

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etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” Xiao at ¶ 0026; see also ¶¶ 0057-0060 (Example 7).

127. As established in the section above, the intermediate alloys Al-Fe and Al-Ni disclosed in Xiao have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao. Those alloys would necessarily contribute FeAl₃, Al₃Ni, Al₃Ni₂, and/or Mg₂Ni to the magnesium composite, which Xiao teaches would lead to the formation of micro-particles, also known as precipitant. Thus, this element of the claim is disclosed by Xiao.

g. “said additive material includes one or more metals selected from the group consisting of copper, nickel, iron, and cobalt,”

128. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, the invention of Xiao generally teaches additive materials containing iron, copper, and nickel. Of the additive materials taught in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Fe, Al-Ni, and Al-Cu contain copper, nickel and iron. This claim element requires the additive material include even only one of these metals. Claim 2 and Example 7 both teach three. Accordingly, Xiao discloses this element of the claim.

- h. “said magnesium composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

129. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement in that table are units regularly used by POSITAs to express measurements of dissolution. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

130. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 patent express the claimed dissolution rate in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table from Xiao by 1,000.

131. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

132. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

133. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 1 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

2. Dependent Claim 4

- a. **“The magnesium composite as defined in claim 1, wherein said additive material includes nickel,”**

134. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 1 to a POSITA in April 2014.

135. The overall teaching of Xiao notes the use of nickel as an additive material. See, e.g., Xiao at ¶ 0026. As I discussed above, Example 7 of Xiao particularly discloses intermediate alloys Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc are used as additive materials. A POSITA in April 2014 would have understood that the intermediate alloy Al-Ni contains nickel. Accordingly, Example 7 of Xiao discloses this element, in accordance with Patent Owner’s definition of “additive material.”

- b. **“said nickel constitutes about 0.05-35 wt % of said magnesium composite,”**

136. Claim 2 of Xiao discloses “Ni: 0.05 to 5% . . . and a sum of the weight percentages of the components is 100%.” In particular, Example 7 of Xiao (which I analyzed and discussed above) discloses 0.5 wt% nickel. Thus, the range of nickel disclosed by Xiao falls within the range claimed in Claim 4 of the ‘653 Patent.

- c. **“said nickel forms galvanically-active in situ precipitate in said magnesium composite.”**

137. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” Xiao at ¶ 0026.

138. A POSITA in April 2014 would have understood that a precipitate would necessarily be formed in place and that the “composite microparticles” disclosed by Xiao are the

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same as the claimed “precipitate” (i.e. “something having a new phase different from what existed before” under Patent Owner’s proposed definition). Xiao would have further disclosed to the POSITA in April 2014 that the corrosion rate of its novel magnesium alloys is accelerated by the formation of micro-batteries between the boundary of the matrix and the grains (i.e. intermetallic composites) of the magnesium alloy. *Id.* A POSITA in April 2014 would have understood this reference to micro-batteries to be a reference to the galvanic activity of *in situ* precipitates. Consequently, all of the limitations of Dependent Claim 4 are taught by Xiao.

3. Dependent Claim 5

a. “The magnesium composite as defined in claim 1, wherein said additive material includes copper,”

139. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 1 to a POSITA in April 2014.

140. The overall teaching of Xiao notes the use of copper as an additive material. See, e.g., Xiao at ¶ 0026. As I discussed above, Example 7 of Xiao particularly discloses intermediate alloys Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc are used as additive materials. A POSITA in April 2014 would have understood that the intermediate alloy Al-Cu contains copper. Accordingly, Example 7 of Xiao discloses this element, in accordance with Patent Owner’s definition of “additive material.”

b. “said copper constitutes about 0.05-35 wt % of said magnesium composite,”

141. Claim 2 of Xiao discloses “Cu: 0.05 to 5%, . . . and a sum of the weight percentages of the components is 100%.” In particular, Example 7 of Xiao (which I analyzed and discussed above) disclosed 0.1% copper. Thus the range of copper disclosed by Xiao falls within the range claimed in Claim 5 of the ‘653 Patent.

c. “said copper forms galvanically-active in situ precipitate in said magnesium composite.”

142. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026.

143. A POSITA in April 2014 would have understood that a precipitate would necessarily be formed in place and that the “composite microparticles” disclosed by Xiao are the same as the claimed precipitate (under Patent Owner’s proposed definition). Xiao would have further disclosed to the POSITA in April 2014 that the corrosion rate of its novel magnesium alloys is accelerated by the formation of micro-batteries between the boundary of the matrix and the grains (i.e. intermetallic composites) of the magnesium alloy. *Id.* A POSITA in April 2014 would have understood this reference to micro-batteries to be a reference to the galvanic activity of the *in situ* precipitate. Consequently, all of the limitations of Dependent Claim 5 are taught by Xiao.

4. Dependent Claim 11

a. “The magnesium composite as defined in claim 1, wherein said additive material is a metal or metal alloy.”

144. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 1 to a POSITA in April 2014.

145. The overall teaching of Xiao notes the use of a variety of metals as additive materials. See, e.g., Xiao at ¶ 0026. As I discussed above, Example 7 of Xiao particularly discloses intermediate alloys Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc are used as additive materials. A POSITA in April 2014 would have understood that all of these intermediate alloys contain metal (i.e., aluminum, iron, nickel, silver, copper, zirconium, and titanium) and that

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zinc is a metal. Accordingly, Example 7 of Xiao discloses this element, in accordance with Patent Owner's definition of "additive material" and, thus, all of the limitations of Dependent Claim 11 are taught by Xiao.

5. Independent Claim 29

a. "A dissolvable magnesium alloy composite"

146. Xiao discloses "a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy..." Xiao at ¶ 0026, ll. 1-9.

147. Thus, Xiao's disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of "a dissolvable magnesium composite."

b. "for use in a ball or other tool component in a well drilling or completion operation,"

148. Xiao discloses that the cast magnesium alloy produced "can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique." *Id.* at ¶ 0001. A POSITA would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. "said dissolvable magnesium alloy composite comprising 60-95 wt % magnesium;"

149. Claim 1 of Xiao discloses a "magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%." As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15), leaving 85 to 60 wt% for the magnesium. The Examples of Xiao disclose a range of magnesium

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from 54.5 wt% - 79.2 wt%. Thus, Xiao discloses a range of magnesium of 54.5 wt% to 85 wt %, which overlaps and covers most of the claimed range. Accordingly, Xiao teaches this limitation of the claim.

d. “[said dissolvable magnesium alloy composite comprising] 0.01-1 wt % zirconium;”

150. Claim 2 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Example 7 of Xiao teaches 0.05 wt% Zirconium in a magnesium alloy. (Examples 1-6 also teach the use of Zirconium in a magnesium alloy in amounts ranging from 0.1 wt% to 0.5 wt%.) Thus, Xiao teaches zirconium within most of the claimed range. Accordingly, Xiao teaches this limitation of the claim.

e. “and about 0.05-45 wt % of a secondary metal [... said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron]”

151. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 of Xiao discloses that the “magnesium alloy according to claim 1, further comprising trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2.

152. These metallic elements are found in the additive materials generally disclosed by Xiao (*i.e.*, intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ti) (Xiao at ¶ 0023) and particularly described in association with Example 7 of Xiao (*Id.* at ¶¶ 0057 - 0060) for which I have already

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calculated (and set forth above) the specific weight percentage (ranges) of each additive material (which has been defined by the Patent Owner as “a material that is added” (see Paragraph 78 of my Declaration)) set forth in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc).

153. In particular, the additive materials aluminum-iron with 30 wt% iron, aluminum-nickel with 45 wt% nickel, and aluminum-copper with 40 wt% copper, which each have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao, also fall well within the range of about 0.05 wt% to 45 wt% of the mixture. For example, the ~~aluminum-iron~~ additive constitutes 3.3 wt% of the mixture (*i.e.*, 1%/0.30); the ~~aluminum-nickel~~ additive constitutes 1.1 wt% of the mixture (*i.e.*, 0.5%/0.45); and the ~~aluminum-copper~~ additive constitutes 0.25 wt% of the mixture (*i.e.*, 0.1%/0.40). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, and Al-Cu, **and** Al-Ti intermediate alloys constituting about 0.05 wt% to 45 wt% of the mixture.

154. Thus, Xiao discloses the inclusion of secondary metals in a magnesium composite within weight percentage ranges within the claimed range. Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running from 0.05 wt % (*i.e.*, the low end of the ~~Copper, Nickel, and Iron, and Titanium~~ ranges) to 15.5 wt % (*i.e.*, the accumulation of the high end of the ~~Copper, Nickel, Iron, and Titanium~~ ranges (5 wt % + 5 wt % + 5 wt % + 0.5 wt %)). A POSITA in April 2014 would have also recognized that the accumulated weight percentages of all of the secondary metals in Example 7 of Xiao (using the alloy compositions discussed above) would have been 9.65 wt%

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(i.e., 3.3 wt% + 1.1 wt% + 0.25 wt% + 5.0 wt%), also within the claimed range. Thus, Xiao teaches secondary metals having 0.05 to 15.5 wt%. Accordingly, Xiao teaches this limitation of the claim.

- f. **“[a secondary metal] to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”**

155. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

156. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026. Thus, all of the limitations of this claim element are disclosed by Xiao.

- g. **“said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron,”**

157. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

the components is 100%.” Of the additive materials taught in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Fe, Al-Ni, Al-Co, and Al-Ti contain copper, nickel, titanium and iron. This claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches four candidates to serve as the secondary metal of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe).

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

158. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

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Xiao at ¶ 0064.

159. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

160. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

161. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the dissolution rate disclosed in Xiao both above and below 90°C are both well above the claimed floor of “at least 5 mg/cm²/hr,” (i.e. at least three

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times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor “at least of 5 mg/cm²/hr.” Consequently, Xiao discloses this element of the claim.

162. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 29 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

6. Independent Claim 37

a. “A dissolvable magnesium alloy composite”

163. Xiao discloses a “magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

164. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a dissolvable magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

165. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. “said dissolvable magnesium alloy composite comprising 60-95 wt % magnesium;”

166. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15), leaving 85 to 60 wt% for the magnesium. The Examples of Xiao disclose a range of magnesium from 54.5 wt% - 79.2 wt%. Thus, Xiao discloses a range of magnesium of 54.5 wt% to 85 wt %, which overlaps and covers most of the claimed range. Accordingly, Xiao teaches this limitation of the claim.

d. “[said dissolvable magnesium alloy composite comprising . . .] 0.05-6 wt % zinc; 0.01-1 wt % zirconium;”

167. Claim 1 of Xiao discloses “Al: 13 to 25%, Zn: 2 to 15%,” and Claim 2 of Xiao discloses secondary metals of “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.”

168. Thus, Xiao discloses a dissolvable magnesium alloy composite including weight ranges of zinc (Zn) and zirconium (Zr), which overlap a portion of the ranges required by this claim element for those metallic elements. Accordingly, Xiao teaches this limitation of the claim.

e. “and [said dissolvable magnesium alloy composite comprising . . .] about 0.05-45 wt % of a secondary metal [. . . said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron]”

169. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal

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within the claimed weight percentage [and specific metal] limitations of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running from 0.05 wt % (*i.e.*, the low end of either of the Copper, Nickel, or Titanium ranges) to 15.5 wt % (*i.e.*, the accumulation of the high end of the Copper, Nickel, Titanium, and Iron ranges (5 wt % + 5 wt % + 0.5 wt% + 5 wt%)). Hence, Xiao discloses the inclusion of secondary metal in a magnesium composite (including one or more metals (*i.e.*, copper, nickel, titanium, and iron)) in amounts that overlap at least a portion of the range required by this claim element. Accordingly, Xiao teaches this limitation of the claim.

f. “[a secondary metal] to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”

170. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($\text{Mg}_{17}\text{Al}_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

171. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the

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magnesium alloy.” *Id.* at ¶ 0026. These elements are among the claimed “secondary metals” disclosed by Xiao. Thus, all of the limitations of this claim element are disclosed by Xiao.

- g. “said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron,”**

172. Xiao discloses one or more of the “secondary metals,” including copper (Cu), nickel (Ni), titanium (Ti) and iron (Fe) as follows: “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%.” Xiao at Claim 2. Of the additive materials taught in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Fe, Al-Ni, Al-Cu, and Al-Ti contain copper, nickel, titanium and iron. This claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches four candidates to serve as the secondary metal of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe).

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

173. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

174. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

175. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

176. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

177. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 37 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

7. Independent Claim 41

a. “A dissolvable magnesium alloy composite”

178. Xiao discloses “a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

179. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a dissolvable magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

180. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. “said dissolvable magnesium alloy composite comprising over 50 wt % magnesium;”

181. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15), leaving 85 to 60 wt% for the magnesium. The Examples of Xiao disclose a range of magnesium from 54.5 wt% - 79.2 wt%. Thus, Xiao discloses a range of magnesium of 54.5 wt% to 85 wt %, which covers most of the claimed range. Accordingly, Xiao teaches this limitation of the claim.

d. “[said dissolvable magnesium alloy composite comprising . . .] one or more metals selected from the group consisting of 0.5-10

wt % aluminum, 0.1-2 wt % zinc, 0.01-1 wt % zirconium, and 0.15-2 wt % manganese;”

182. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%,” and Claim 2 of Xiao discloses secondary metals of “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.”

183. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the “main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium.” *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032.

184. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao’s disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates disclosed by Xiao.

185. Thus, Xiao discloses a novel magnesium alloy including at least two metals, *i.e.*, zinc and zirconium, at weight percentages within the respective claimed ranges of this claim element of the '653 Patent. Xiao also discloses two examples of a prior art magnesium alloy, AZ91D that includes at least four metals, *i.e.*, aluminum, zinc, zirconium, and manganese within the respectively claimed weight percentage ranges of this claim element of the '653 Patent. Accordingly, Xiao discloses all of the limitations of this claim element.

- e. **“and [said dissolvable magnesium alloy composite comprising. . .] about 0.05-45 wt % of a secondary metal [. . . said secondary metal including one or more metals selected from the group consisting of copper, nickel, and cobalt]”**

186. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal within the claimed weight percentage [and specific metal] limitations of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running from 0.05 wt % (*i.e.*, the low end of the Copper, Nickel or Titanium ranges) to 15.5 wt % (*i.e.*, the accumulation of the high end of the Copper, Nickel, Titanium, and Iron ranges (5 wt % + 5 wt % + 0.5 wt% + 5 wt%)). Accordingly, Xiao teaches this limitation of the claim.

- f. **“[a secondary metal] to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”**

187. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

188. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026. These elements are among the claimed “secondary metals” disclosed by Xiao. Thus, all of the limitations of this claim element are disclosed by Xiao.

- g. **“said secondary metal including one or more metals selected from the group consisting of copper, nickel, and cobalt,”**

189. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Of the additive materials taught in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Ni, and Al-Cu contain copper and nickel. This

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claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches two candidates to serve as the secondary metal of this claim: Copper (Cu) and Nickel (Ni).

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

190. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

191. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed

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in this table in Xiao by 1,000.

192. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

193. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well

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above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

194. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 41 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

8. Dependent Claim 43

a. **“The dissolvable magnesium composite as defined in claim 41, wherein said secondary metal includes nickel,”**

195. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 41 to a POSITA in April 2014.

196. Claim 2 of Xiao discloses a “magnesium alloy according to claim 1, further comprising trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao discloses the use of nickel as a secondary metal.

b. **“said nickel forms galvanically-active in situ precipitate in said magnesium composite.”**

197. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” Xiao at ¶ 0026.

198. A POSITA in April 2014 would have understood that a precipitate would necessarily be formed in place and that the “composite microparticles” disclosed by Xiao are the same as the claimed “precipitate” (i.e. “something having a new phase different from what existed

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before” under Patent Owner’s proposed definition). Consequently, all of the limitations of Dependent Claim 43 are taught by Xiao.

9. Independent Claim 45

a. “A dissolvable magnesium alloy composite”

199. Xiao discloses “a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag **which can** enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

200. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a dissolvable magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

201. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA in August 2014 would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. “said dissolvable magnesium alloy composite comprising over 50 % magnesium;”

202. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15), leaving 85 to 60 wt% for the magnesium. The Examples of Xiao disclose a range of magnesium from 54.5 wt%

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~ 79.2 wt%. Thus, Xiao discloses a range of magnesium of 54.5 wt% to 85 wt %, which is over 50 wt % magnesium, thus fully disclosing this element of the claim.

- d. **“[said dissolvable magnesium alloy composite comprising . . .] one or more metals selected from the group consisting of 0.1-3 wt % zinc, 0.01-1 wt % zirconium, 0.05-1 wt % manganese, 0.0002-0.04 wt % boron, and 0.4-0.7 wt % bismuth;”**

203. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%,” and Claim 2 of Xiao discloses secondary metals of “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.”

204. Thus, even though this claim element only requires certain weight percentages of one of zinc, zirconium, manganese, boron or bismuth, Xiao actually discloses a dissolvable magnesium alloy composite including weight ranges of both zinc (Zn) and zirconium (Zr), which overlap a portion of the ranges required by this claim element for those metallic elements. Accordingly, Xiao teaches this limitation of the claim.

- e. **“and [said dissolvable magnesium alloy composite comprising] about 0.05-45 wt % of a secondary metal [. . . said secondary metal including one or more metals selected from the group consisting of copper, nickel, and cobalt]”**

205. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal within the claimed weight percentage [and specific metal] limitations of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running

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from 0.05 wt % (*i.e.*, the low end of the Copper and Nickel ranges) to 10 wt % (*i.e.*, the accumulation of the high end of the Copper and Nickel ranges (5 wt % + 5 wt %)). Accordingly, Xiao meets this element of the claim.

f. “[a secondary metal] to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”

206. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($\text{Mg}_{17}\text{Al}_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

207. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026. These elements are among the claimed “secondary metals” disclosed by Xiao. Thus, all of the limitations of this claim element are disclosed by Xiao.

g. “said secondary metal including one or more metals selected from the group consisting of copper, nickel, and cobalt,”

208. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of

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the components is 100%.” Of the additive materials taught in Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Ni, and Al-Cu contain copper and nickel. This claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches two candidates to serve as the secondary metal of this claim: Copper (Cu) and Nickel (Ni).

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

209. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

210. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent

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express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

211. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

212. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

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213. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 45 of the '653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner's definitions (set forth in Paragraph 78 of my Declaration).

10. Independent Claim 49

a. "A magnesium composite"

214. Xiao discloses a "magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy..." Xiao at ¶ 0026, ll. 1--9.

215. Thus, Xiao's disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of "a magnesium composite."

b. "[magnesium composite] that includes in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite,"

216. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes "the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy," and "the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy." *Id.* at ¶ 0026.

217. Xiao further discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” Xiao at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate.

218. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are naturally and necessarily generated by the *in situ* reaction between magnesium and any and all of the disclosed metal additives forming *in situ* precipitate. Thus, all of the limitations of this claim element are disclosed by Xiao.

c. “said magnesium composite comprising a mixture of magnesium or a magnesium alloy and an additive material,”

219. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace . . . , next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022.

220. Xiao discloses that these “intermediate alloys” are Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti, which are heated to dry and then added to the magnesium-aluminum alloy melt.” Xiao at ¶ 0023. These intermediate alloys meet Patent Owner’s proposed definition of “additive material,” i.e. “a material that is added.”

221. The addition of one or more of these intermediate alloys to the melted magnesium alloy necessarily results in a mixture of magnesium or magnesium alloy and the additive material. Thus, Xiao discloses all of the limitations of this claim element.

- d. **“said additive material constituting about 0.05-45 wt % of said mixture, [said additive material includes one or more metals selected from the group consisting of copper, nickel, titanium, iron, and cobalt]”**

222. Claim 1 of Xiao discloses: a “magnesium alloy, comprising the components at the weight percentages as follows: **Al: 13 to 25%, Zn: 2 to 15%**, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 discloses: a “magnesium alloy, according to Claim 1, further comprising the trace elements at the weight percentages as follows: **Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%**; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2.

223. These metallic elements are found in the additive materials generally disclosed by Xiao (*i.e.*, intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ti) (Xiao at ¶ 0023) and particularly described in association with Example 7 of Xiao (*Id.* at ¶¶ 0057 - 0060) for which I have already calculated (and set forth above) the specific weight percentage (ranges) of each additive material (which has been defined by the Patent Owner as “a material that is added” (see Paragraph 78 of my Declaration)) set forth in Example 7 of Xiao (*i.e.* Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc).

224. In particular, the additive materials aluminum-iron with 30 wt% iron, aluminum-nickel with 45 wt% nickel, and aluminum-copper with 40 wt% copper, which each have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao, also fall well within the range of about 0.05 wt% to 45 wt% of the mixture. For example, the ~~aluminum-iron~~ additive constitutes 3.3 wt% of the mixture (*i.e.*, 1%/0.30); the ~~aluminum-nickel~~ additive constitutes 1.1 wt% of the mixture (*i.e.*, 0.5%/0.45); and the ~~aluminum-copper~~ additive constitutes 0.25 wt% of the mixture (*i.e.*, 0.1%/0.40). A POSITA in April 2014 would have also recognized that the accumulated weight percentages of all of the

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secondary metals in Example 7 of Xiao (using the alloy compositions discussed above) would have been 9.65 wt% (*i.e.*, 3.3 wt% + 1.1 wt% + 0.25 wt% + 5.0 wt%), also within the claimed range. Thus, Xiao teaches secondary metals having 0.05 to 15.5 wt%. Accordingly, Xiao teaches this limitation of the claim.

- e. **“said additive material includes one or more metals selected from the group consisting of copper, nickel, titanium, iron, and cobalt,”**

225. Xiao discloses one or more of the “secondary metals,” including copper (Cu), nickel (Ni), titanium (Ti) and iron (Fe) as follows: “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%.” Xiao at Claim 2. Of the additive materials taught in Example 7 of Xiao (*i.e.* Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Fe, Al-Ni, Al-Cu, and Al-Ti contain copper, nickel, titanium and iron. This claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches four candidates to serve as the secondary metal of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Accordingly, all of the elements of this claim limitation are disclosed by Xiao.

- f. **“said magnesium composite including in situ precipitation of galvanically-active intermetallic phases that include [sic] said additive material,”**

226. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which

[micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

227. Xiao further discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate. As noted above, at least Fe, Cu, and Ni are “additive materials.” Consequently, the in situ precipitation of galvanically-active intermetallic phases will include one or more of these additive materials. Thus, Xiao discloses all of this element of this claim limitation.

- g. **“said additive material located in sufficient quantities in said galvanically-active intermetallic phases so as to obtain a composition and morphology of said galvanically-active intermetallic phases such that a galvanic corrosion rate along said galvanically-active intermetallic phases causes said magnesium composite to have a dissolution rate of at least at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

228. Claim 2 of Xiao discloses: a “magnesium alloy, according to claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2. Thus, Xiao discloses four metals that could serve as the claimed “additive material” and have weight % quantities that fall within the range of this claim—i.e., they are located in “sufficient quantities.”

229. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the

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magnesium alloy.” *Id.* ¶ 0026. A POSITA would understand that the galvanically-active intermetallic phases (“composite micro-particles”) have a morphology that enhances the corrosion dissolution rate of the alloy due to a larger number of smaller particles throughout the microstructure. A POSITA would also understand the relationship between “composite micro-particles” and morphology of the galvanically-active intermetallic phases.

230. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement in that table are units regularly used by POSITAs to express measurements of dissolution. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

231. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent

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express the claimed dissolution rate in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

2. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

232. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

233. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 49 of the '653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner's definitions (set forth in Paragraph 78 of my Declaration).

11. Dependent Claim 69

- a. **"The magnesium composite as defined in claim 49, wherein said additive material has a melting point temperature that is 100°C. greater than a melting temperature of said magnesium or magnesium alloy."**

234. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 49 to a POSITA in April 2014.

235. A POSITA would have understood "melting temperature" in this claim element to be a reference to the smelting temperature or temperature of the melt when the additive material is being added to the magnesium or magnesium alloy, not the "melting point temperature" as that measurement is used for the additive material.

236. Xiao generally discloses "loading pure magnesium and pure aluminum into a smelting furnace and increasing the temperature to 700 to 730 °C, next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting and increasing the temperature to 740 to 780°C" Xiao at ¶¶ 0021–0022; see also *Id.* at Claim 5 ("the melting temperature of the pure magnesium and pure aluminum is from 700 to 730 °C.")

237. Examples 1-7 of Xiao teach different melting or smelting temperatures for the magnesium-aluminum alloy, ranging from a low of 700°C in Example 1 to a high of 730 °C in Examples 2, 5, and 7. Xiao ¶¶ 0034–0060. In each Example, "[a]fter melting" the intermediate

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alloy are “added into the resulting magnesium-aluminum alloy melt, and at the same time the temperature is raised” to a different temperature depending on the example. *Id.*

238. The ~~additive materials~~ noted above are one or more of the ~~intermediate alloys~~: Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti. *Id.* at ¶ 0023. As I noted in Paragraph 78 of Declaration, Patent Owner has taken the position that “melting point temperature” would have meant “temperature at which liquid is formed” to a POSITA in April 2014.

239. As already noted in Paragraph 152 of my Declaration (above), based on the typical phase diagrams, a POSITA in April 2014 would have recognized that ~~Al-Fe~~ had a variable melting point temperature ranging from 1538°C (pure iron) down to 652°C for a eutectic point near 99 wt% aluminum; ~~Al-Ni~~ had a variable melting point temperature that ranges from 1640°C down to 640°C (depending upon the alloy mixture); and ~~Al-Cu~~ had a variable melting point temperature ranging from 548°C up to 1084°C (depending upon the alloy mixture). A POSITA in April 2014 would have been able to determine the specific melting point temperature of a specific alloy mixture based on the content of these typical phase diagrams.

240. Example 7 specifically discloses a melting or smelting temperature of 730°C. Xiao at ¶ 0060. I specifically analyzed Example 7 of Xiao above to determine (using particular intermediate alloy compositions) the melting point temperatures of the intermediate alloys added. As a result, it is my opinion that a POSITA in April 2014 would recognized from Example 7 of Xiao that at least an ~~aluminum-nickel~~ additive having 45 wt% nickel has a melting point temperature of 854°C which is 100°C greater than the melting or smelting temperatures of the magnesium aluminum alloy used in Example 7 (*i.e.*, 730°C) and otherwise taught generally by Xiao (*i.e.*, 700-730°C). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions could have fallen within the teachings of Example 7 of Xiao as

well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, **and** Al-Cu intermediate alloys that would have had melting point temperatures that were 100°C. greater than the smelting temperatures of the magnesium alloy generally taught by Xiao (*i.e.*, 700-730°C).¹⁴ Thus, Xiao discloses all of the limitations of Dependent Claim 69.

12. Dependent Claim 70

- a. **“The magnesium composite as defined in claim 49, wherein said magnesium composite is at least partially included in a down hole well component,”**

241. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 49 to a POSITA in April 2014.

242. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA in August 2014 would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

- b. **“said down hole well component including one or more components selected from the group consisting of a sleeve, frac**

¹⁴ It is worth pointing out—although I would disagree with either notion—that if Patent Owner argues either that “melting temperature” was a typographical error (which I doubt given the other claims that say “melting point temperature” and the numerous Certificates of Correction that did not address this issue) or simply argues that “melting temperature of said magnesium or magnesium alloy” means “melting point temperature of said magnesium or magnesium alloy,” not only would the Al-Ni intermediate alloy with 45 wt% nickel exceed the *melting point temperature* of pure magnesium (*i.e.*, 650°C) and the *melting point temperature of the initially loaded magnesium-aluminum alloy* (*i.e.*, 438°C) of Example 7 using the constituents discussed in Paragraphs 114-118 of my Declaration (*i.e.*, a composition of 78.5 wt% Mg and 21.5 wt% Al), by at least 100°C, but also the Al-Cu, Al-Fe, Al-Ti and Al-Zr intermediate alloys, having the constituents set forth in those Paragraphs of my Declaration would similarly exceed that limitation.

ball, hydraulic actuating tooling, tube, valve, valve component, or plug.”

243. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA in August 2014 would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim. Consequently, all of the limitations of Dependent Claim 70 are taught by Xiao.

13. Independent Claim 73

a. “A dissolvable magnesium composite”

244. Xiao discloses “a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag **which can** enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

245. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a dissolvable magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

246. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA in August 2014 would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

- c. **“said dissolvable magnesium composite includes in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite,”**

247. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

248. Xiao further discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” Xiao at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate.

249. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are naturally and necessarily generated by the *in situ* reaction between magnesium and any and all of the disclosed metal additives forming *in situ* precipitate. Thus, all of the limitations of this claim element are disclosed by Xiao.

d. “said magnesium composite comprising a mixture of magnesium or a magnesium alloy and an additive material,”

250. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace . . . , next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022.

251. Xiao discloses that these “intermediate alloys” are Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti, which are heated to dry and then added to the magnesium-aluminum alloy melt.” Xiao at ¶ 0023. These intermediate alloys meet Patent Owner’s proposed definition of “additive material,” i.e. “a material that is added.”

252. The addition of one or more of these intermediate alloys to the melted magnesium alloy necessarily results in a mixture of magnesium or magnesium alloy and the additive material. Thus, Xiao discloses all of the limitations of this claim element.

e. “said additive material constituting about 0.05 wt % of said mixture, said additive material is a metal or metal alloy,”

253. The overall teaching of Xiao notes the use of a variety of metals as additive materials. See, e.g., Xiao at ¶ 0026. For instance, Claim 2 of Xiao discloses a “magnesium alloy according to claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* This disclosure references a number of different metal additive materials (i.e. copper, nickel, zirconium and titanium) each of which Xiao teaches may constitute about 0.05wt % of the mixture. Thus, Xiao fully discloses these limitations of this claim element.

- f. **“said additive material includes one or more metals selected from the group consisting of copper, nickel, titanium, iron, silicon, and cobalt,”**

254. Of the additive metal materials discussed in the immediately preceding paragraph (i.e. copper, nickel, zirconium and titanium), each disclosed as one of the potential options among six metals. This claim element requires the additive material include even only one of these metals. Accordingly, Xiao discloses this element of the claim.

- g. **“said magnesium composite including in situ precipitation of galvanically-active intermetallic phases that include said additive material,”**

255. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

256. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026. A POSITA in August 2014 would have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate. As noted above, at least Fe, Cu, and Ni are “additive materials.” Consequently, the in situ precipitation of

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galvanically-active intermetallic phases will include one or more of these additive materials. Thus, Xiao discloses all of the limitations of this claim element.

- h. **“said additive material located in sufficient quantities in said galvanically-active intermetallic phases so as to obtain a composition and morphology of said galvanically-active intermetallic phases such that a galvanic corrosion rate along said galvanically-active intermetallic phases causes said magnesium composite to have a dissolution rate of at least at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

257. As already noted above, other limitations in this claim require that “additive material” be limited to 0.05 wt% of one or more of copper, nickel, zirconium and/or titanium metals. Claim 2 of Xiao discloses: a “magnesium alloy, according to claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2. Thus, Xiao discloses “sufficient quantities” of each of the copper, nickel, zirconium and titanium (which has been defined by the Patent Owner as “enough additive material” (see Paragraph 78 of my Declaration)).

258. Xiao further discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* ¶ 0026. A POSITA would understand that the galvanically-active intermetallic phases (“composite micro-particles”) have a morphology that enhances the corrosion dissolution rate of the alloy due to a larger number of smaller particles throughout the microstructure. A POSITA would also understand the relationship between “composite micro-particles” and morphology of the galvanically-active intermetallic phases. Thus, Xiao further teaches these limitations of this claim element.

259. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution ($\text{g}\cdot\text{cm}^{-2}\cdot\text{h}^{-1}$)	Decomposition rate at 93 °C in 3% KCl solution ($\text{g}\cdot\text{cm}^{-2}\cdot\text{h}^{-1}$)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

260. Xiao provides dissolution rates in $\text{g}/\text{cm}^2/\text{hr}$, while the claims of the '653 Patent state dissolution rates in $\text{mg}/\text{cm}^2/\text{hr}$. A POSITA in April 2014 would have known that converting from $\text{g}/\text{cm}^2/\text{hr}$ to $\text{mg}/\text{cm}^2/\text{hr}$, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

261. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

262. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of the claim is also disclosed by Xiao.

263. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 73 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

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B. Ground II: Claims 8, 25, 33, 55, and 74 are anticipated, or at least made obvious, by Xiao.

264. It is my opinion that Xiao either anticipates or least makes obvious Claims 25, 33, 55, and 74 of the '653 Patent.

1. Dependent Claim 8 - "The magnesium composite as defined in claim 1, wherein said magnesium composite is subjected to a surface treatment to improve a surface hardness of said magnesium composite, said surface treatment including peening, heat treatment, aluminizing, or combinations thereof."

265. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 1 to a POSITA in April 2014.

266. Xiao does not disclose or otherwise suggest subjecting a magnesium composite to a surface treatment (i.e. peening, heat treatment, aluminizing or combinations thereof) nor does it teach that surface treatment would achieve any of the benefits set forth in Claim 8 of the '653 Patent.

267. Xiao discloses that in a particular U.S. Patent a method is disclosed "for preparing a composite material having a decomposable multilayer coated core-shell structure (U.S. Patent No. US2011/0132143A1, 2011). As discussed within Xiao, this U.S. patent publication discloses an electroless plating process applied on the surface of particles of nanoscale core metal powders (such as magnesium, aluminum, zinc, manganese and alloys thereof) to coat multiple layers of a nano-shell of different metals or metal oxides, such as Al, Ni, Al₂O₃, and the like, and then the composite powder is sintered to form a nanocomposite material having certain decomposition feature [sic]." Xiao at ¶ 0002.

268. A POSITA in April 2014 would have understood that the sintering discussed within Xiao was a well-known type of surface treatment that can be used to improve the surface hardness of the sintered metal. See, e.g., Ex. 1203 ("Powder metal technology is well known to the persons

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skilled in the art and generally comprises the formation of metal powders which are compacted and then subjected to an elevated temperature so as to produce a sintered product.”). Consequently, Xiao teaches a magnesium composite subjected to a heat treating surface treatment to improve surface hardness of the magnesium.

2. Independent Claim 25

a. “A dissolvable magnesium alloy composite”

269. Xiao discloses “a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag **which can** enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

270. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a dissolvable magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

271. Xiao discloses that the cast magnesium alloy “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA in August 2014 would have understood that a tripping ball was a type of tool component in an oil well drilling operation.

c. “said dissolvable magnesium alloy composite comprising at least 85 wt % magnesium;”

272. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15).

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Thus, claim 1 of Xiao discloses a range of magnesium including 85 wt %. This disclosure of Xiao overlaps the claimed range.

273. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the “main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium.” *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032. As such, the total range of the non-magnesium elements disclosed in the comparative or prior art alloys of Xiao is 88.8% to 91.2%. Thus, Xiao discloses a range of magnesium of at least 85 wt %.

274. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao’s disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates.

- d. **“[said dissolvable magnesium alloy composite comprising . . .]
one or more metals selected from the group consisting of 0.5-10**

wt % aluminum, 0.05-6 wt % zinc, 0.01-3 wt % zirconium, and 0.15-2 wt % manganese;"

275. Claim 1 of Xiao discloses a "magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%," and Claim 2 of Xiao discloses secondary metals of "Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%."

276. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the "main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium." *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032.

277. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao's disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that "[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy." *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates disclosed by Xiao.

278. Thus, Xiao discloses a novel magnesium alloy including at least two metals, *i.e.*, zinc and zirconium, at weight percentages within the respective claimed ranges of this claim element of the '653 Patent. Xiao also discloses two examples of a prior art magnesium alloy, AZ91D that includes at least four metals, *i.e.*, aluminum, zinc, zirconium, and manganese within the respectively claimed weight percentage ranges of this claim element of the '653 Patent. Accordingly, Xiao meets this element of the claim.

- e. **“and [said dissolvable magnesium alloy composite comprising . . .] about 0.05-45 wt % of a secondary metal [. . . said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron]”**

279. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal within the claimed weight percentage [and specific metal] limitations of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running from 0.05 wt % (*i.e.*, the low end of the Copper, Nickel or Titanium ranges) to 15.5 wt % (*i.e.*, the accumulation of the high end of the Copper, Nickel, Titanium, and Iron ranges (5 wt % + 5 wt % + 0.5 wt% + 5 wt%)).

- f. **“to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”**

280. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the

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magnesium alloy.” *Id.* at ¶ 0026. These elements are among the claimed “secondary metals” disclosed by Xiao. Thus, Xiao discloses all of the limitations of this claim element.

- g. “said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron,”**

281. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Accordingly, Xiao teaches this element of the claim.

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

282. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

283. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

284. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45

Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

285. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the dissolution rate both above and below 90°C are both well above (at least three times) the claimed floor of “at least 5 mg/cm²/hr,” it is my opinion that a POSITA in April 2014 would have expected the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of the claim is also disclosed by Xiao.

286. While none of the examples disclosed in Xiao include 85% of magnesium, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao’s disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy which appear to make the surprisingly large improvement in dissolution rates. The improvement is illustrated, for instance, by Example 1 of Xiao which comprises a magnesium alloy composite comprising about 77% magnesium, zinc within the claimed range (0.05-6 wt%), zirconium within the claimed range (0.01-3 wt%), and nickel (“the secondary metal”) within the claimed range (0.05 - 45 wt%). Comparing the constituents of the “comparative example” (which is AZ91D magnesium alloy) with Example 1 (and the other examples) of Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art of the

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“comparative example”) provides for Xiao’s surprising increase in dissolution rate over the prior art. It is my opinion that a POSITA in April 2014 would have recognized that the addition of 8 wt% magnesium (to make the total magnesium content at least 85%) in Example 1 by reducing the weight percentages of Aluminum, Zinc, Silver, Titanium, and Zirconium would result in a composition with a dissolution rate at 90°C in a 3% KCl solution of “at least of 5 mg/cm²/hr.”

3. Independent Claim 33

a. “A dissolvable magnesium alloy composite”

287. Xiao discloses “a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

288. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a magnesium composite.”

b. “for use in a ball or other tool component in a well drilling or completion operation,”

289. Xiao discloses that the cast magnesium alloy, “can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique.” *Id.* at ¶ 0001. A POSITA would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. “said dissolvable magnesium alloy composite comprising 60-95 wt % magnesium;”

290. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15),

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leaving 85 to 60 wt% for the magnesium. The Examples of Xiao disclose a range of magnesium from 54.5 wt% - 79.2 wt%. Thus, Xiao discloses a range of magnesium of 54.5 wt% to 85 wt %, which overlaps and covers most of the claimed range. Accordingly, Xiao teaches this limitation of the claim.

d. “[said dissolvable magnesium alloy composite comprising . . .] 0.5-10 wt % aluminum; 0.05-6 wt % zinc; 0.15-2 wt % manganese;”

291. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Thus, Xiao discloses a range of zinc (2-15%) that overlaps and covers most of the claimed range (0.05-6 wt%). Accordingly, Xiao teaches this limitation of the claim.

292. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the “main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium.” *Id.* at ¶ 0003. Thus, Xiao also discloses the inclusion of 8.3 to 9.7 wt % aluminum, 0.35 to 1.0 wt % zinc, and 0.15 to 0.5 wt% manganese within each of the specifically claimed ranges in this claim element of the ‘653 Patent.

293. Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao’s disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy, which “improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of “Comparative example 1” in Xiao (an AZ91D magnesium alloy) with the other examples in Table 1 of Xiao (Xiao at ¶ 0061) the introduction of

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Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates. A POSITA in April 2014 would have recognized that the advantages of the novel magnesium composite found in the addition of iron copper, and/or nickel would have also directly benefited the prior art example and, thus, a POSITA would have recognized the desirability of combining those separate disclosures in Xiao.

294. Thus, Xiao discloses a dissolvable magnesium alloy composite including weight ranges of aluminum, zinc and manganese, which overlap at least a portion of the ranges required by this claim element for those metallic elements. Accordingly, Xiao teaches all of these limitations of the claim element.

- e. **“and [said dissolvable magnesium alloy composite comprising . . .] about 0.05-45 wt % of a secondary metal [. . . said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron]”**

295. Claim 2 of Xiao discloses a “magnesium alloy according to claim 1 further comprising trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” Thus, Xiao teaches four candidates to serve as the secondary metal within the claimed weight percentage [and specific metal] limitations of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe). Moreover, as this claim internally defines “a secondary metal” as “including one or more metals,” Xiao also discloses a range of secondary metal running from 0.05 wt % (*i.e.*, the low end of the Copper, Nickel or Titanium ranges) to 15.5 wt % (*i.e.*, the accumulation of the high end of the Copper, Nickel, Titanium, and Iron ranges (5 wt % + 5 wt % + 0.5 wt% + 5 wt%)). Hence, Xiao discloses the inclusion of secondary metal in a magnesium composite (including one or more metals (*i.e.*, copper, nickel, titanium, and iron)) in amounts that

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overlap at least a portion of the range required by this claim element. Accordingly, Xiao teaches this limitation of the claim.

- f. **“[a secondary metal] to form a galvanically-active intermetallic particle that promotes corrosion of said dissolvable magnesium alloy composite,”**

296. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

297. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026. These elements are among the claimed “secondary metals” disclosed by Xiao. Thus, all of the limitations of this claim element are disclosed by Xiao.

- g. **“said secondary metal including one or more metals selected from the group consisting of copper, nickel, cobalt, titanium and iron,”**

298. Xiao discloses one or more of the “secondary metals,” including copper (Cu), nickel (Ni), titanium (Ti) and iron (Fe) as follows: “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%.” Xiao at Claim 2. Of the additive materials taught in

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Example 7 of Xiao (i.e. Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc), Al-Fe, Al-Ni, Al-Cu, and Al-Ti contain copper, nickel, titanium and iron. This claim element only requires the secondary metal include one of these metals. Thus, Xiao teaches four candidates to serve as the secondary metal of this claim: Copper (Cu), Nickel (Ni), Titanium (Ti), and Iron (Fe).

- h. “said magnesium alloy composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”

299. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement are the units used by POSITAs to measure dissolution rates. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

300. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express dissolution rates in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table in Xiao by 1,000.

301. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

302. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

303. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao would have fully disclosed each and every element of Claim 33 of the '653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner's definitions (set forth in Paragraph 78 of my Declaration).

4. Dependent Claim 55

- a. **"The magnesium composite as defined in claim 49, wherein said magnesium alloy includes at least 85 wt. % magnesium,"**

304. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 49 to a POSITA in April 2014.

305. Claim 1 of Xiao discloses a "magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%." As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15). Thus, claim 1 of Xiao discloses a range of magnesium including 85 wt %. This disclosure of Xiao overlaps the claimed range.

306. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the "main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium." *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032. As such, the total range of the non-magnesium elements disclosed in the comparative or prior art alloys of Xiao is 88.8% to 91.2%. Thus, Xiao discloses a range of magnesium of at least 85 wt %.

307. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao's disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that "[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy." *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates.

- b. **“and one or more metals selected from the group consisting of 0.5-10 wt. % aluminum, 0.05-6 wt. % zinc, 0.01-3 wt. % zirconium, and 0.15-2 wt. % manganese.”**

308. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%,” and Claim 2 of Xiao discloses secondary metals of “Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.”

309. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the “main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium.” *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032.

310. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao's disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that "[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy." *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates disclosed by Xiao.

311. Thus, Xiao discloses a novel magnesium alloy including at least two metals, *i.e.*, zinc and zirconium, at weight percentages within the respective claimed ranges of this claim element of the '653 Patent. Xiao also discloses two examples of a prior art magnesium alloy, AZ91D that includes at least four metals, *i.e.*, aluminum, zinc, zirconium, and manganese within the respectively claimed weight percentage ranges of this claim element of the '653 Patent. Accordingly, Xiao discloses all of the limitations of this claim element.

5. Independent Claim 74

a. "A dissolvable magnesium composite"

312. Xiao discloses "a magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy..." Xiao at ¶ 0026, ll. 1–9.

313. Thus, Xiao's disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of "a dissolvable magnesium composite."

b. "for use in a ball or other tool component in a well drilling or completion operation,"

314. Xiao discloses a cast magnesium alloy that "can be used as a tripping ball material for a multi-stage sliding sleeve staged-fracturing technique." *Id.* at ¶ 0001. A POSITA would have understood that a tripping ball was a type of tool component in an oil well drilling operation. Thus, Xiao teaches this limitation of the claim.

c. "said dissolvable magnesium composite includes in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite,"

315. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes "the β ($\text{Mg}_{17}\text{Al}_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy," and "the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy." *Id.* at ¶ 0026.

316. Xiao discloses that "[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy." *Id.* at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood

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this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate.

317. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are necessarily generated by the *in situ* reaction between magnesium and any and all of the disclosed metal additives forming *in situ* precipitate. Thus, all of the limitations of this claim element are disclosed by Xiao.

d. “said magnesium composite comprising a mixture of magnesium or a magnesium alloy and an additive material,”

318. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace . . . , next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022.

319. Xiao discloses that these “intermediate alloys” are Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti, which are heated to dry and then added to the magnesium-aluminum alloy melt.” *Id.* at ¶ 0023. These intermediate alloys meet Patent Owner’s proposed definition of “additive material,” i.e. “a material that is added.”

320. The addition of one or more of these intermediate alloys to the melted magnesium alloy necessarily results in a mixture of magnesium or magnesium alloy and the additive material. Thus, Xiao discloses all of the limitations of this claim element.

e. “said additive material constituting at least 0.1 wt % of said mixture, [...said additive material is a metal material selected from the group consisting of copper, nickel, and cobalt]”

321. Claim 1 of Xiao discloses: a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 discloses: a

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“magnesium alloy, according to claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2. Thus, Xiao discloses two metals that could serve as the claimed “additive material” and have weight % quantities that fall within the range of this claim element.

322. These metallic elements are found in the additive materials generally disclosed by Xiao (*i.e.*, intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ti) (Xiao at ¶ 0023) and particularly described in association with Example 7 of Xiao (*Id.* at ¶¶ 0057 - 0060) for which I have already calculated (and set forth above) the specific weight percentage (ranges) of each additive material (which has been defined by the Patent Owner as “a material that is added” (see Paragraph 78 of my Declaration)) set forth in Example 7 of Xiao (*i.e.* Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc).

323. In particular, the additive materials aluminum-iron with 30 wt% iron, aluminum-nickel with 45 wt% nickel, and aluminum-copper with 40 wt% copper, which each have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao, also fall well within the range of about 0.05 wt% to 45 wt% of the mixture. For example, the aluminum-iron additive constitutes 3.3 wt% of the mixture (*i.e.*, 1%/0.30); the aluminum-nickel additive constitutes 1.1 wt% of the mixture (*i.e.*, 0.5%/0.45); and the aluminum-copper additive constitutes 0.25 wt% of the mixture (*i.e.*, 0.1%/0.40). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, and Al-Cu intermediate alloys constituting at least 0.1 wt% of the mixture. Accordingly, this element of the claim is disclosed by Xiao. These metallic elements are found in

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the intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti (i.e., additives) of Xiao. Xiao at ¶ 0023.

f. “said magnesium in said magnesium composite constituting at least 85 wt %;”

324. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” As such, the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (i.e., 13 + 2) to 40% (i.e., 25 + 15). Thus, claim 1 of Xiao discloses a range of magnesium including 85 wt %. This disclosure of Xiao overlaps the claimed range.

325. Xiao also discloses a prior art magnesium alloy represented by Mg-Al-Zn (with AZ91D magnesium alloy being the most widely used) wherein the “main components of this alloy and the respective weight percentages are as follows: Al 8.3 to 9.7, Zn 0.35 to 1.0, Mn 0.15 to 0.5, and the remainder is magnesium.” *Id.* at ¶ 0003. Additionally, Xiao discloses a comparative example using AZ91D as a comparative alloy, wherein the composition of the AZ91D comparative alloy is 9 wt % Al, 1 wt % Zn, 0.3 wt % Zr, and 0.1 wt % Mn, with the remainder being magnesium. *Id.* at ¶ 0032. As such, the total range of the non-magnesium elements disclosed in the comparative or prior art alloys of Xiao is 88.8% to 91.2%. Thus, Xiao discloses a range of magnesium of at least 85 wt %.

326. Further, Xiao discloses that a primary difference between this prior art magnesium alloy and the novel magnesium alloys taught by Xiao’s disclosure lies in the addition of metallic elements like Iron, Copper, and/or Nickel into the alloy. In particular, Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the

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magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. Also comparing the constituents of the comparative example AZ91D magnesium alloy with the other examples in Table 1 of Xiao (Xiao at ¶ 0061), the introduction of Iron, Copper, and/or Nickel (alongside the Aluminum, Zinc, Zirconium, and Manganese already found in the prior art) appears to make the surprisingly large improvement in dissolution rates.

g. “said additive material is a metal material selected from the group consisting of copper, nickel, and cobalt,”

327. Claim 2 of Xiao discloses a “magnesium alloy according to Claim 1, further comprising the trace elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” This claim element requires that the additive material be one of the metals in the claimed group. Thus, Xiao teaches two candidates to serve as the additive material meeting this limitation secondary metal of the claim: Copper (Cu) and Nickel (Ni).

h. “said magnesium composite including in situ precipitation of galvanically-active intermetallic phases that include said additive material,”

328. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

329. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026.

330. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are necessarily generated by the in situ reaction between magnesium Mg and each of the disclosed metal additives forming in situ precipitate that includes the additive material (*i.e.*, Cu or Ni) in place. Thus, this claim element was fully disclosed by Xiao.

- i. **“said magnesium composite has a dissolution rate of 84-325 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”**

331. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement in that table are units regularly used by POSITAs to express measurements of dissolution. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Id. at ¶ 0064.

332. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 patent express the claimed dissolution rate in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table from Xiao by 1,000.

333. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5
Example 1	35	74
Example 2	15	45

Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

334. The examples (excluding the comparative [prior art] example) provided in Xiao therefore expressly disclose dissolution rates up to 74 mg/cm²/hr in 3 wt.% KCl water at 93°C.

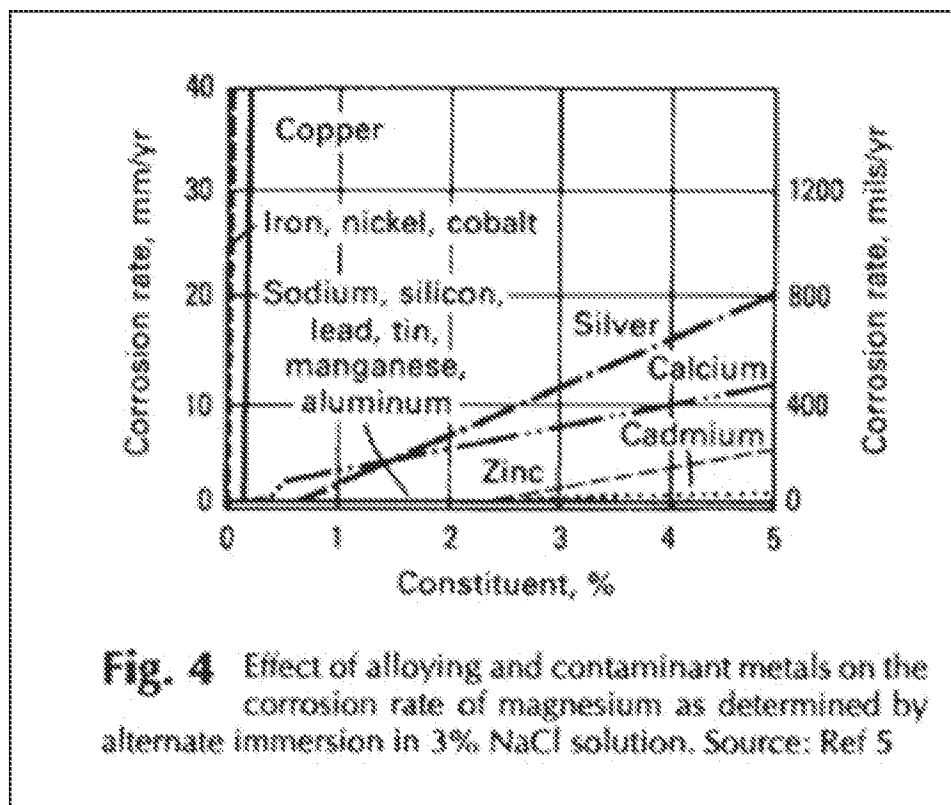
335. It is my opinion that a POSITA reading the Xiao reference in April 2014 would have understood that Xiao additionally discloses dissolution rates above the claimed floor of 84 mg/cm²/hr at 90°C because (1) the dissolution corrosion rates in the Xiao examples of Xiao are very close to the claimed floor of 84 mg/cm²/hr at 90°C (for example, Example 1 exhibited a dissolution rate of 74 mg/cm²/hr at 93°C, Example 6 a dissolution rate of 63 mg/cm²/hr at 93°C, and Example 7 a dissolution rate of 57 mg/cm²/hr at 93°C (Xiao at 0026)); and (2) a POSITA in April 2014 would have expected that other magnesium compositions having additive amounts in the ranges as disclosed by Xiao, but with higher amounts of copper, nickel, and/or iron than the amounts used in the tested Xiao examples would improve corrosion performance. In particular, even though they come close to the 84 mg/cm²/hr at 90°C, Examples 1, 6 and 7 of the Xiao examples had less aggregate copper, nickel and iron (as shown in the table here:

	wt% Copper	wt% Nickel	wt% Iron
Example 1	0	5	0.1
Example 6	1	0.2	1.5
Example 7	0.1	0.5	1

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than taught by Claim 2 of Xiao which says that there can be 5 wt% for each of copper, nickel, and iron in a magnesium composite. Thus, the Examples in Xiao were using lower amounts of these specific dissolution-enhancing additive elements in assessing dissolution rates. It is my opinion that a POSITA in April 2014 would have understood that Xiao inherently discloses magnesium compositions having dissolution rates necessarily well above the claimed floor of at least 84 mg/cm²/hr ranges because Xiao discloses that the dissolution-enhancing additive elements may be present in higher amounts (e.g., up to 5 wt% for **each** of copper, nickel, and iron (*Id.* at Claim 2)), as further evidenced below.

336. Confirming my belief that a dissolution rate of at least 84 mg/cm²/hr ranges is inherently disclosed by Xiao, it was well known prior to the priority date of April 2014 that additions of copper, iron, nickel and cobalt cause a sharp linear increase in the corrosion rate of magnesium as evidenced by Shaw. Shaw is a printed publication entitled “Corrosion Resistance of Magnesium Alloys” published in 2003 in the ASM Handbook, Vol. 13A. *Id.* Figure 4 from the Shaw publication, set forth below, illustrates the dramatic and linear effect of small additions of these impurities on magnesium corrosion rates. In addition, the ASM Handbook is a very common reference document used by metallurgical and materials engineers/scientists and would have been well known. As such, the recitation of the claimed dissolution rate of 84-325 mg/cm²/hr at 90°C was not a new property or use but rather a property that would be inherent in the compositions disclosed in Xiao, as evidenced by Shaw as published in the ASM Handbook.



Shaw at Figure 4.

C. Ground III: Claims 7, 12, 13, and 71 are Obvious over Xiao in view of Hassan

337. It is my opinion that the disclosure of Xiao [Xiao] in combination with the disclosures of Hassan [Hassan] would have rendered Claims 7 and 8 of the '653 Patent obvious to a POSITA in April 2014.

1. **Dependent Claim 7 -- "The magnesium composite as defined in claim 1, where said magnesium composite is subjected to a deformation processing to reduce grain size of said magnesium composite, increase tensile yield strength of said magnesium composite, increase elongation of said magnesium composite, or combinations thereof."**

338. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 1 to a POSITA in April 2014.

339. Xiao does not disclose or otherwise suggest subjecting a magnesium composite to deformation processing nor does it teach that deformation processing would achieve any of the

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benefits set forth in Claim 7 of the '653 Patent. Rather, Xiao discloses dissolvable magnesium composites with accelerated dissolution rates and other improved properties. Hassan (like Xiao) discloses magnesium based materials or alloys and teaches that there are benefits to reinforcing these materials or alloys with other metals or metal alloys to improve their properties.

340. Hassan, on the other hand, does teach deformation processing and its benefits with respect to magnesium-based composites reinforced with nickel made using a cast melt technique. Hassan at p. 2467, cols 1–2.

341. It is my opinion that a POSITA in April 2014 would have been motivated to combine the disclosure of Xiao with the disclosure of deformation processing in Hassan rendering Claim 7 obvious. First, Xiao and Hassan are both directed to improving the properties of magnesium based materials, especially those for use in devices or tools. Hassan, for instance, teaches that:

increasing hostile service conditions that the modern engineering devices have to withstand have led the materials scientists across the globe to create new materials with enhanced properties when compared to the conventional materials. One way to improve the properties of conventional metallic materials is to reinforce them judiciously keeping the end application in mind. Among the reinforced metallic materials, magnesium based composites are becoming the strong candidates for lightweight structural application due to their superior specific mechanical properties.

Hassan at 2467. Hassan also recognizes that type of processing, type, size, and volume fraction of reinforcement are “common factors governing the end properties of a metal matrix composite[.]”

Id.

342. Xiao similarly teaches in the context of its smelt casted magnesium alloy, the use of reinforcing metals or metal alloys to enhance corrosion performance and/or improve the compressive strength of the formed magnesium material. Xiao at ¶ 0026. In particular, Xiao noted that existing magnesium alloys (such as AZ91D) had low compressive strength and slow

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decomposition rates, making them unsuitable as material for, for example, a tripping ball used in oil well drilling. *Id.* at 0003.

343. As discussed at length above, Xiao responded to those recognized problems in the art by “adjusting the chemical composition and preparation process” to prepare a light and pressure-proof cast magnesium alloy that adds elements which can enhance the corrosion performance of the magnesium alloy. *Id.* at 0004.

344. A POSITA would be motivated to modify the disclosed magnesium alloys and magnesium-alloy-based tripping ball material, taught in Xiao to further increase and/or control the rate of dissolution.

345. More specifically, a POSITA would look to Hassan, which teaches pure magnesium reinforced with nickel particulates that exhibits improved physical and mechanical properties over magnesium alloy AZ91. Hassan at p. 2467, col. 2. Hassan also teaches that careful “selection of reinforcing phase remains one of the most critical factors in developing a composite material with superior properties when compared to its monolithic counterparts.” *Id.* Additionally, Hassan notes that its magnesium composites possess improved thermal expansion and mechanical characteristics (*Id.* at p. 2473, col. 2), which would be beneficial in oil field applications. Accordingly, a POSITA would have recognized the benefits set forth in Hassan applied to the magnesium alloy used in the tools taught in Xiao.

346. Hassan teaches the “synthesis of monolithic and nickel reinforced magnesium composites (Mg/Nip),” including heating the magnesium with reinforcement particulates (placed in multi-layer sandwich form) to 750°C, stirring the mixture, treating with argon gas, and depositing the resulting composite onto a metal substrate. *Id.* at 2468.

347. Importantly for Claim 7 of the ‘653 Patent, Hassan discloses that the deposited magnesium ingots may then be subjected to secondary processing. For example, Hassan teaches that the nickel-reinforced magnesium ingots are machined and hot extruded to obtain rods of 8 mm diameter. *Id.* Analysis of the composite of Hassan “showed the reduction in the size of elemental nickel particulates in the extruded composites” (see Table 1). In other words, the extrusion in Hassan resulted in a reduction of particulate size of the magnesium composite.

348. A POSITA in April 2014 would have been motivated to treat the magnesium alloys disclosed in Xiao using the secondary processing techniques disclosed by Hassan such that the size of additive particulates and magnesium composite could be controlled and optimized. Xiao already disclosed that controlling the particulate size of its magnesium alloy was desirable; Xiao simply teaches the use of argon treatment and a refining agent to do so (rather than the deformation processing claimed in Claim 7 of the ‘653 Patent). Xiao at ¶¶ 0036 and 0044. Accordingly, a POSITA in April 2014 would have been motivated to combine Xiao with Hassan.

349. Moreover, a POSITA would have had a reasonable expectation of successfully combining the magnesium alloy of Xiao with the secondary processing techniques of Hassan. Those secondary processing techniques of Hassan were conventionally used in metal alloy treatment and such processing techniques have been known for decades to optimize particulate size of metal alloys and improve the properties.

350. A POSITA would therefore have had a reasonable expectation of success in making the alloy of Xiao and treating it with a secondary processing technique such as extrusion as disclosed by Hassan and later claimed by Claim 7 of the ‘653 Patent. Accordingly, Claim 7 should be found obvious over Xiao in view of Hassan.

351.

2. Independent Claim 12

a. “A magnesium composite”

352. Xiao discloses a “magnesium alloy...and further adds elements of Fe, Cu, Ni, and Ag which can enhance the corrosion performance of the magnesium alloy...” Xiao at ¶ 0026, ll. 1–9.

353. Thus, Xiao’s disclosure of a combination of a magnesium alloy and elements of iron, copper, nickel, and silver thus meets the construction of “a magnesium composite.”

b. “[magnesium composite] that includes in situ precipitation of galvanically-active intermetallic phases to enable controlled dissolution of said magnesium composite”

354. Xiao discloses that its invention it adopts a magnesium alloy with high aluminum and zinc content and further adds elements Fe, Cu, Ni and Ag which can form intermetallics and enhance the corrosion performance of the magnesium alloy. Xiao explains the corrosion mechanism within a magnesium alloy in terms of a cathode phase, which Xiao explains includes “the β ($Mg_{17}Al_{12}$) phase and eutectic phase on the grain boundary of the magnesium alloy,” and “the magnesium matrix α phase which functions as an anode phase, so that the matrix and the grain boundary of the magnesium alloy form a large amount of micro-batteries, which [micro-batteries] greatly accelerate the corrosion decomposition of magnesium alloy.” *Id.* at ¶ 0026.

355. Xiao further discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll 15-18. A POSITA in August 2014 would

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have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate.

356. A POSITA reading the Xiao reference in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are naturally and necessarily generated by the *in situ* reaction between magnesium and any and all of the disclosed metal additives forming *in situ* precipitate. Thus, all of the limitations of this claim element are disclosed by Xiao.

c. “comprising a mixture of a magnesium or a magnesium alloy and an additive material,”

357. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace . . . , next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022.

358. Xiao discloses that these “intermediate alloys” are Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti, which are heated to dry and then added to the magnesium-aluminum alloy melt.” *Id.* at ¶ 0023. These intermediate alloys meet Patent Owner’s proposed definition of “additive material,” i.e. “a material that is added.”

359. The addition of one or more of these intermediate alloys to the melted magnesium alloy necessarily results in a mixture of magnesium or magnesium alloy and the additive material. Thus, Xiao discloses all of the limitations of this claim element.

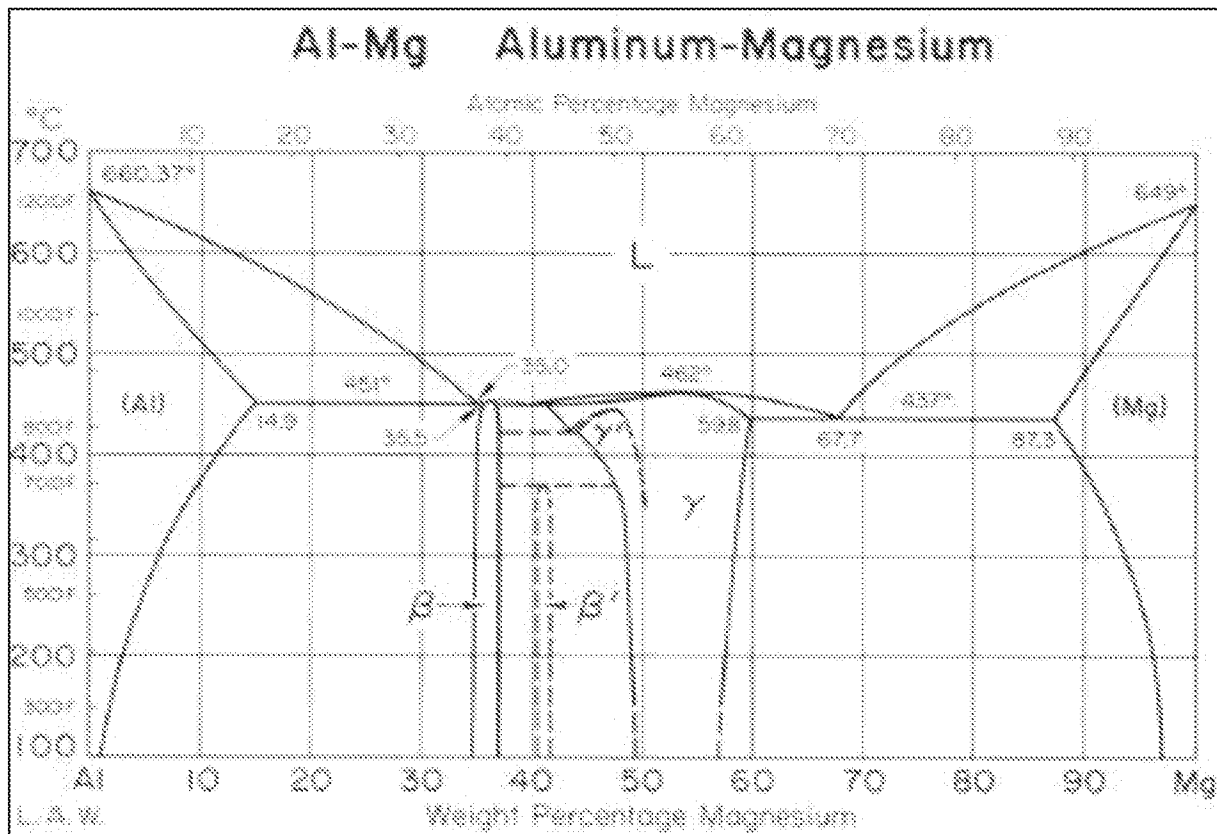
d. “said additive material having a greater melting point temperature than a solidus temperature of said magnesium, [. . . said additive material including one or more metals selected from the group consisting of copper, nickel cobalt, titanium, and iron]”

360. All of the prior elements of Independent Claim 12 had referred to “magnesium composite” rather than just “magnesium,” which the claim defined as comprising “a mixture

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of magnesium or magnesium alloy (and an additive material).” It is my opinion that a POSITA would have understood the reference to “magnesium” in this claim element as reference to the previous limitation of “magnesium or magnesium alloy.”

361. Using a typical phase diagram, a POSITA in April 2014 would have readily determined that the solidus temperature of magnesium is the temperature at which a metal first begins to melt during heating and not necessarily when the metal is completely liquidus.



The POSITA would also use this phase diagram to find the solidus temperature of the magnesium-aluminum alloy disclosed in Xiao to be in a range of 650°C for pure magnesium and down to 437°C for aluminum additions up to 40wt%. The solidus temperature is 437°C for the magnesium-aluminum alloys disclosed in Xiao having in the range of 13 wt% to 25 wt% aluminum.

362. The ~~additive materials~~ disclosed in Xiao that were noted above are one or more of the ~~intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti.~~ *Id.* at ¶ 0023.

363. Patent Owner has taken the position that “melting point temperature” would have meant “temperature at which liquid is formed” to a POSITA in April 2014. The POSITA in April 2014 using typical phase diagrams for each of the additive materials (here the “intermediate alloys” disclosed in Xiao) would be able to readily determine the melting point temperature for each intermediate alloy. For example, the Al-Fe phase diagram shows a variable melting point temperature ranging from 1538°C (pure iron) down to 655°C for a eutectic temperature between about 63 wt% aluminum to near 99 wt% aluminum. The Al-Ni phase diagram also shows a variable melting point temperature that ranges from 1640°C down to 640°C depending upon the alloy content. The Al-Cu phase diagram shows a variable melting point temperature ranging from 548°C up to 1084°C depending upon the alloy mixture. A POSITA in April 2014 would have readily determined the specific melting temperature of a specific alloy mixture based on the content of these typical phase diagrams.

364. Xiao discloses a variety of Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti alloy ~~mixtures~~ with a variety of constituencies. For instance, Xiao specifically teaches in Example 7 that:

The composition of the alloy and the respective percentages by weight are as follows: 25% Al-10% Zn-1% Fe-0.5% Ni-0.1% Cu-0.5% Ti-0.05% Zr, and the remainder is Mg.

Xiao at ¶ 0059. Xiao teaches that the magnesium alloy of Example 7, as a whole, ends up with the maximum amount of aluminum (i.e. 25 wt%) taught as being within the invention of Xiao (see, Xiao ¶ 0026). Xiao specifically discloses--with respect to Example 7--that portions of that aluminum content are added into a magnesium-aluminum melt as an Al-Fe intermediate alloy,

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an Al-Ni intermediate alloy, an Al-Cu intermediate alloy, an Al-Ag intermediate alloy, an Al-Zr intermediate alloy, and an Al-Ti intermediate alloy. Xiao at ¶ 0060. Thus, it is necessary to prepare mass balance calculations to determine the relative concentrations of the pure magnesium and pure aluminum initially loaded into the smelting furnace in order to determine its solidus temperature.

365. First, a POSITA in April 2014, would have converted the weight percentages to grams to perform mass balances. As a result, a POSITA would have understood in April 2014 that Example 7 of Xiao includes 62.85 grams of magnesium (i.e., 100 grams - 37.15 grams (i.e., 25 grams (Al) - 10 grams (Zn) - 1 gram (Fe) - 0.5 grams (Ni) - 0.1 gram (Cu) - 0.5 grams (Ti) - 0.05 grams (Zr))).

366. First, a POSITA in April 2014, would have converted the weight percentages to grams to perform mass balances. As a result, a POSITA would have understood in April 2014 that Example 7 of Xiao includes 62.85 grams of magnesium (i.e., 100 grams - 37.15 grams (i.e., 25 grams (Al) - 10 grams (Zn) - 1 gram (Fe) - 0.5 grams (Ni) - 0.1 gram (Cu) - 0.5 grams (Ti) - 0.05 grams (Zr))).

367. The following intermediate alloy compositions were chosen for the initial mass balance calculations: Al-Fe (30 wt% Fe), Al-Ni (45 wt% Ni), Al-Cu (40 wt% Cu), Al-Ti (10 wt% Ti), Al-Zr (20 wt% Zr) alloy mixtures.

368. As would a POSITA in April 2014, (using the weight percentages-to-grams conversion noted above) I performed the initial mass balances.

369. Thus, using the initially selected Al-30Fe, Al-45Ni, Al-40Cu, Al-10Ti, and Al-20Zr alloys would have resulted in 7.79 grams of Aluminum being added to the overall alloy as components of the intermediate alloys (as opposed to the aluminum introduced into the ultimate

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alloy of Example 7 in the initial melt). Since Example 7 of Xiao calls for a total of 25 grams (i.e. 25 wt%) of Aluminum, 17.21 grams of Aluminum would have had to have been initially loaded into the smelting furnace in Example 7 along with the 62.85 grams of magnesium (see calculation above). Thus, the initial melt of Example 7 (using the intermediate alloys selected) would have had a composition of 78.5 wt% Mg and 21.5 wt% Al.

370. Next, a POSITA would have consulted the Mg-Al phase diagram to determine that the solidus temperature of the initial magnesium alloy (i.e. 78.5 wt% Mg and 21.5 wt% Al) of Example 7 of Xiao to be 437 °C.

371. A POSITA would also consult the relevant phase diagram to determine the melting point temperature of the various additive materials disclosed in Xiao. An aluminum-iron alloy with 30 wt% iron would have a melting point temperature of 655 °C, an aluminum-nickel alloy with 45 wt% Ni would have a melting point temperature of 854 °C, an aluminum-copper alloy with 40 wt% Cu would have a melting point temperature of 548°C, an aluminum-titanium alloy with 10 wt% Ti would have a melting point temperature of 665°C, and an aluminum-zirconium alloy with 20 wt% Zr would have a melting point temperature of 661°C. Thus, each of these additive materials from Example 7 of Xiao (with the constituencies selected above) would have had a greater melting point temperature than the solidus temperature of magnesium or the magnesium-aluminum alloy (i.e. 437°C) corresponding to 21.5 wt% aluminum which is the calculated amount of pure aluminum in pure magnesium initially loaded into the smelting furnace in Example 7. A POSITA in April 2014 would have also recognized that other compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, **and** Al-Cu intermediate alloys having greater melting point

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temperatures than the solidus temperature of initial magnesium alloy loaded in the various Examples of Xiao. Thus, Xiao discloses all of the limitations of this claim element.

e. “said composite including greater than 50 wt % magnesium,”

372. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: Al: 13 to 25%, Zn: 2 to 15%; the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1.

373. A POSITA would have understood that the total range of the non-magnesium elements disclosed in Claim 1 of Xiao is 15% (*i.e.*, 13 + 2) to 40% (*i.e.*, 25 + 15). Thus, claim 1 of Xiao would have further disclosed to a POSITA a range of magnesium of 60 wt% to 85 wt%, which range is “greater than 50 wt% magnesium” required by this limitation of the claim. Further, a POSITA would have understood that the composite of Example 7 (using the example intermediate alloys selected above) would have contained 62.85 wt% magnesium (as already calculated above), which is also greater than 50 wt% magnesium” required by this limitation of the Claim. A POSITA in April 2014 would have also recognized that the selection of other intermediate alloy compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in would have resulted in magnesium composites that included greater than 50 wt% (up to about 85 wt%) magnesium. Thus, this element of the claim was disclosed by Xiao.

f. “said additive material constituting about 0.05 wt %-45 wt % of said magnesium composite, [. . . said additive material including one or more metals selected from the group consisting of copper, nickel cobalt, titanium, and iron]”

374. Claim 1 of Xiao discloses a “magnesium alloy, comprising the components at the weight percentages as follows: **Al: 13 to 25%, Zn: 2 to 15%**, the remainder is Mg, and a sum of the weight percentages of the components is 100%.” Xiao at Claim 1. And Claim 2 discloses: a

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“magnesium alloy according to claim 1, further comprising the trade elements at the weight percentages as follows: Fe: 0.1 to 5%, Cu: 0.05 to 5%, Ni: 0.05 to 5%, Zr: 0.05 to 0.5%, Ti: 0.05 to 0.5%; and a sum of the weight percentages of the components is 100%.” *Id.* at Claim 2.

375. These metallic elements are found in the additive materials generally disclosed by Xiao (*i.e.*, intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti) (Xiao at ¶ 0023) and particularly described in association with Example 7 of Xiao (*Id.* at ¶¶ 0057 - 0060) for which I have already calculated (and set forth above) the specific weight percentage (ranges) of each additive material (which has been defined by the Patent Owner as “a material that is added” (see Paragraph 78 of my Declaration)) set forth in Example 7 of Xiao (*i.e.* Al-Fe, Al-Ni, Al-Ag, Al-Cu, Al-Zr, Al-Ti and Zinc).

376. In particular, the additive materials aluminum-iron with 30 wt% iron, aluminum-nickel with 45 wt% nickel, and aluminum-copper with 40 wt% copper, which each have greater melting point temperatures than the solidus temperature of magnesium or the magnesium aluminum alloy disclosed in Xiao, also fall well within the range of about 0.05 wt% to 45 wt% of the mixture. For example, the aluminum-iron additive constitutes 3.3 wt% of the mixture (*i.e.*, 1%/0.30); the aluminum-nickel additive constitutes 1.1 wt% of the mixture (*i.e.*, 0.5%/0.45); and the aluminum-copper additive constitutes 0.25 wt% of the mixture (*i.e.*, 0.1%/0.40). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions would have fallen within the teachings of Example 7 of Xiao as well as the other teachings of Xiao and resulted in Al-Fe, Al-Ni, **and** Al-Cu intermediate alloys constituting about 0.05 wt% to 45 wt% of the magnesium composite. Accordingly, this element of the claim is disclosed by Xiao.

- g. “said additive material having a melting point temperature that is 100°C. greater than a melting temperature of said magnesium or magnesium alloy,”**

377. A POSITA would have understood “melting temperature” in this claim element to be a reference to the smelting temperature or temperature of the melt when the additive material is being added to the magnesium or magnesium alloy, not the “melting point temperature” as that measurement is used for the additive material.

378. Xiao generally discloses “loading pure magnesium and pure aluminum into a smelting furnace and increasing the temperature to 700 to 730 °C, next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting and increasing the temperature to 740 to 780°C” Xiao at ¶¶ 0021–0022; see also *Id.* at Claim 5 (“the melting temperature of the pure magnesium and pure aluminum is from 700 to 730 °C.”)

379. Examples 1-7 of Xiao teach different melting or smelting temperatures for the magnesium-aluminum alloy, ranging from a low of 700°C in Example 1 to a high of 730 °C in Examples 2, 5, and 7. Xiao ¶¶ 0034–0060. In each Example, “[a]fter melting” the intermediate alloy are “added into the resulting magnesium-aluminum alloy melt, and at the same time the temperature is raised” to a different temperature depending on the example. *Id.*

380. The additive materials noted above are one or more of the intermediate alloys: Al-Fe, Al-Ni, Al-Cu, Al-Ag, Al-Zr, Al-Ti. *Id.* at ¶ 0023. As I noted in Paragraph 78 of Declaration, Patent Owner has taken the position that “melting point temperature” would have meant “temperature at which liquid is formed” to a POSITA in April 2014.

381. As already noted in Paragraph 152 of my Declaration (above), based on the typical phase diagrams, a POSITA in April 2014 would have recognized that Al-Fe had a variable melting

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point temperature ranging from 1538°C (pure iron) down to 652°C for a eutectic point near 99 wt% aluminum; Al-Ni had a variable melting point temperature that ranges from 1640°C down to 640°C (depending upon the alloy mixture); and Al-Cu had a variable melting point temperature ranging from 548°C up to 1084°C (depending upon the alloy mixture). A POSITA in April 2014 would have been able to determine the specific melting point temperature of a specific alloy mixture based on the content of these typical phase diagrams.

382. Example 7 specifically discloses a melting or smelting temperature of 730°C. Xiao at ¶ 0060. I specifically analyzed Example 7 of Xiao above to determine (using particular intermediate alloy compositions) the melting point temperatures of the intermediate alloys added. As a result, it is my opinion that a POSITA in April 2014 would recognized from Example 7 of Xiao that at least an aluminum-nickel additive having 45 wt% nickel has a melting point temperature of 854°C which is 100°C greater than the melting or smelting temperatures of the magnesium aluminum alloy used in Example 7 (*i.e.*, 730°C) and otherwise taught generally by Xiao (*i.e.*, 700-730°C). A POSITA in April 2014 would have also recognized that other intermediate alloy compositions could have fallen within the teachings of Example 7 of Xiao and resulted in Al-Fe, Al-Ni, **and** Al-Cu intermediate alloys that would have had melting point temperatures that were 100°C. greater than the smelting temperatures of the magnesium alloy generally taught by Xiao (*i.e.*, 700-730°C).¹⁵ Thus, Xiao discloses all of the elements of this claim limitation.

¹⁵ It is worth pointing out—although I would disagree with either notion—that if Patent Owner argues either that “melting temperature” was a typographical error (which I doubt given the other claims that say “melting point temperature” and the numerous Certificates of Correction that did not address this issue) or simply argues that “melting temperature of said magnesium or magnesium alloy” means “melting point temperature of said magnesium or magnesium alloy,” not only would the Al-Ni intermediate alloy with 45 wt% nickel exceed the *melting point temperature* of pure magnesium (*i.e.*, 650°C) and the *melting point temperature of the initially loaded*

- h. **“said additive material includes one or more metals selected from the group consisting of copper, nickel, cobalt, titanium, and iron,”**

383. The intermediate alloys Al-Cu, Al-Ti, Al-Fe, **and** Al-Ni exhibit specific chemistry ranges with melting point temperatures that are both (i) greater than the solidus temperature of the magnesium aluminum alloy disclosed in Xiao and (ii) 100°C greater than the melting/smelting temperature of that alloy (disclosed in Xiao to be 700-730°C). For example, in Example 7 of Xiao, an ~~aluminum-nickel~~ additive having 45 wt% nickel used in the material balance calculations, has a melting point temperature of 854°C determined from the Al-Ni phase diagram, the melting point temperature being 100°C greater than the melting temperature of that Example 7 of Xiao (i.e., 730°C). A POSITA in April 2014 would have recognized that an Al-Ni intermediate alloy of Example 7 of Xiao contained nickel, which is a metal. A POSITA in April 2014 would have also recognized that the Al-Cu, Al-Ti, and Al-Fe intermediate alloys would have also met the other temperature and weight percentage limitations of this claim, and would have further recognized they respectively included copper, titanium and iron each of which are metals. Thus, Xiao discloses the use of one or more additive materials of one or more metals including copper, nickel, titanium, and/or iron.

- i. **“at least a portion of said additive material remaining unalloyed additive material,”**

384. Xiao discloses that “[e]lements such as Fe, Co, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles.” *Id.* at ¶ 0026.

magnesium-aluminum alloy (i.e., 438°C) of Example 7 using the constituents discussed in Paragraphs 114-118 of my Declaration (i.e., a composition of 78.5 wt% Mg and 21.5 wt% Al), by at least 100°C, but also the Al-Cu, Al-Fe, Al-Ti and Al-Zr intermediate alloys, having the constituents set forth in those Paragraphs of my Declaration would similarly exceed that limitation.

385. From the foregoing elements of the claim we know that the potential claimed “additive material” disclosed by Xiao is limited to Fe, Cu, Ni, and Ag. However, Xiao does not disclose whether any of the additive material remains “unalloyed” (which has been defined by the Patent Owner as “portion of the additive material that does not form a new compound” (see Paragraph 78 of my Declaration)).

386. Hassan, on the other hand, specifically discloses that magnesium composites containing additive materials, such as nickel, may remain unreacted (i.e. does not form a new compound). In particular, Hassan states that:

[s]evere reaction between magnesium melt and nickel particulates during DMD processing led to the reduction of the particulate size and formation of Mg_2Ni intermetallics [13]. **The results of quantitative determination of unreacted nickel** (see Table I), microstructural characterization illustrating the presence of reaction products (see Fig. 1) and XRD results (see Table II) showing the presence of Mg_2Ni supports the experimental observations.

TABLE I Results of density and porosity measurements

Material	Reinforcement in composites				Density (g/cm ³)
	(wt%)	(vol%) ^a	(vol%) ^b	Size ^c	
Mg	—	—	—	—	1.7395 ± 0.0005
Mg/7.3Ni _p	7.3	1.5	0.1	2.7 ± 0.6	1.9046 ± 0.0038
Mg/14.0Ni _p	14.0	3.1	1.3	2.5 ± 0.4	2.0677 ± 0.0012
Mg/24.9Ni _p	24.9	6.1	4.3	9.0 ± 4.6	2.3834 ± 0.0092

^aComputed by using the total amount of Ni retained in composite samples.

^bIndicates the amount of Ni in the unreacted form present in composite samples.

^cResult of cumulative image analysis conducted on fifteen representative SEM micrographs for each composite.

TABLE II Results of X-ray diffraction studies and coefficient of thermal expansion analysis

Materials	Number of matching peaks					CTE ($\times 10^{-6}/^{\circ}\text{C}$)
	Mg	Ni	Mg ₂ Ni	NiO	Ni ₂ O ₃	
Mg	9 [3]	—	—	—	—	28.60 $\pm$ 0.07
Mg/7.3Ni _p	6 [3]	—	6 [2]	—	—	27.54 $\pm$ 0.26
Mg/14.0Ni _p	5 [3]	—	8 [2]	—	—	26.35 $\pm$ 0.09
Mg/24.9Ni _p	6 [3]	2 [1]	16 [2]	1 [1]	1	20.75 $\pm$ 0.56

[] indicates the number of main peaks matched.

Hassan at 2472 (emphasis added).

387. Hassan (like Xiao) discloses the fabrication of magnesium based materials or alloys and teaches that there are benefits to reinforcing these materials or alloys with other metals or metal alloys to improve the physical properties of the resulting magnesium composite. Hassan also recognizes that type of processing, type, size, and volume fraction of reinforcement are “common factors governing the end properties of a metal matrix composite[.]” Hassan at 2467. Xiao similarly teaches in the context of its smelt casted magnesium alloy, the use of reinforcing metals or metal alloys to enhance corrosion performance and/or improve the compressive strength of the formed magnesium material. Xiao at ¶ 0026. In particular, Xiao noted that existing magnesium alloys (such as AZ91D) had low compressive strength and slow decomposition rates, making them unsuitable as material for, for example, a tripping ball used in oil well drilling. *Id* at 0003.

388. Unlike Xiao, which does not explicitly mention the possibility of there being unreacted additives, Hassan specifically provides experimental data showing—under similar

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conditions of magnesium composite fabrication as those in Xiao—that some of the additives, particularly nickel, will remain unreacted and unalloyed.

389. Given this motivation to combine Xiao with Hassan, it is my opinion that a POSITA in April 2014 would have recognized that these two references disclose this limitation of the claim.

j. “said magnesium composite including in situ precipitation of galvanically-active intermetallic phases that includes said unalloyed additive material,”

390. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles, which can improve the corrosion performance of the magnesium alloy, thereby promoting the decomposition of the magnesium alloy.” *Id.* at ¶ 0026, ll. 15–18. A POSITA in August 2014 would have understood this disclosure of “intermetallic composite micro-particles” to be a reference to intermetallic precipitate.

391. As noted above, Hassan discloses that added nickel (Ni) will remain unalloyed (i.e. unreacted) under certain conditions.

392. A POSITA reading the Xiao and Hassan references in April 2014 would have recognized that the precipitation of galvanically-active intermetallic phases (“micro-batteries”) are necessarily generated by the *in situ* reaction between magnesium and the disclosed metal additives forming *in situ* precipitate on or with any unalloyed or unreacted additive material. Thus, Xiao together with Hassan disclosed this element of the claim.

k. “said magnesium composite has a dissolution rate of at least 5 mg/cm²/hr. in 3 wt % KCl water mixture at 90°C.”

393. A POSITA in April 2014 would have understood the English translation of Xiao to disclose a table of dissolution rates (“decomposition rates”) because the units of measurement in

that table are units regularly used by POSITAs to express measurements of dissolution. In particular, Xiao provides dissolution rates for its various examples, as follows:

	Room temperature tensile strength σ_b (MPa)	Decomposition rate at 70 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)	Decomposition rate at 93 °C in 3% KCl solution (g.cm ⁻² .h ⁻¹)
Comparative example 1	232	0.00026	0.0005
Example 1	360	0.035	0.074
Example 2	385	0.015	0.045
Example 3	410	0.013	0.036
Example 4	375	0.034	0.058
Example 5	392	0.025	0.048
Example 6	365	0.021	0.063
Example 7	387	0.036	0.057

Xiao at ¶ 0064.

394. Xiao provides dissolution rates in g/cm²/hr, while the claims of the '653 Patent express the claimed dissolution rate in mg/cm²/hr. A POSITA in April 2014 would have known that converting from g/cm²/hr to mg/cm²/hr, merely requires multiplication of the numbers disclosed in this table from Xiao by 1,000.

395. Thus, the dissolution rates disclosed in Xiao convert to:

	Decomposition rate at 70°C in 3% KCl solution mg/cm ² /hr	Decomposition rate at 93°C in 3% KCl solution mg/cm ² /hr
Comparative example 1	0.26	0.5

Example 1	35	74
Example 2	15	45
Example 3	13	36
Example 4	34	58
Example 5	25	48
Example 6	21	63
Example 7	36	57

396. Each of the seven examples (excluding the comparative [prior art] example) provided in Xiao therefore discloses a dissolution rate of “at least 5 mg/cm²/hr in 3 wt.% KCl water” at both 70°C or 93°C. Given that the disclosed dissolution rates of Xiao both above and below 90°C are well above the claimed floor of “at least 5 mg/cm²/hr” (i.e. at least three times overall and for Example 7 at least seven times) it is my opinion that a POSITA in April 2014 would have recognized the dissolution rate of the examples in Xiao at 93°C to also be necessarily well above the claimed floor of “at least of 5 mg/cm²/hr.” Consequently, this element of Claim 1 is also disclosed by Xiao.

397. Accordingly, as set forth in the immediately foregoing paragraphs, it is my opinion that Xiao, in view of Hassan’s disclosure that Nickel would remain unalloyed, would have fully disclosed each and every element of Claim 12 of the ‘653 Patent to a POSITA in or before April 2014 in accordance with Patent Owner’s definitions (set forth in Paragraph 78 of my Declaration).

3. **Dependent Claim 13 -- “The magnesium composite as defined in claim 12, wherein said additive material is added to said magnesium or magnesium alloy while said magnesium or magnesium alloy is at a temperature that is above said solidus temperature of said magnesium and a temperature that is less**

than a melting point of said additive material to form said mixture.”

398. As set forth above, it is my opinion that Xiao in combination with Hassan would have disclosed all elements of Claim 12 to a POSITA in April 2014.

399. Xiao discloses “first loading pure magnesium and pure aluminum into a smelting furnace, next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” Xiao at Claim 4. Xiao further discloses “loading pure magnesium and pure aluminum into a smelting furnace and increasing the temperature to 700 to 730 °C, next loading pure zinc and an [sic] intermediate alloys of trace element components into a resulting magnesium-aluminum alloy melt after melting.” *Id.* at ¶ 0022. Using a typical phase diagram, a POSITA in April 2014 would have readily determined that the solidus temperature of magnesium is 650°C. The POSITA would also use the phase diagram to find the solidus temperature of the magnesium-aluminum alloy disclosed by Xiao to be between 437-650°C.

400. Xiao further discloses that the pure Zinc and intermediate alloys are loaded into the magnesium-aluminum melt, which is at a temperature of 700 to 730 °C, and then “increasing the temperature to 740 to 780°C.” Xiao at ¶ 0022.

401. Next, given the limitation of Independent Claim 12 (addressed above) that “said additive material having a melting point temperature that is 100°C greater than a melting temperature of said magnesium or magnesium alloy,” any additive material that meets the limitations of Claim 12 will also necessarily meeting the limitation that the “additive material is added to said . . . magnesium alloy while said . . . magnesium alloy is at . . . a temperature that is less than a melting point of said additive material” given Xiao’s disclosure that the intermediate alloys are added to the magnesium-aluminum melt at a temperature of 700 to 730 °C, (and then

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increased to 740 to 780°C). As noted above in Paragraph 381 of my Declaration (above), the intermediate alloys Al-Cu, Al-Ti, Al-Fe, **and** Al-Ni exhibit specific chemistry ranges with melting point temperatures that are both (i) greater than the solidus temperature of the magnesium aluminum alloy disclosed in Xiao and (ii) 100°C greater than the melting/smelting temperature of that alloy (disclosed in Xiao to be 700-730°C) and, thus also meets the added limitations of this dependent claim. Thus, Xiao discloses all of the limitations of Dependent Claim 13.

4. Dependent Claim 71

- a. **“The magnesium composite as defined in claim 49, wherein at least a portion of said additive material remains unalloyed additive material in said magnesium composite.”**

402. As set forth above, it is my opinion that Xiao would have disclosed all elements of Claim 49 to a POSITA in April 2014.

403. Xiao discloses that “[e]lements such as Fe, Cu, Ni, Ag, etc., in the magnesium alloy can form a large number of intermetallic composite micro-particles.” *Id.* at ¶ 0026.

404. From the foregoing elements of the claim we know that the potential claimed “additive material” disclosed by Xiao is limited to Cu, Ni, Ti, Fe, and Co. However, Xiao does not disclose whether any of the additive material remains “unalloyed” (which has been defined by the Patent Owner as “portion of the additive material that does not form a new compound” (see Paragraph 78 of my Declaration)).

405. Hassan, on the other hand, specifically discloses that magnesium composites containing additive materials, such as nickel, may remain unreacted (i.e. does not form a new compound). In particular, Hassan states that:

[s]evere reaction between magnesium melt and nickel particulates during DMD processing led to the reduction of the particulate size and formation of Mg₂Ni intermetallics [13]. **The results of quantitative determination of unreacted**

nickel (see Table I), microstructural characterization illustrating the presence of reaction products (see Fig. 1) and XRD results (see Table II) showing the presence of Mg_2Ni supports the experimental observations.

TABLE I Results of density and porosity measurements

Material	Reinforcement in composites				Density (g/cm^3)
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Mg/7.3Ni _p	7.3	1.5	0.1	2.7 ± 0.6	1.9046 ± 0.0038
Mg/14.0Ni _p	14.0	3.1	1.3	2.5 ± 0.4	2.0677 ± 0.0002
Mg/24.9Ni _p	24.9	6.1	4.3	9.0 ± 4.6	2.3834 ± 0.0092

^aComputed by using the total amount of Ni retained in composite samples.

^bIndicates the amount of Ni in the unreacted form present in composite samples.

^cResult of cumulative image analysis conducted on fifteen representative SEM micrographs for each composite.

TABLE II Results of X-ray diffraction studies and coefficient of thermal expansion analysis

Materials	Number of matching peaks					CTE ($\times 10^{-6}/^\circ\text{C}$)
	Mg	Ni	Mg_2Ni	NiO	Ni_2O_3	
Mg	9 [3]	—	—	—	—	28.60 ± 0.07
Mg/7.3Ni _p	6 [3]	—	6 [2]	—	—	27.54 ± 0.26
Mg/14.0Ni _p	5 [3]	—	8 [2]	—	—	26.35 ± 0.09
Mg/24.9Ni _p	6 [3]	2 [1]	16 [2]	1 [1]	1	20.75 ± 0.56

[] indicates the number of main peaks matched.

Hassan at 2472 (emphasis added).

406. Hassan (like Xiao) discloses the fabrication of magnesium based materials or alloys and teaches that there are benefits to reinforcing these materials or alloys with other metals or metal alloys to improve the physical properties of the resulting magnesium composite. Hassan also recognizes that type of processing, type, size, and volume fraction of reinforcement are “common

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factors governing the end properties of a metal matrix composite[.]” Hassan at 2467. Xiao similarly teaches in the context of its smelt casted magnesium alloy, the use of reinforcing metals or metal alloys to enhance corrosion performance and/or improve the compressive strength of the formed magnesium material. Xiao at ¶ 0026. In particular, Xiao noted that existing magnesium alloys (such as AZ91D) had low compressive strength and slow decomposition rates, making them unsuitable as material for, for example, a tripping ball used in oil well drilling. *Id* at 0003.

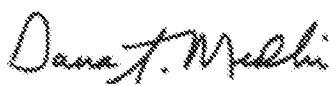
407. Unlike Xiao, which does not explicitly mention the possibility of there being unreacted additives, Hassan specifically provides experimental data showing--under similar conditions of magnesium composite fabrication as those in Xiao--that some of the additives, particularly nickel, will remain unreacted and unalloyed.

408. Given this motivation to combine Xiao with Hassan, it is my opinion that a POSITA in April 2014 would have recognized that these two references disclose this limitation of the claim. Consequently, all of the limitations of Dependent Claim 71 are taught by Xiao in combination with Hassan.

VIII. CONCLUSION

I hereby declare under penalty of perjury under the law of the United States of America that the foregoing is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements are punishable by fine or imprisonment or both. 18 U.S.C. § 1001.

Dated: July 6, 2021

By: 
 Dana J. Medlin, Ph.D., P.E., FASM

60802

Xiao Example #7 - Mass Balance

Assume 100 gr

- 1) 25% Al
- 10% Zn
- 1% Fe
- 0.5% Ni
- 0.1% Cu
- 0.5% Ti
- 0.05% Zr

37.15% Alloys

62.85% Mg gr (Balance)

100.00 Total

① Mg (m.p. 650°C) + Al (m.p. 660°C) heat to 730°C

② Add: Al-Fe + Al-Ni + Al-Cu + ~~Al-Mg~~ + Al-Zr +
Al-Ti + pure Zn

Raised to 760°C, Then lowered to 730°C,
degassed then cooled to 710°C, Then cooled.

Al-Fe 1% Fe

(70% Al + 30% Fe)

m.p. = 650°C

$$\frac{x \text{ gr Al}}{1.0 \text{ gr Fe}} = \frac{0.70 \text{ gr Al}}{0.30 \text{ gr Fe}}$$

$$x = 2.33 \text{ gr Al}$$

60002

Prepared by

DT/ML/103

Date

2/1/2000

2

Al-Ni

0.5% Ni

(55% Al + 45% Ni)

m.p. = 854°C

$$\frac{x \text{ gr Al}}{0.5 \text{ gr Ni}} = \frac{0.55 \text{ gr Al}}{0.45 \text{ gr Ni}}$$

$$x = 0.61 \text{ gr Al}$$

0.1% Cu

(60% Al + 40% Cu)

m.p. = 548°C

$$\frac{x \text{ gr Al}}{0.1 \text{ gr Cu}} = \frac{0.60 \text{ gr Al}}{0.40 \text{ gr Cu}}$$

$$x = 0.15 \text{ gr Al}$$

0.5% Ti

(90% Al + 10% Ti)

m.p. = 665°C

$$\frac{x \text{ gr Al}}{0.5 \text{ gr Ti}} = \frac{0.90 \text{ gr Al}}{0.10 \text{ gr Ti}}$$

$$x = 4.5 \text{ gr Al}$$

0.05% Zr

(80% Al + 20% Zr)

m.p. = 661°C

$$\frac{x \text{ gr Al}}{0.05 \text{ gr Zr}} = \frac{0.80 \text{ gr Al}}{0.20 \text{ gr Zr}}$$

$$x = 0.20 \text{ gr Al}$$

60002

Prepared by: D. J. Mullen

Date: 9/11/2010

Zn added as pure 10%

Total Al added as intermediate alloy:

$$2.33\text{gr} + 0.61\text{gr} + 0.15\text{gr} + 4.5\text{gr} + 0.20\text{gr} = 7.79\text{gr}$$

Mass Balance:

$$25\text{gr Al} - 7.79\text{gr} = 17.21\text{gr}$$

↑ from step ②

Start: ① 17.21 gr Al + 62.85 gr Mg and melt
Subtotal: 80.06 gr at 730°C

② Add Intermediate alloys

$$\begin{array}{l} 10\text{gr Fe} + 2.33\text{gr Al} \quad (\text{Al-Fe}) \\ 0.5\text{gr Ni} + 0.61\text{gr Al} \quad (\text{Al-Ni}) \\ 0.1\text{gr Cu} + 0.15\text{gr Al} \quad (\text{Al-Cu}) \\ 0.5\text{gr Ti} + 4.5\text{gr Al} \quad (\text{Al-Ti}) \\ 0.05\text{gr Zr} + 0.20\text{gr Al} \quad (\text{Al-Zr}) \\ \hline 9.94\text{gr} \end{array}$$

10gr Zn

$$80.06\text{gr} + 9.94\text{gr} + 10\text{gr} = 100.0\text{gr}$$