IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO. LTD.; AND
SAMSUNG ELECTRONICS AMERICA, INC.,
Petitioner,

v.

REDSTONE LOGICS LLC,
Patent Owner.

Case No. IPR2024-00974
Patent No. 9,253,925

DECLARATION OF LELAND J. SPANGLER, PH.D.

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iv. Limitation 3[c]: an electronic device attached to said mounting surface and disposed within said space; and 87

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iv. Limitation 15[c]: an electronic device attached to said mounting surface and disposed within said space; and 96

v. Limitation15[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty–five degrees of parallel to said mounting surface, ... 96

vi. Limitation 15[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section, ... 96

vii. Limitation 15[f]: wherein said first thermal conductivity is greater than said second thermal conductivity, ... 96

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i. Preamble: An electronic assembly comprising: 114

ii. Limitation 3[a]: a support structure comprising walls enclosing a space; 115

iii. Limitation 3[b]: a circuit substrate coupled to a first portion of said support structure, said circuit substrate comprising a mounting surface; 115

iv. Limitation 3[c]: an electronic device attached to said mounting surface and disposed within said space; and 115

v. Limitation 3[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty–five degrees of parallel to said mounting surface,..... 115

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vii. Limitation 3[f]: wherein for each said section, said first thermal conductivity is at least one–hundred times greater than said second thermal conductivity, ... 130

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v. Element 15[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty-five degrees of parallel to said mounting surface, ... 133

vi. Element 15[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section, ... 133

vii. Element 15[f]: wherein said first thermal conductivity is greater than said second thermal conductivity, ... 133

viii. Element 15[g]: wherein a thermally conductive path from said space enclosed by said walls of said support structure out of said electronic assembly that has a greatest thermal conductivity comprises a thermal path through contiguous ones of said sections of said panel to an outer edge of an outer one of said sections of said panel, and 134

ix. Element 15[h]: wherein said electronic assembly further comprises a thermally conductive adhesive coupling said outer edge of said outer one of said sections to said support structure. 138

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Appendix A: Curriculum Vitae of Leland Spangler, Ph.D.

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Signature Page

I. INTRODUCTION AND SUMMARY OF OPINIONS

1. I, Dr. Leland J. Spangler, have been asked to submit this declaration on behalf of defendants Samsung Electronics Co., Ltd and Samsung Electronics America, Inc. (hereby known as Samsung) by way of its counsel, in support of the above captioned matter. I have been retained as a technical expert by Samsung to provide opinions regarding the validity of the asserted claims of US patent 9,253,925 in light of prior art, commercial maturity and the obviousness to a Person of Ordinary Skill in the Art (POSITA) at the time the patent was filed.

2. My current curriculum vitae is appended to this declaration as Appendix A and a summary of my Expert Witness History is appended hereto as Appendix B of this declaration.

3. To summarize my conclusions regarding claims 3, 15 and 16 of the '925 patent:

(a) The purported inventions in the '925 patent have previously been patented and/or described prior to 2013. This opinion is based on the mature state of the use of thermally anisotropic flexible graphite sheets as a heat spreader in electronic devices, as well as my own personal experience with these technologies at the time the '925 patent was issued.

(b) The preponderance of prior patent art demonstrates the obviousness of the asserted Claims of the '925 patent. This is particularly true when considering the combination of specific patent disclosures prior to 2013.

(c) I conclude, therefore, that claims 3, 15 and 16 of US Patent 9,253,925 would have been obvious to a POSITA at the time of the invention.

4. My conclusions are based on my review of the materials identified below, as well as my review of technical publications such as journals and textbooks, and my own knowledge, training, and 35 years of experience in the design and manufacture of electronic and semiconductor products including packages and substrates having devices with thermal management challenges.

5. In the remainder of this declaration, I provide further information on my background and experience, and I describe the mature state of the graphite heat sink industry prior to 2013, the well-developed technology, innovative designs, extensive patent literature, and the widespread commercial availability of graphite, thermally anisotropic, flexible graphite sheets and graphite heat spreaders made of such materials for thermal management in electronic devices, all before 2013. This declaration concludes with a detailed set of opinions regarding each of the claim elements of the ’925 patent.

6. My analysis and conclusions are based on the information made available to me at this time, and I reserve the right to modify my analysis or conclusions in the event that additional information is presented to me at a later date.

II. EXPERT QUALIFICATIONS

7. I earned a Ph.D. in Electrical Engineering from The University of Michigan in 1988. My graduate work focused on single-crystal silicon, glass-substrate transistors

and sensors device physics, and fabrication technologies and the associated circuits made with such devices. The transistors I designed and fabricated had the fastest electron mobility of any glass-substrate silicon transistor at the time.

8. From 1985 to 1988, while still in graduate school, I helped start and was the Director of Research and Development at Integrated Microsystems, Inc. In that role, I was responsible for hardware, software, and fabrication technology development for silicon-based neural recording probes and blood oxygen sensors.

9. From 1988 to 1989, I was a member of the scientific staff at Bell Northern Research. In that role, I designed a database processor integrated circuit and an associative memory chip for TCP/IP-based wide-area network applications. The systems that these chips were to be used in were precursors to the Internet.

10. From 1989 to 1993, I was a Lead Product Design Engineer and an Engineering Supervisor at Ford Electronics Division of Ford Motor Company in Dearborn, Michigan. At Ford Electronics, I initiated a silicon automotive sensor program and assisted in the design and development of sensors, integrated circuits, and electronic modules for automotive safety and engine control systems. My primary function was to develop and bring to production one of the first MEMS (MicroElectroMechanical Systems) airbag accelerometers, including the design and fabrication of the associated interface integrated circuit and package. The

accelerometer that was designed was, in part, based on technology developed during my Ph.D. work at The University of Michigan. In 1993, the accelerometer program, as well as several engineers, were transferred to Ford Microelectronics, Inc. in Colorado Springs to take the device into production. At the time, I also served on several internal technology assessment and planning teams that established integrated circuit and sensor product roadmaps at the corporate level for Ford Motor Company.

11. From 1993 to 1998, I was a Principal Engineer and Engineering Manager at Ford Microelectronics, Inc. in Colorado Springs, Colorado. In that role, I was responsible for the design, development, and qualification of silicon automotive integrated circuits and sensors including the accelerometer that had been developed at Ford Electronics in Dearborn, Michigan. This accelerometer was the first plastic packaged surface mount accelerometer qualified for automotive use. I was directly involved in the design of the integrated circuits, sensor die and packages and the fabrication technologies that were used to manufacture them. Accelerometers are nominally very sensitive to heat and the design of this accelerometer was driven in large part by the need to manage the heat generated from the circuit element in such a manner that it did not degrade the operation of the sense element. Due to the detailed analysis of the thermal aspects of the device, it was released for production without the need for temperature compensation circuits. Virtually all other

accelerometers manufactured at that time required some form of temperature compensation, which added cost and complexity to those devices. This accelerometer had several different variations driven by the product and technology roadmaps that I was responsible for. Over the course of two or so years (1997-1999) about 12 million of these accelerometers were manufactured and installed in Ford, Volvo and Mazda cars and trucks worldwide.

12. At Ford Microelectronics, I was also the international corporate technology expert for silicon sensors. In that role, I had direct responsibility for interfacing with companies that develop and manufacture the components used in automotive products including integrated circuit and sense element chips. I worked closely with engineers at automotive and semiconductor suppliers throughout the world including some of the largest electronic packaging companies in the world.

13. From 1998 to 2000, I was a Principal Integrated Circuit Design Engineer at Intel and Ford Microelectronics. I was responsible for designing baseband circuits for wireless devices, and memory devices including output amplifiers and input circuits for use in mixed-signal CMOS integrated circuits. In this role I was responsible for understanding the details of the fabrication and packaging technologies used to manufacture these ICs. At Intel, I also was responsible for the design of interface and voltage boost circuits for Flash Memory chips. This required direct involvement

in wafer fabrication and packaging technologies. I also developed a novel lateral transistor in a CMOS integrated circuit process for use in a negative voltage input circuit.

14. In 2001, I was a Principal Engineer at Coventor, Inc., a semiconductor modeling software and product design services company. In the design services group, I was responsible for the design of semiconductor packages and assembly processes for RF, optical, and telecom integrated circuits and MEMS devices including the packaging and integration of optical and electrical components, laser diodes, optical windows, and coatings and their assembly processes so that the product could meet functional, cost, and reliability requirements. Thermal management, including the design of heat sinks and heat spreaders was a major driver in my designs of the optical components, in particular laser diodes, since considerable heat can be generated by the laser diode. If this heat is not spread away from other components, it can cause functional and reliability issues.

15. From 2001 to 2010, I was employed at Aspen Technologies, LLC, an electronics product development and package and assembly subcontract company. I was originally hired by Aspen Technologies as a principal engineer, responsible for package design and assembly process development. I was promoted through various positions including Director of Engineering and Vice President of Engineering,

eventually becoming the President and Chief Technical Officer in 2009. In that role, I was responsible for all corporate operations including sales, marketing, design, engineering, manufacturing, finance and quality activities for a wide range of products including LEDs, sensors, ICs, RF devices, optical displays, pressure sensors, photonic devices, mirror arrays, microfluidic products, diagnostic and implantable biomedical devices, and DNA sequencing chips, as well as a host of other semiconductor devices and electronic products that use semiconductor die and other semiconductor components. Customers included large mil-aero companies such as Boeing and Lockheed Martin as well as smaller companies such as Silicon Light Machines and Aeroflex. Industrial and electronic customers ranged from Agilent and Hewlett-Packard to Atmel, National Semiconductor, and Intel. Medical customers ranged from large companies like Stryker Instruments, Boston Scientific, and Life Technologies to startups such as Endotronics, and Cantimer.

16. Over the course of my ten years at Aspen Technologies, I was directly involved in the design, development, packaging and commercialization efforts for over 350 products, several of which had very challenging thermal management requirements. One of those products during the 2005-2006 time frame, was a laser-illuminated 64-million pixel display. The device had such challenging thermal requirements that I needed to design and develop an innovative heat spreader package and liquid-based thermal dissipation system.

17. Another device that I helped develop at Aspen Technologies in the 2002-2003 time frame was a package for a DNA sequencing chip. Due to the extreme sensitivity of the biochemical reactions on the chip surface, special considerations needed to be made to hold the chip temperature within a few fractions of a degree from nominal, despite ambient temperature variations and the thermal energy being generated by the chip itself. In the 2006-2010 time frame, I also helped develop a second DNA sequencing chip that operated on a different principle, but had similar thermal management requirements. I design a custom package and assembly process materials that allowed the surface of the chip to maintain temperature gradients less than 1 degree Celsius.

18. More recently in my present consulting company Aspen Microsystems, LLC, I helped a third company develop their DNA sequencing chip package. I was directly responsible for the design of the heat sink in the package and the thermal interface to the system. As with the two previous DNA chips that I worked on, managing the thermal properties of the device given the heat that is generated by the chip itself was a major challenge.

19. Additionally, while at Aspen Technologies, we were a qualified manufacturer of package enclosures for multi-chip electronic devices for Agilent Technologies. These devices were used in some of Agilent's most sophisticated instruments and

required unique thermal solutions including heat spreaders thermal interface materials and adhesives in order to maintain the extreme performance requirements that Agilent has for their products. Aspen Technologies, Inc. assembled devices with frames or support structures prior to 2010 for companies such as Agilent and Lockheed Martin.

20. In order to properly support the technical package assembly requirements of Aspen Technologies customers, we had a wide range of package assembly equipment including die attach machines, wirebonders, flip chip assembly equipment as well as dispensing, solder reflow furnaces along with many other specialized pieces of electronic assembly equipment. This equipment was used to assemble hundreds of different types of devices including lidded Ball Grid Arrays (BGAs), optical devices including LED assemblies as well as complex assemblies that contained a number of different components attached to a substrate using wirebond, solder and conductive epoxy materials.

21. At Aspen Technologies, products were assembled on virtually any material that is used for electronic substrate including ceramics such as alumina, Low-Temperature Cofired Ceramic (LTCC) and aluminum nitride, organic material such as FR4 PCB materials, polyimide and BT Resin substrates and fluorocarbon substrates made from PTFE materials. In some applications, these substrates were

mounted in package bodies that were made of metals, ceramics or plastics and in many cases included heat spreaders and lids.

22. The assembly of these devices required the use of adhesives, encapsulants and interface materials that are designed specifically for electronic assembly. Prior to 2010 at Aspen Microsystems, I was responsible for specifying adhesives and encapsulants including epoxies, acrylic and silicone-based materials to meet the needs of the product that we were assembling. Some adhesives had wide ranging applicability being thermally and electrically conductive while also having excellent adhesion strength to many different materials used in electronic assembly. Other times specific materials had to be chosen for specific purposes related to thermo-mechanical performance, dispensing and application properties as well as the required cure schedule. In several occasions I had to work with the adhesive manufacturers to custom formulate an adhesive to meet an unusual requirement for a specific product.

23. It was this broad understanding of packaging, substrate, adhesive, and encapsulant materials, along with the understanding of how to design packages and assembly processes that allowed customers electronic packaging challenges to be met. This combined with the equipment and people that could assemble these packages with these materials that lead to Aspen Technologies success. Aspen

Technologies, LLC was sold in late 2010 and no longer exists in the form described here.

24. After selling Aspen Technologies, from 2011 until 2012, I was employed as the Vice President of Development for Treehouse Design, Inc. In that role, I was responsible for the product development of several innovative medical and industrial products. These included sensors and integrated circuits for medical surgical robots as well as optical communication systems for industrial applications. These optical communication systems required me to design packages and assembly processes that included LED and laser diode products that also had specific heat spreader requirements.

25. Prior to 2011, as a consultant, I created and executed development plans for various microelectronic and microsystem products, including pressure sensors, solar devices, medical diagnostic equipment, optical sensors, inertial sensors, and advanced integrated circuits. I also helped develop glass substrate pressure and temperature sensors, CMOS and bipolar SOI circuits, and helped develop their fabrication processes. I have also provided consulting services for a number of customers in designing microelectronic fabrication facilities, equipment and processes, organizational development, quality and manufacturing operations.

26. In 2011, I started consulting and contract product engineering on a full-time basis under the auspices of my own consulting and contract engineering company, Aspen Microsystems, LLC. Since 2012 and continuously to the present, this has been my full-time occupation. My clients are companies and organizations that use electronic components and semiconductor technologies in their operations or in their products. I have also provided educational services in semiconductor device fabrication, packaging, and assembly technologies for both public and private customers.

27. Throughout my career, I have designed packages and assembly processes for hundreds of individual electronic products. The successful design of these packages and assembly processes leveraged my experience in materials and manufacturing processes, as well as the experience in matching the design, material, and process tradeoffs with the functional, thermal, reliability, manufacturability and cost needs of the application.

28. I have designed substrates, lids and heat spreaders for packages for electronic products including products that contain LEDs, high performance integrated circuits as well as power semiconductors. The design and specification of these substrates, lids and heat spreaders must include details of the materials that are used to make them. Selection of those materials must take in the thermal requirements of the

devices and the impact and tradeoffs these design features have on the performance and reliability of the product. Another example of an electronic device that required detailed thermal management is a power thyristor used in the ignition systems of commercial and military aircraft engines. This high voltage switch is manufactured on a custom substrate with a heat spreader lid and a thermal interface material inside the package enclosure that allows heat to flow from the electronic component to the heat spreader and into the surrounding environment. Due to supply chain issues, I was asked by the client, Champion Aerospace, to help bring the device into production at a new facility improve the thermal dissipation of the device and to qualify the manufacturing operations at the new supplier and at Champion Aerospace. This required the redesign of the thermal interface of the device and the process used to assemble it. Champion Aerospace made a substantial financial investment in the new process resulting in significantly improved yields and device performance characteristics. The is still in production to this day and is used to start the jet engines of many commercial and military aircraft in the US.

29. From 2006 until 2019, I was an Editor of the IEEE Journal of Microelectromechanical Systems (JMEMS). I also served on the Board of Directors of the Transducers Research Foundation, from 2008 until 2018. From 2004 to 2012, I was a member of the International Steering Committee Member of the Transducers

Conference. I have been a Member of the Institute of Electrical and Electronics Engineers (IEEE) for 40 years.

30. I have been named an inventor on sixteen US and international patents, most of which relate to the assembly of electronic and semiconductor devices and packages.

31. I have published more than twenty journal and conference papers. I also teach multi-day technical classes throughout the world in both public and private settings in the areas of semiconductors, MEMS, and device packaging and assembly.

32. I am being compensated at $500 per hour for my services in this proceeding. My compensation is not contingent upon my performance, the outcome of this proceeding, or any issues involved in or related to this matter. My opinions are additionally guided by my appreciation of how a person of ordinary skill in the art ("POSITA") would have understood the claims of the '925 patent at the time of the alleged invention, which I have been asked to assume is January 11, 2013, which counsel informs me is the earliest possible priority date for the '925 patent.

III. LEGAL UNDERSTANDING

33. I am not an attorney. I have, however, been informed by counsel of certain legal standards and have applied those standards, described below, in formulating my opinions.

1. Claim Construction

34. I understand that "claim construction" is the process of determining a patent claim's meaning. I also have been informed that the proper construction of a claim term is the meaning that a person of ordinary skill in the art (i.e., the technical field to which the patent relates) would have given to that term at the time when the relevant patent application was filed in the United States Patent and Trademark Office. I also have been informed that, in this proceeding, claim construction will be determined by the Patent Trial and Appeal Board ("the Board"). I further understand that the proper construction of any term that requires construction is how a person of ordinary skill in the art would understand the term based on its use in the claims, specification, and file history of the patent.

35. I understand that claim terms that are not construed by the Board should be given their ordinary and customary meaning as understood by a person of ordinary skill in the art.

2. Obviousness

36. I understand that prior art includes patents and printed publications that existed before the earliest filing date (the "effective filing date") of the claims in the patent. I also understand that a patent will be prior art if it was filed before the effective

filing date of the claimed invention, while a printed publication will be prior art if it was publicly available before that date.

37. In analyzing obviousness in light of the prior art, I understand that it is important to understand the scope of the claims, the level of skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and any objective indicia of non-obviousness (also called secondary considerations).

38. I understand that a patent claim is unpatentable for obviousness if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in the art ("POSITA") to which said subject matter pertains.

39. I understand to determine the level of ordinary skill in the art several factors are considered including: (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the education level of active workers in the field.

40. I understand that obviousness may be based on one reference or a combination of references. I understand that when a patented invention is a combination of known elements, the Board must determine whether there was an apparent reason to

combine the known elements in the fashion claimed by the patent at issue by considering the teachings of prior art references, the effects of demands known to people working in the field or present in the marketplace, and the background knowledge possessed by a POSITA.

41. I have been informed that there are several rationales for combining references or modifying a reference to show obviousness of the claimed subject matter, including: (1) combining prior art elements according to known methods to yield predictable results; (2) simple substitution of one known element for another to obtain predictable results; (3) use of a known technique to improve a similar device (method or product) in the same way; (4) applying a known technique to a known device (method or product) ready for improvement to yield predictable results; (5) choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and (6) some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art references or to combine prior art reference teachings arrive at the claimed invention.

42. I understand that in order to prove that a claimed invention is not patentable for obviousness, a petitioner must (1) identify the differences between the claim and particular disclosures in the prior art references, singly or in combination, (2) specifically explain how the prior art references could have been combined in order

to arrive at the subject matter of the claimed invention, and (3) specifically explain why a POSITA would have had reasons to so combine the prior art references.

43. I understand that objective indicia are probative evidence of non-obviousness. I understand that objective indicia regarding non-obviousness of patent claims include commercial success, skepticism, industry praise or recognition, long-felt but unmet need, and evidence of copying.

44. I further understand that there must be a nexus between the objective indicia of non-obviousness and the merits of the claimed invention. I understand that the required nexus can be demonstrated through either a presumption, where the evidence is tied to a specific product and that product embodies and is coextensive with the claimed features, or by showing that the evidence of objective indicia results from the unique characteristics of the claimed invention as a whole.

IV. PERSON OF ORDINARY SKILL IN THE ART ("POSITA")

45. I understand that the claims are construed from the POSITA's viewpoint, and the factual determinations underlying a legal conclusion of obviousness (in particular, the scope and content of the prior art, and the differences between the prior art and the claims) are performed from the perspective a POSITA.

46. I have been informed by counsel that the following five non-exclusive factors may be used to determine the level of skill level in the relevant art:

(1) the types of problems encountered in the art;

(2) the prior art solutions to those problems;

(3) the rapidity with which innovations are made;

(4) the sophistication of the technology; and

(5) the educational level of active workers in the field.

47. As it relates to this technology, I believe a person of ordinary skill in the art at the time of the alleged invention would have the following characteristics: (1) a bachelor's degree in electrical or mechanical engineering or an equivalent degree; (2) a minimum of two to five years of experience in the design of electronic packages and assembly processes; and (3) general knowledge of engineering that would include understanding of electronic products including portable electronics.

48. Based upon my education and experience as set forth above, I believe that I would qualify as at least a POSITA in the relevant time frame. At the time of the alleged invention, I had a sufficient level of knowledge, experience, and education to provide an expert opinion in the field of the '925 Patent.

V. GRAPHITE AND ITS USE IN HEAT SPREADERS

49. This portion of my declaration contains background information about the graphite industry as well as details of material properties of graphite and the processing techniques that were developed to form heat spreaders with large values of thermal anisotropy. Included in this section are specific examples of the use of

thermally anisotropic graphite heat spreaders in commercially available products, as well as information concerning the design latitude that engineers had at their disposal when tackling thermal management issues. All of the references used in this declaration were publicly available prior to 2013.

50. Prior to 2013, the graphite industry had grown dramatically with the diversity of material offerings, manufacturing methods and designs spreading to many different industries. Graphite is resistant to most chemical reactions, making it suitable for use in corrosive environments. Graphite was commonly employed in manufacturing processes such as the production of crucibles, molds for metal casting, and fixtures for thermal processes. Graphite was also used for high-temperature applications like rocket nozzles and brake linings. Its combination of high melting point, low reactivity, and excellent strength-to-weight ratio makes graphite an indispensable material in many electronic sectors including electrodes in batteries, fuel cells, and electrical contacts and heat spreaders. In addition to its inertness, graphite has a relatively low density and has been formed into thin sheets and a wide range of shapes making it ideal for use in mobile electronics.

51. The background portion of this declaration details how thermal management engineers, component and system designers along with graphite suppliers worked together prior to 2013 to routinely solve challenging heat management problems in

commercially available electronic systems with the use of thermally anisotropic graphite.

52. This background information also provides the technical basis for my opinion that the asserted claims of the '925 patent would have been obvious to a POSITA at the time of the purported invention. This background section concludes with a description of related patents, one filed as far back as 1992, further illustrating the maturity of the technology prior to 2013.

1. Material Properties of Graphite

53. Carbon, element 14 in the periodic table, has many different crystalline structures or "allotropes" including graphite, diamond, fullerene as well as amorphous forms such as coal. *(Pierson, Ex. 1011, pg. 40-41)*. Some of these allotropes have been synthesized in the laboratory since the late 1800's. *(Acheson, Ex. 1018)*. Graphite has been processed to form materials with high degrees of crystal orientation since the early 1960's. *(Blackman, Ex. 1014)* and natural graphite has been used as a heat spreader since at least 1992. *(Banks, Ex. 1025)*. Commercial entities have been manufacturing heat spreader products with synthetic graphite in the form of Highly Ordered Pyrolytic Graphite (HOPG) for at least a decade prior to 2013.

54. Graphite has a crystalline structure that consists of carbon atoms covalently bonded in a hexagonal or honeycomb lattice that is nominally one atom thick. The covalent bonds within the hexagonal arrangement of carbon atoms are very strong and as a result there is very strong coupling between the atoms. A single sheet of hexagonally coupled carbon is referred to as graphene. Stacks of graphene sheets are referred to as graphite. Graphene sheets are stacked on top of each other are bonded together only by weak van der Waals forces and as such, the graphene sheets can be separated from each other and can easily glide past each other. The later characteristic is what give this form of carbon its excellent lubrication properties.

55. In graphite, crystallographers define a single graphene sheet as the "ab-plane" or "ab-direction." The direction perpendicular to the ab-plane is known as the "c-axis" or "c-direction." Because of this unique crystalline structure of graphite, many of the physical properties of graphite, are orientation dependent or "anisotropic"; that is, their properties in the ab-direction are different than in the c-direction.

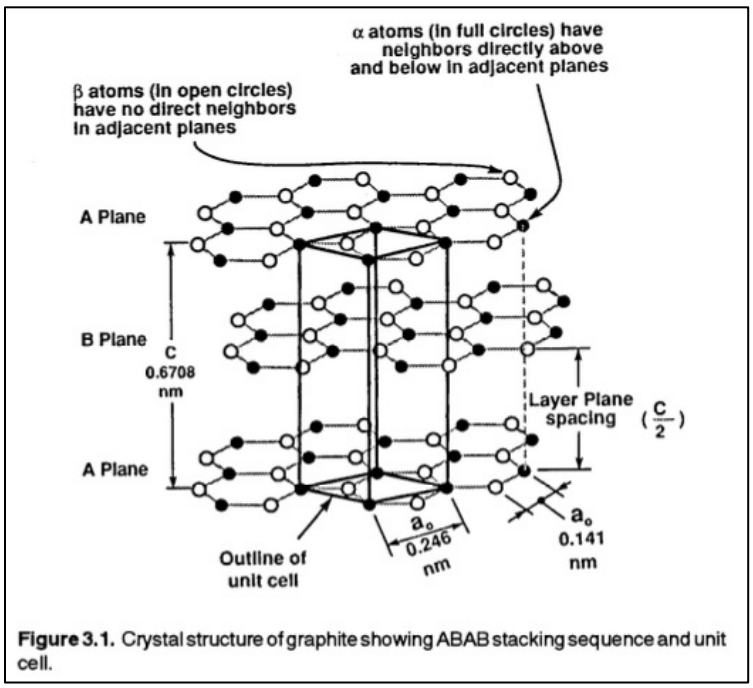


Figure 1: The crystallographic structure of graphite showing the ab-direction and the c-direction as well as how individual layers of graphene stack on each other. *(Pierson, Ex.1011).*

56. Many of the physical, electrical, thermal, and acoustic properties of graphene are anisotropic. This anisotropy is due to the very strong covalent bonds between carbon atoms in the hexagonally structured ab-planes. This allows electrons and phonons to easily propagate from one carbon atom to another in that direction. Weak van der Waals bonding between carbon atoms in the c-direction results in much less efficient electron and phonon propagation in that direction. A phonon is a quantum of atomic vibrational energy and phonon-phonon coupling is the means by which thermal energy is conducted within a solid. The weak bonding between sheets of

graphene makes them easy to separate and gives graphite it's excellent lubricating properties.

57. The advanced state of the scientific understanding of these anisotropic properties of graphite prior to 2013 led manufacturing and product engineers to develop innovative ways to leverage these unique properties of graphite in their products. This in turn led to the broad expansion of the industry and to the development of an extremely wide array of different forms of graphite allowing engineers to tradeoff material properties, manufacturing methods and cost. Prior to 2013, thermal management engineers had many different forms of thermally anisotropic graphite available to them. As will be described in the following sections, the advantages of graphite in some sense enabled cell phones to be as small and lightweight as they were prior to 2013.

58. At a molecular level, graphite consists of hexagonal planes of graphene that are stacked on top of each other to make graphite. However, at a macroscopic level, graphite comes in chunk, flake and/or fiber form of various sizes ranging from dozens of microns to centimeters in size. Commercially useable forms such as sheets or three-dimensional shapes are often fabricated from these flakes or fibers.

59. Most of the methods to manufacture synthetic graphite flakes and fibers fall into two broad categories: 1) pyrolysis of a solid or liquid precursor, or 2) pyrolysis from

a gas precursor onto a substrate. The later process is also known as Chemical Vapor Deposition (CVD). Each of these processes must be finely tuned and the precursors must be highly refined and purified to maximize the fraction of the precursor that is converted to graphite. The precursor that is not converted to graphite, while still made of carbon, can be considered a contaminant in the design of heat spreaders because they reduce the thermal anisotropy of the resulting material.

60. The solid pyrolysis process involves high temperature processing of a precursor such as polyacrylonitrile, Rayon, or pitch along with spinning and annealing techniques to make graphite fibers of various sizes. *(Pierson, Ex. 1011)*. These fibers can be further spun and twisted into a yarn and woven into sheets or formed into custom 3-dimensional shapes.

61. The gas -phase or CVD method of making graphite uses a gas precursor such as ethylene (C_2H_6) or acetylene (C_2H_2) and a specially designed substrate in a heated reactor. The precursor gas is highly purified and broken down at high temperature and the resulting carbon molecules deposit directly on the substrate in the reactor. The result is referred to as Pyrolytic Graphite (PG), a highly pure carbon film that can have a very high percent of graphite. The graphite film from a PG process can be coated directly onto a product, or the film can be removed from the substrate and

processed further resulting in graphite flakes of various sizes and shapes. *(Wu, Ex. 1012).*

62. Graphite fibers and flakes can then be further processed to form various shapes. They can be encased in epoxy materials resulting in products with great strength and light weight. Graphite can also be pressed in it's pure form by various means into a wide range of shapes. The specific methods used to form graphite flakes into a solid form have a significant impact on the resulting mechanical and thermal properties, in particular on thermal conductivity and thermal anisotropy.

63. The thermal anisotropy of graphite can vary widely based on factors such as purity, density, fiber or flake size, mosaicity and other parameters. Larger size flakes generally result in higher thermal conductivity since the thermal energy does not have to couple from one flake to another though non-covalent bonds. Impurities in graphite reduce thermal conductivity and anisotropy because they disrupt the phonon-phonon coupling between the carbon atoms in the ab-direction while they increase phonon-phonon coupling between adjacent sheets of graphene in the c-direction. Application of graphite in heat spreader applications drove the technology to allow it to be formed into thin, flexible sheets that had the desired shape well before 2013.

64. Higher density graphite sheets will generally have greater thermal conductivity and anisotropy due the more compact structure and often due to a lower level of mosaicity. "Mosaicity" is the term that crystallographers use to describe the distribution of crystal plane orientations in graphite. As graphite flakes are pressed into their desired shape, the orientation of those flakes and fibers changes and, under the right conditions, they can more fully align themselves in a preferred orientation. The higher the percentage of flakes that are oriented in the same direction, (low mosaicity) the greater the thermal anisotropy of the graphite. *(Marder, Ex. 1013 and Ex. 1016)*. It could easily be understood that materials that have higher anisotropy also cost more due to the additional refinement and process control that is needed to create these superior performing materials. These factors and the associated tradeoffs were well understood by both graphite manufacturers and thermal management engineers as well as electronic product designers prior to 2013.

65. Prior to 2013, graphite sheets could be made by any number of different processes, but the process that offered one of the highest degrees of anisotropy is referred to as: HOPG, (Highly Ordered Pyrolytic Graphite). The development of the HOPG process goes back to at least 1962. *(Blackman, Ex. 1014)*. Although not referred to by that name in 1962, the process he describes uses applied pressure and temperature to achieve greater alignment of the graphene sheets in the resulting bulk material. The process allowed great flexibility in the use of graphite in challenging

product applications. HOPG is a form of graphite that uses specific pressure and temperature profiles in molds to compact the graphite flake in such a manner that the ab-direction of the flakes is very consistent in the desired direction, while at the same time ensuring that the desired mechanical properties (i.e., flexibility and strength) are incorporated as well. See Figure 2 below.

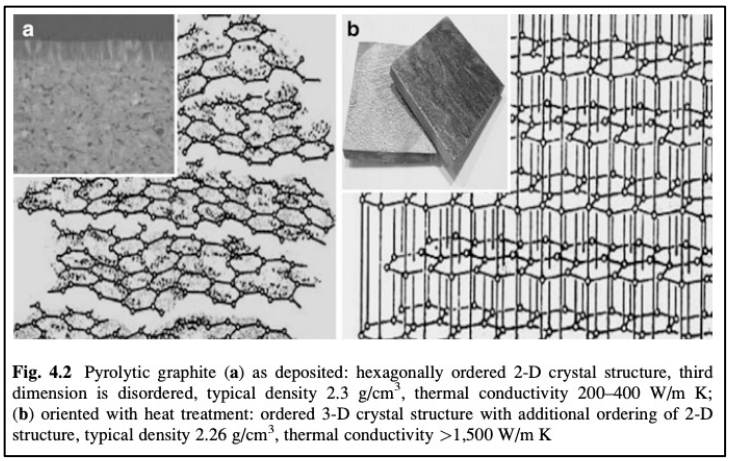


Fig. 4.2 Pyrolytic graphite (**a**) as deposited: hexagonally ordered 2-D crystal structure, third dimension is disordered, typical density 2.3 g/cm^3, thermal conductivity 200–400 W/m K; (**b**) oriented with heat treatment: ordered 3-D crystal structure with additional ordering of 2-D structure, typical density 2.26 g/cm^3, thermal conductivity >1,500 W/m K

Figure 2: An image of "as deposited" graphite flakes (left) and highly ordered pyrolytic graphite (right), *(Tong, Ex. 1015).*

66. Thermal conductivity of materials is often measured in units of Watts per meter per Kelvin, abbreviated as "W/mK." A material that has a thermal conductivity of one W/mK allows the transmission of one watt of power through one meter of that material with a temperature gradient across that meter of material of one Kelvin. From this definition, one can see that the total thermal energy that is passed through a material is proportional to the thickness of that material. Thus, for a material of a given thermal conductivity a thinner sample will pass thermal energy more readily than a thicker sample of the same material.

67. Thermal anisotropy of graphite is the ratio of thermal conductivity in the ab-direction to the thermal conductivity in the c-direction. In the Handbook of Carbon, Graphite, Diamond and Fullerenes, published in 1993, *(Pierson, Ex. 1011)*, the thermal conductivity of graphite was listed as being 390 W/mK in the ab-directions while it is only 2 W/mK in the c-direction, with a resulting thermal anisotropy of 145. An excerpt from that book is shown in Figure 3 below.

Table 3.6. Thermal Conductivity of Selected Materials

	W/m·K at 25°C
Pyrolytic graphite:	
ab directions	390
c direction	2

Figure 3: Data from 1993 showing a thermal anisotropy of 145 for pyrolytic graphite. *(Ex 1011, Pierson).*

68. The thermal anisotropy of graphite sheets continued to increase over the years as several companies, notably in the US and Japan, developed and refined their manufacturing methods. One of the primary driving forces in the early 2000's was the realization that the pyrolytic deposition process, combined with hot isostatic pressing could be used to manufacture thin, flexible HOPG graphite sheets for heat spreaders for electronic devices, in particular for mobile electronics. These were particularly advantageous for heat spreaders in mobile electronics due to the high thermal conductivity in the ab-direction, very thin size and light weight, high reliability as well as a high degree of manufacturability.

69. The thermal conductivity of graphite in the ab-direction is quite large, even compared with metals such as copper and aluminum that are known for high thermal conductivity. Most ceramics have a relatively low thermal conductivity except for Aluminum Nitride (AlN) which has a thermal conductivity about half of copper. Printed circuit board materials generally have a rather low thermal conductivity as do pure epoxies. As discussed in Section V.3 of this report, the thermal conductivity of epoxy adhesives can be increased by the use of fillers. In, Table 1, below, the thermal conductivity for some of the materials discussed in this declaration is summarized.

Material		Approximate Thermal Conductivity (W/mK)*	Exhibit #
Copper		388	Chung *(Ex. 1019)*
Aluminum		222	Chung *(Ex. 1019)*
Silver Filled Epoxy		29	EpoTek *(Ex. 1035)*
Aluminum Nitride		170	Nozaki *(Ex. 0097)*
Printed Circuit Board		0.5 to 0.3	Kandasamy *(Ex. 1037)*
Thermal interface material		0.5 to 10	Hanai *(Ex. 0019)*
Nozaki	Graphite ab-direction	up to 1200	Nozaki *(Ex. 0090)*
	Graphite c-direction	4 to 6	Nozaki *(Ex. 0090)*
Hanai	Graphite ab-direction	200 to 800	Hanai *(Ex. 0019)*
	Graphite c-direction	5 to 20	Hanai *(Ex. 0019)*

Table 1: Thermal conductivity for selected materials. * The value of thermal conductivity of a material can vary depending on composition, method of preparation, the temperature of the material among other factors.

2. Manufacture of Graphite Sheets and Products prior to 2013

70. Prior to 2013, the wide range of manufacturing process available for forming graphite into various shapes and specialty products with tailored material characteristics lead to the rapid expansion of the graphite industry. One of the most important uses of thermally anisotropic graphite was in heat spreaders for mobile electronic devices such as cell phones and laptop computers that had thermal management challenges. The ability to form graphite into thin sheets of various forms with low mosaicity, and a high degree of crystalline alignment resulted in the

availability of heat spreaders that had extremely high thermal anisotropy with extremely high thermal conductivity in the plane of the sheet.

71. As early as 2006, Minteq International of Easton, PA, reported the commercial availability of Pyrolytic Graphite with a thermal conductivity in the "ab-direction" of greater than 1900 W/mK while in the orthogonal direction, or "c-direction" of 7 W/mK. This corresponds to a thermal anisotropy of approximately 275. *(Lemak, Ex. 1017)*. In this same publication, this very large value of anisotropy was compared to "standard" Pyrolytic Graphite with thermal conductivity in the "a-b direction" of 449 W/mK and in the "c-direction" of 1.9 W/mK, corresponding to a thermal anisotropy of about 235. During this time (2006), Minteq *(Lemak, Ex. 1017)* designed and manufactured flexible, thermally anisotropic graphite sheets for heat spreader applications for electronic devices as well as for other applications.

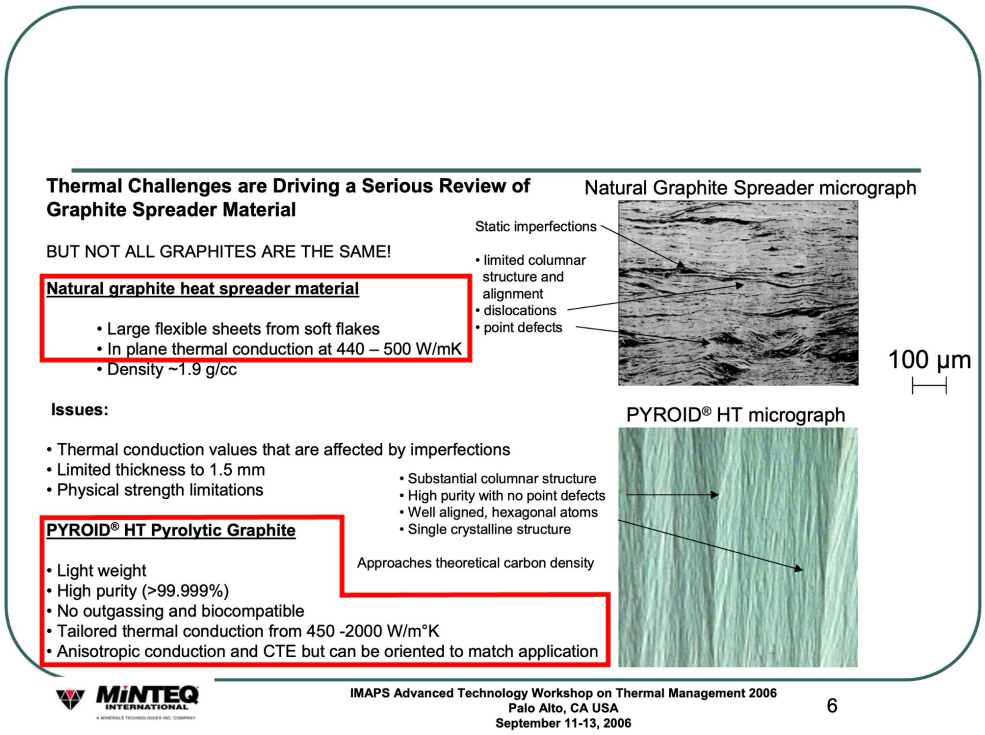


Figure 4: An annotated portion of a technical presentation from 2006 extoling the benefits of graphite while also emphasizing the thermal properties could be tailored to a specific application requirement. *(Lemak, Ex. 1017).*

72. In their 2006 presentation, Minteq emphasized that not all graphite was the same, but as early as 2006, highly refined graphite with thermal anisotropy far exceeding 100 was readily available for a wide range of applications with a wide range of material properties and cost.

73. In 2012, a company by the name of ThermaCore, presented advances in thermal management by incorporating HOPG in their metal clad heat spreaders. *(Marder, Ex. 1013 and Ex. 1016).* In addition to showing how the thermally anisotropic graphite could aid in electronic systems for the avionics industry, they also published

data comparing "as deposited" "Pyrolytic Graphite" with "Pyrolytic Graphite after Annealing and Highly Ordering" processes. The anisotropy increased from about 100 for the "as-deposited" material, to 170 for the annealed graphite, and as high as 200 for the highly order pyrolytic graphite.

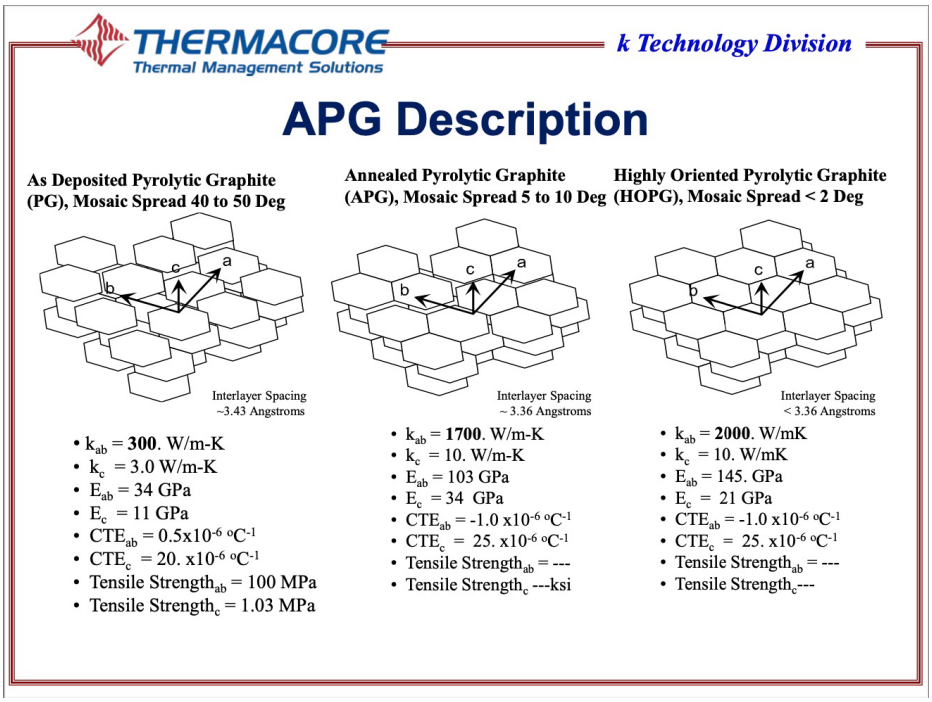


Figure 5: An image from a presentation in 2012 showing the relationship of mosaicity and anisotropy of three forms of graphite *(Marder, Ex. 1013 and 1016).*

74. It is clear that designers and engineers had access to a wide range of thermally anisotropic flexible graphite sheets to solve thermal management challenges prior to 2013. The maturation of graphite materials and manufacturing techniques along with the developed capabilities for thermal modeling and designing heat spreaders to solve thermal management challenges combined with the demands of mobile

electronics gave component and product designers many options for transferring heat from sources to heat sinks in portable electronics in particular.

75. The paper by Chung and Takizawa compares the performance of various thermally anisotropic graphite materials with conventional heat sink material such as copper and aluminum and highlights the advantages and disadvantages of the different materials in various applications. *(Chung, Ex. 1019).*

76. Besides HOPG, other methods to manufacture graphite products prior to 2013 include isostatic pressure, extrusion, and machining as well as combining graphite fibers with epoxy to make epoxy-graphite composites. Each of these different methods was developed for specific applications that traded off properties such as size, anisotropy, thickness, weight and cost.

3. Other Package Assembly Materials Used in Conjunction with Graphite

77. Graphite has been used as a heat spreader in electronic devices well prior to 2013. Specific discussion of graphite heat spreaders and their application follows this section. In order to incorporate graphite heat spreaders into an electronic package however, other materials such as adhesives and thermal interface materials are commonly used. This section describes some of these materials and their characteristics as a POSITA would understand prior to 2013.

78. Adhesive materials are widely used in electronic assemblies for example to attach components to substrates and lids to packages. Epoxy resin-based materials are among the most common adhesives for these purposes. Pure epoxy resins in and of themselves are rarely used. Almost all epoxy adhesives used in electronic assemblies contain fillers to change the properties of the adhesive material. Epoxies are noted for retaining strong adhesive properties despite having a high concentration of these fillers. One of the most common fillers is silver flake which causes the resulting epoxy-based adhesive to become thermally and electrically conductive. A common silver filled epoxy used prior to 2013 is a material made by the company Epoxy Technology of Bellerica, MA. The material Epo-Tek H20E forms a strong bond to many different electronic package materials. According to the July 2007 version of the datasheet for this silver filled epoxy has a thermal conductivity of 29 W/mK and it is "used extensively for thermal management applications due to its high thermal conductivity" *(Epo-Tek, Ex. 1035)*. Many other filler systems and many other epoxy-based adhesives were available for package assembly applications prior to 2013.

79. Thermal energy is primarily passed through the silver filled epoxy by way of the silver flakes that touch each other as they are imbedded in the epoxy material *(Inoue, Ex 1036)*. Factors such as application method, size and shape of the silver flakes and particles, silver loading and cure schedule all impact both the electrical and

thermal conductivity of the silver filled epoxy. As a POSITA would know, these thermally conductive epoxy adhesives similar to Epo-Tek H20E, are typically used with a bondline of about 0.001 inch or about 25 microns. This thin section of adhesive material provides minimal resistance to the flow of thermal energy despite the fact that the thermal conductivity is not as high as copper or graphite in the a-b direction.

80. Thermal management in electronic devices consists of dissipating heat away from the heat generating components as well as shielding heat-sensitive components from the heat generating components. In order to effectively couple heat from a heat generating component into a heat spreader, a POSITA would often use what is called a Thermal Interface Material (TIM). Thermal Interface Materials are often silicone-based materials that are soft and they easily conform to the asperities that exist on the surfaces of the heat generating element and the heat spreader. *(Prasher, Ex. 1039)*. By conforming to the asperities, the gaps and voids that otherwise might exist at either of the two surfaces are greatly reduced and as such intimate contact is formed between the TIM and the two surfaces. This intimate contact allows the thermal energy to pass easily from the heat source to the heat spreader because gaps and voids, if present at an interface, inhibit the transfer of thermal energy. *(Prasher, Ex. 1039)*.

81. Furthermore, since TIMs are soft, as the dimensions between the heat source and the heat spreader change due to differences in the Coefficient of Thermal Expansion (CTE), the TIM can maintain intimate contact with the two surfaces while not introduce any undesired mechanical stresses that a more rigid material might. Kuo explicitly this issue in the '173 patent. *(Ex. 1004)*. The softness of TIMs also allow intimate contact between the surfaces despite variations due to the manufacturing process. TIMs are available as in dispensable form as well as in sheets of various thicknesses and they include thermal greases, pressure sensitive or dispensed adhesives, fill materials and pliable sheets. TIMs are somewhat interchangeable based on manufacturing processes, cost and other product design parameters. TIMs were widely available prior to 2013 and I had first-hand direct experience using them in the assembly of electronic devices that required the thermal management characteristics that a TIM would provide, in particular in attaching lids over flip chip BGA devices that were in production at my previous company, Aspen Technologies, Inc. Thermal Interface Materials will be discussed throughout this declaration.

4. Graphite Heat Spreaders

82. The importance and desirability of spreading heat from its source to a heat sink via a heat spreader in electronic packages has been well known for many years prior to the issuance of the '925 patent. Traditional materials such as copper and aluminum were used widely until graphite materials with high degree of thermal

conductivity and thermal anisotropy were developed. *(Chung, Ex. 1019)*. Norley and his colleagues from GrafTech published a paper in 2001extoling the value of graphite as a heat spreader for electronic applications. *(Norley, Ex. 1020)*. This paper emphasized the wide diversity of materials available to the product designer, even in their natural form.

83. GrafTech continued to make advances in heat sinks and heat spreaders by showing the dramatic design flexibility the material had. The paper by Shives in 2004 showed heat sink fins that were only 0.5mm thick, yet 30 mm tall and 114 mm long. *(Shives, Ex. 1021)*. This extreme aspect ratio emphasizes the design flexibility of graphite sheets that was available to a POSITA at the time of the invention.

5. Graphite Heat Spreaders in Mobile Electronics and Cell Phones

84. The late 2000's was a period of great growth in the electronics industry, driven in large part by the introduction and widespread adoption of mobile electronics such as cell phones and laptops. One of the major challenges to reducing the size of portable electronics is heat management. As consumers clamored for smaller cell phones and laptop computers with greater performance, the thermal challenges increased dramatically.

85. This was highlighted in a 2009 paper published by Lakhkar and colleagues entitled "Multi-objective Optimization of Heat Spreader for Portable Systems

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Applications." This paper shows highly detailed engineering analysis of a portable electronic device and the challenges that exist in dissipating heat from localized sources such as the microprocessor and the memory chips. *(Lakhkar, Ex. 1022)*. Hot spots in a mobile device are not only undesired by the individual holding the portable device, but they also can impact the performance of components, in particular displays as the heat changes their characteristics. Hot spots could for example, cause one portion of the display to show different colors than the rest of the display, obviously a highly undesired situation for the user.

86. Lakhkar describes how to use a panel of anisotropic graphite as a heat spreader to optimize the thermal performance of a laptop computer. The paper describes how this would benefit the design of the heat spreader by defining different contiguous sections of the panel as heat producing sections, while other contiguous sections are cooler. The author describes a method to analyze these contiguous sections, or blocks, to optimize the size and shape of the graphite heat spreader and to minimize the effect that "hot spots" in the device so as to minimize their impact on the user.

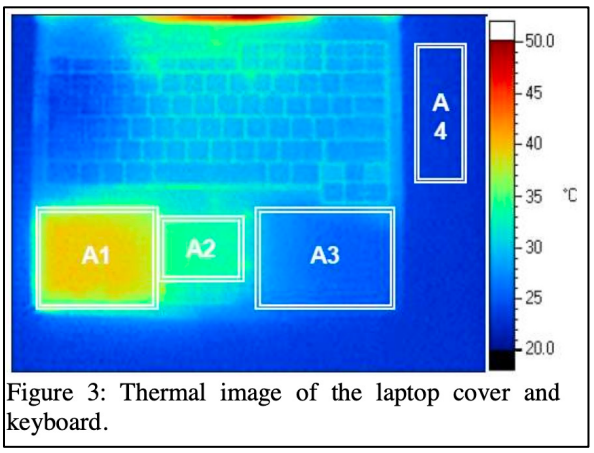


Figure 3: Thermal image of the laptop cover and keyboard.

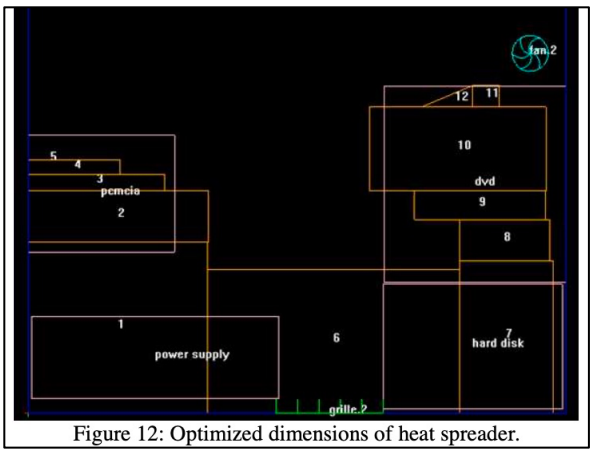


Figure 12: Optimized dimensions of heat spreader.

Figure 6: The thermal modeling strategy from a 2009 paper showing how contiguous sections in the thermally anisotropic graphite heat spreader could be optimized to reduce "hot spots" in a laptop computer. *(Lakhkar, Ex. 1022)*

87. The use of thermally anisotropic graphite heat spreaders was so ubiquitous among designers of electronic products that the semiconductor company Freescale Corporation in 2012, published a 90-page Application Note entitled "Thermal Management Guidelines." (AN4579, Ex. 1023). This document details how to incorporate thermally anisotropic graphite heat spreaders into portable electronic systems to address their unique thermal management challenges. The application note compares various graphite materials with isotropic materials such as copper and aluminum, and notes that the advantages of graphite in mobile electronics. The Application Note states that "Flexible graphite heat spreaders give product designers the tools to overcome the complex challenges of thermal management." *(AN4579, Ex. 1023)*.

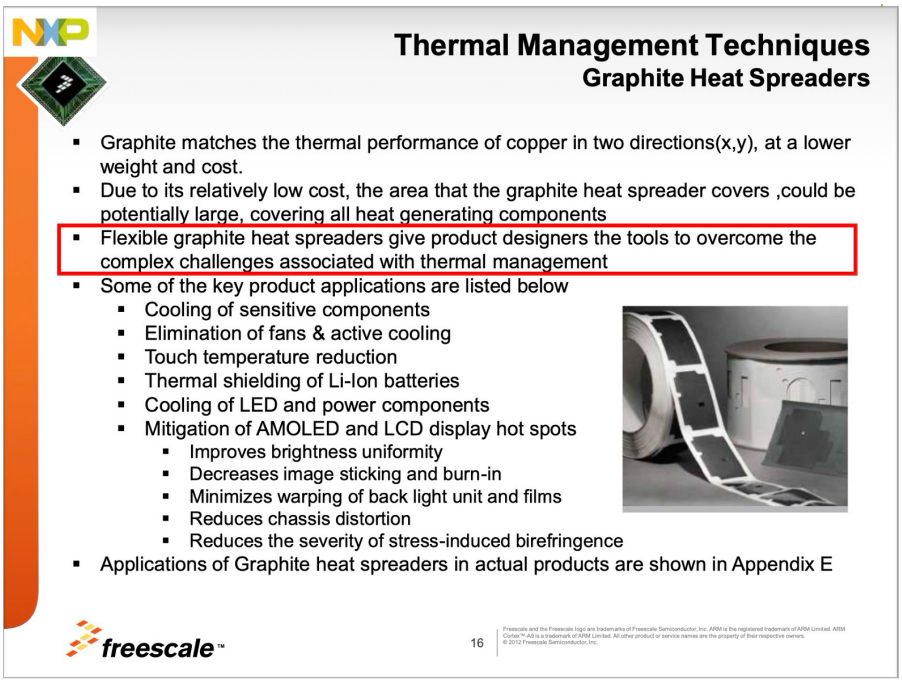


Figure 7: An annotated page from Freescale Application Note AN4579 highlighting the flexibility that designers had in using graphite sheets as a heat spreader prior to 2013. *(Ex. 1023).*

88. As stated in the Appendix E of the Freescale application note at least three commercially available products prior to 2013 used anisotropic graphite heat spreaders for thermal management. These three example products, the Kindle Fire, Apple iPad3 and the Blackberry Playbook from RIM are shown in Figure 8 below with the graphite heat spreader identified in each of the teardowns. Each of these teardowns have links to websites and YouTube videos that document the teardown of these commercially available portable electronic devices. Section IX.2.a.v of this declaration has a more detailed analysis of the graphite heat spreader used in the Blackberry PlayBook.



Figure 8: Examples from the Freescale Application Note AN4579 showing the use of thermally anisotropic graphite sheets in commercially available portable electronic devices prior to 2013 *(Ex.1023)*.

89. The pervasiveness of thermally anisotropic flexible graphite sheets was so great that in early 2012 one of the major manufacturers of graphite heat spreaders presented a conference paper that described several of the applications that use anisotropic graphite heat spreaders. *(Smalc, Ex. 1024 and Ex. 1016).* Martin Smalc's presentation, excerpts of which are shown below, gives examples of graphite heat spreaders used in LED light fixtures, flat panel displays, and notably smart phones

where the GrafTech product addresses thermal management challenges by transferring heat from sources such as LEDs and power amplifiers to the case of the phone. This presentation shows the mature state of thermally anisotropic graphite sheets and the design flexibility that was available to designers of electronics components prior to 2013.

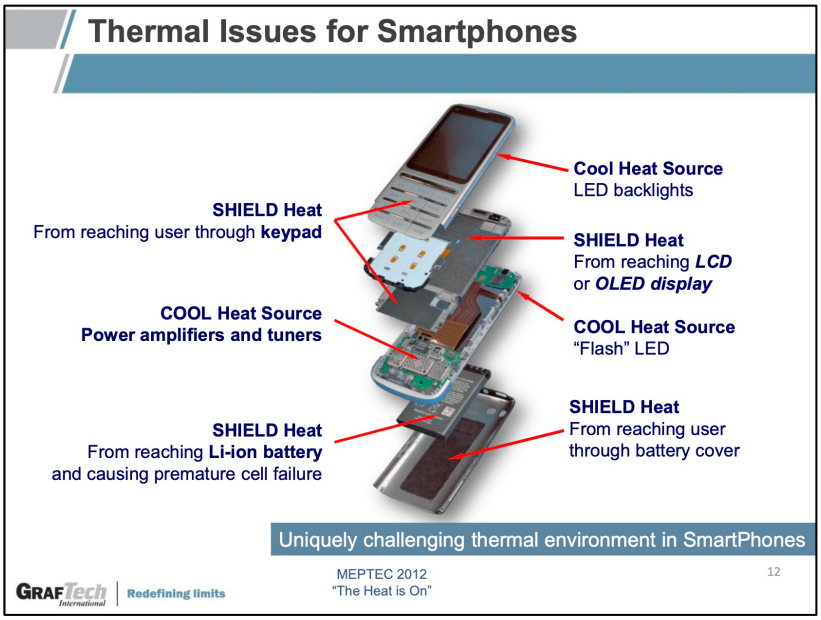


Figure 9: Image from GrafTech presentation in 2012 showing the multiple uses for thermally anisotropic flexible graphite sheets in cell phones. *(Smalc, Ex. 1024).*

VI. SELECTED EARLY PATENT LITERATURE REGARDING GRAPHITE HEAT SPREADERS FOR ELECTRONIC DEVICES

90. The anisotropy of graphite, and the benefit of being able to form flexible graphite sheets into three dimensional shapes with desirable thermal properties has been well known since prior to the turn of the century. As the demands of electronic packaging

grew, so did the understanding, refinement and application of thermally anisotropic, flexible graphite sheets.

1. US Patent, 5,224,030 (Banks, Ex. 1025)

91. As early as 1992, Banks and his co-inventors at NASA describe in US Patent, 5,224,030 a "Semiconductor Cooling Apparatus" made of thermally anisotropic graphite fibers surrounded by epoxy binder materials. *(Banks, Ex. 1025)*. In Figure 10 below, an annotated version of Figure 1 of the '030 patent, Item 10 is a "heat transfer device…used to conduct heat from heat source 12 to a heat sink 14." *(Banks, Ex. 1025, 2:63)*. The "heat transfer device" is made of "highly oriented graphite fibers" to "facilitate the spreading of semiconductor waste heat by utilizing the…graphite fiber." *(Banks, Ex. 1025, 4:8)*.

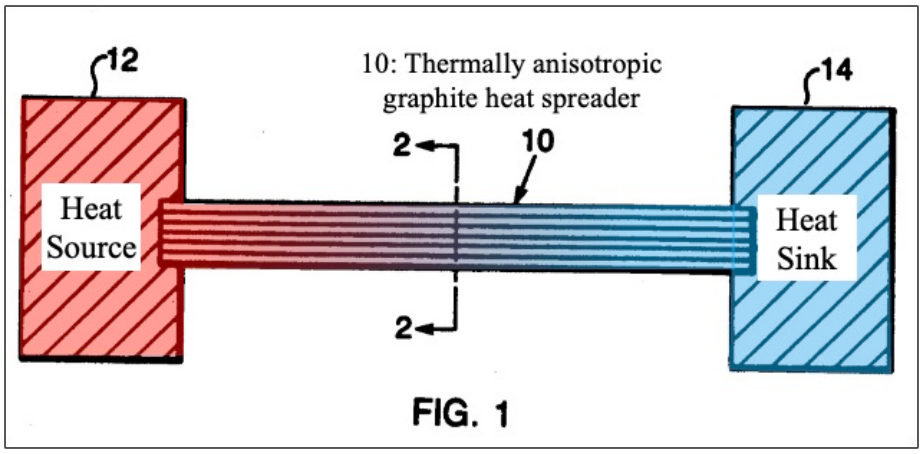


Figure 10: An annotated copy of Figure 1 from the patent issued to NASA in 1992 illustrating the use of thermally anisotropic graphite as a heat spreader. *(Banks, Ex. 1025)*.

92. The invention is specifically focused on use as a thermally anisotropic graphite heat spreader for electronic devices as Claim 1 of the Banks patent states, "A semiconductor cooling apparatus comprising a heat source comprising a semiconductor component…a heat sink…(and) graphite fibers in thermal contact with both heat source and heat sink for passively conducting heat between."

93. Furthermore, the inventors understood that a variety of methods could be employed to create the thermally anisotropic heat spreader, including machining the thermally anisotropic heat sink into arbitrary shapes as needed by a specific design.

> *In addition, the heat transfer device may be simply made of intercalated highly oriented pyrolytic graphite and suitably machined rather than being made of fibers. (Banks, Ex. 1025, 4:13).*

94. This shows that the idea of using graphite sheets for cooling electronic components existed more than 20 years prior to the '925 patent being issued.

2. US Patent, 5,902,762 (Mercuri, Ex. 1026)

95. A few years later, Mercuri and his colleagues at UCAR Carbon Technology Corporation patented in 1997, the concept of using flexible anisotropic graphite sheets for thermal applications. In US Patent, 5,902,762, entitled "Flexible Graphite Composite", these inventors describe the anisotropy of graphite and utilize this property to create epoxy impregnated graphite foils "possessing desirable heat transfer properties." *(Mercuri, Ex. 1026, 1:67)*. The patent utilized the anisotropic

crystalline structure of graphite to facilitate the impregnation of epoxy between the graphene flakes "due to the well-known anisotropy of flexible graphite." *(Mercuri, Ex. 1026, 2:10)*. The inventors understood the importance of making the sheets thin. They describe them as being "Typically 0.1 and 3.5 mm thick." *(Mercuri, Ex. 1026, 3:3)*. Furthermore, they understood the importance of the graphite sheet extending throughout the plane of the thin sheet to the perimeter of the device as the Summary of the Invention states:

> *The present invention relates to a composite of a sheet of flexible graphite having opposed parallel planar outer surface and ...fiber particles which are embedded in the flexible sheet and which extend from interior the flexible sheet to at least one of the planar outer surfaces of the flexible graphite sheet. (Mercuri, Ex. 1026, 2:34)*.

3. US Patent 5,991,155 (Kobayashi, Ex. 1027)

96. Later in 1999, inventors Kobayashi and Nonaka addressed thermal issues in portable electronic devices in US Patent 5,991,155, "Heat Sink Assembly Including Flexible Heat Spreader Sheet." *(Kobayashi, Ex. 1027)*. Their invention was oriented towards using thin flexible, thermally anisotropic sheets of graphite to transfer heat from an "exothermic device" to the case of the mobile device while avoiding the transfer a heat to adjacent electronic components.

> *A first object of the present invention is to improve the overall efficiency of the radiating and cooling process, including a process of transmitting the heat from the exothermic device to the inside wall surface of the casing ...via the heat spreader sheet, while the heat*

> *spreader sheet is made of a flexible material having high thermal conductivity, such as graphite or graphite composite. (Kobayashi, Ex. 1027, 2:16)*

97. As shown in Figure 1 of the '155 patent, annotated in Figure 11 below, the inventors understood the need to manage heat in portable electronic devices by mean of a thin graphite sheet that was formed in such a manner as to transfer the heat from the electronic components to the case of the mobile device via a thermally anisotropic graphite sheet while at the same time avoiding other components in the mobile electronic device.

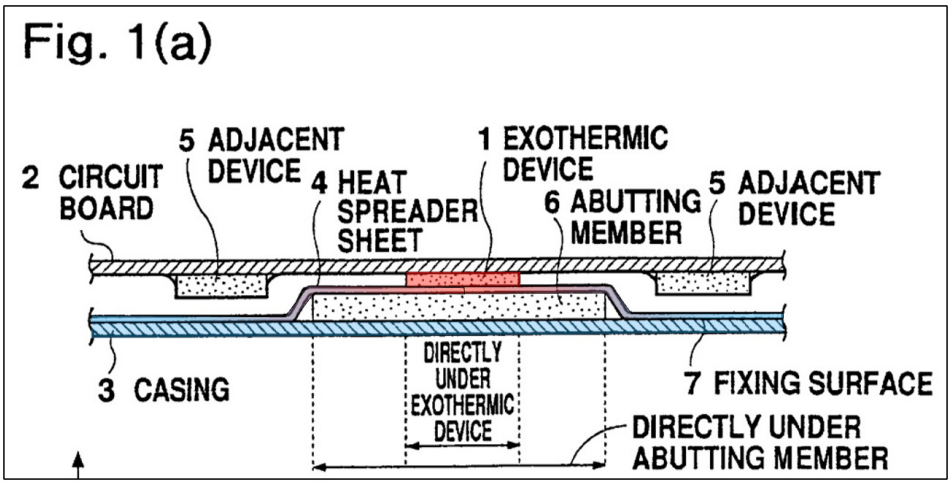


Figure 11: An annotated image from Kobayashi, *(Ex. 1027)* showing the electronic heat generating component in red (1) and the casing (3) shown in blue to which the heat was transferred by means of heat spreader sheet.

98. The inventors of the '155 patent understood the value of using a thermally anisotropic material due to its greater thermal conductivity in the ab-plane of the graphite.

> *In addition, in order to make this aerial heat insulation further effective, it is desirable to make heat spreader sheet 4 using a material having higher thermal conductivity in the horizontal direction in the figure…. (Kobayashi, Ex. 1027, 7:22)*

99. Furthermore, they understood the importance of making good thermal contact from the thermally anisotropic graphite heat sink to both the heat source and heat sink by means of thermal interface materials which could be flexible.

> *In this embodiment, elastic supporting frame 10 is arranged between abutting member 6 and the inside wall surface of casing 3, …to cause the surface of heat spreader sheet 4 to suitably come into contact with the surface of exothermic device 1, regardless of the spacing of mounted forms of exothermic device 1. (Kobayashi, Ex. 1027, 6:54).*

100. The inventors also understood that a thermally anisotropic graphite sheet only cools interior electronic devices if the heat is transported to an outer portion of the mobile device, i.e. the case.

> *Heat spreader sheet 4 is fixed to the inside wall surface of casing 3 at a portion other than the portion covering abutting member 6. Adhesive materials. Such as a heat conductive adhesive or a thermal grease are present on the inside wall surface of casing 3 and fixing surface 7 of heat spreader …(Kobayashi, Ex. 1027, 5:26).*

101. Finally, the inventors of the '155 patent understood that design flexibility is needed to adapt the invention to each specific application. In particular this means that components of various heights from the substrate, as well as distance from each other require different shapes to be incorporated into the flexible, graphite sheet.

> *Furthermore, it is possible to prevent contact of heat spreader sheet 4 with adjacent device 5, especially with lead wires or the like, 55 because heat spreader sheet 4 conforms to the outside shape of abutting member 6. Consequently, the intervals between adjacent devices mounted on circuit board 2 can be reduced, and a heat sink more suitable for a compact electronic apparatus, that is, a portable electronic apparatus…(Kobayashi, Ex. 1027, 5:53).*

102. These patents demonstrate the idea of using thermally anisotropic flexible graphite sheets for heat spreaders that are light weight, and can flexibly contour over the topology of electronic components on a substrate was well known prior to the turn of the century.

4. US Patent 7,292,441 (Smalc, Ex. 1028)

103. M.D. Smalc and co-inventors of US Patent 7,292,441, issued in 2006, expanded the use of flexible, thermally anisotropic graphite sheets to address the thermal management challenges and the space constraints in portable electronic devices which contain multiple electronic components on a substrate. *(Smalc, Ex. 1028)*. These components likely have differing heights from the mounting substrate. Figure 2b of the '441 patent, shown below, shows an example of how thin, flexible, thermally anisotropic graphite sheets could be incorporated into a cell phone. Smalc describes his invention as "…a conformable solution which provides both heat dissipation and heat blocking (or shielding in an environment where available space is limited" *(Smalc, Ex 1028, 5:23-25)*

104. The ’441 patent teaches that “These materials are anisotropic and allow thermal dissipation devices to be designed to preferentially transfer heat in selected directions. *(Smalc, Ex. 1028, 2:2)*. This is important because the specific design of these types of graphite sheets is highly dependent on the design of the cell phone and the electronic components mounted to the substrate.

105. For example, one use of the anisotropic graphite sheet disclosed is in the form of a sheet of compressed particles of exfoliated graphite 10 placed in contact with a heat source inside a laptop computer and oriented to spread heat from the source to a heat sink 124 located inside the computer, but spaced away from the heat source because space constraints would not allow the heat sink to be spaced closer to the heat-generating components. In addition, the graphite sheet shields and thus prevents the environment near the heat-generating elements from overheating. *(Smalc, Ex. 1028, 14:58 to 15:11)*. The ‘441 Patent teaches that a similar solution could be employed inside a mobile phone for the same purposes: to spread heat away from the heat-generating components to heat sinking structure (not shown) located elsewhere in the device and to shield the environment (that is, the user and other components such as the keypad) from excessive heat. *(Smalc, Ex. 1028, 15:18-50*).

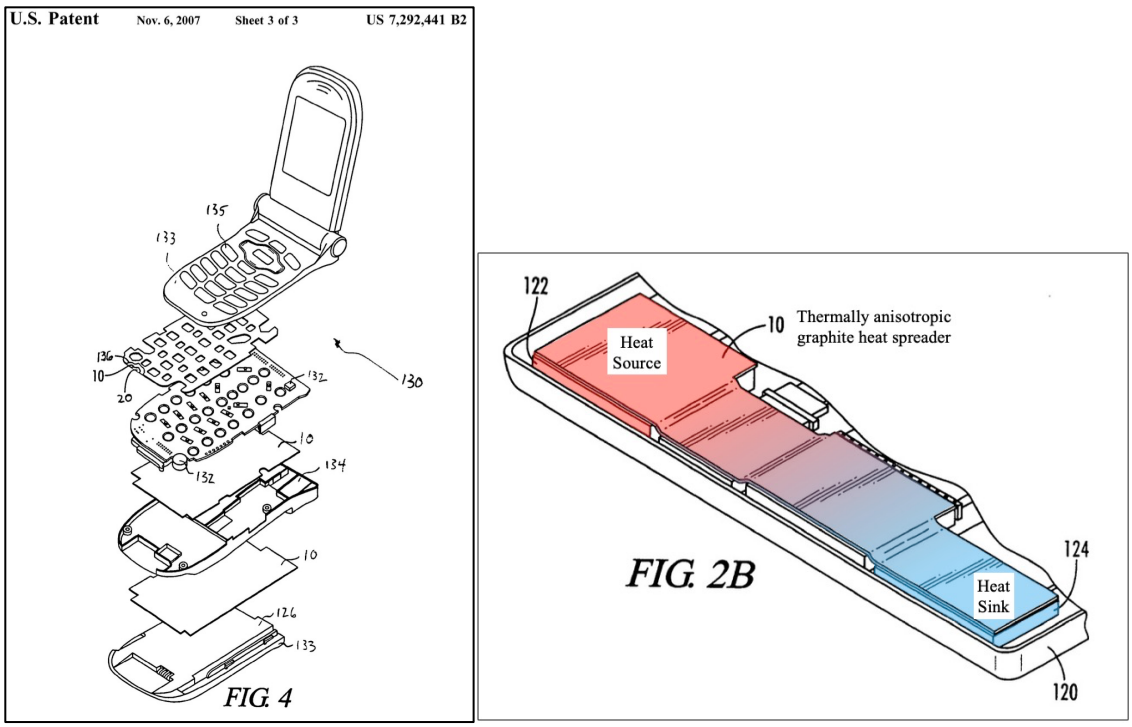


Figure 12: Annotated image from Smalc, *(Ex. 1028)* showing the thermally anisotropic graphite sheet (10) contouring over the components in a cell phone.

106. Smalc also teaches that the graphite heat spreader should be thought of as having contiguous sections, each with a surface that is parallel to the mounting surface, one in "operative contact" with a heat source and the other in contact with a heat sink *(Smalc, Ex 1028, 4:1-17)*. Additionally, Smalc identifies the value of a thermally anisotropic heat spreader not only to transfer heat preferentially to the heat sink, but also to shield components on the other side of the heat spreader from "hot spots" (Smalc, Ex 1028, 4:22-29). Smalc also identifies the value of a graphite heat spreader is shielding other components from undesired electromagnetic radiation (EMI/RF) *(Smalc, Ex 1028, 4:30-37)*.

107. The specification of the Smalc patent describes in detail various ways of processing graphite to form heat spreaders with various properties. This gives clear evidence of the sophisticated nature of graphite technology for heat spreaders prior to 2013.

5. U.S. Patent 6,404,070 (Higashi, Ex. 1029)

Higashi and his co-inventors described in the year 2000, a "heat dissipation plate" for electronic components that is comprised of graphite fibers woven into sheets and impregnated with an epoxy resin. The inventors describe the advantages of using graphite to dissipate the heat as being lighter in weight, smaller in thickness than conventional metal plates that were often used for this application The heat dissipation characteristics of the Higashi invention are at least equal to or greater than metal. The inventors understood the importance of connecting the graphite heat spreader that in in contact with the electronic component to a frame that surrounds that component to improve the thermal performance of the device.

> *"Frame 60 is comprised of a resin film, a metal foil, etc. that has a rectangular form surrounding the semiconductor chip 12 and forms an integrated solid by being bonded to the heat dissipation plate 10…to provide both a mechanical support…and a further improved heat dissipation from the semiconductor device." (Higashi, Ex. 1029, 7:9).*

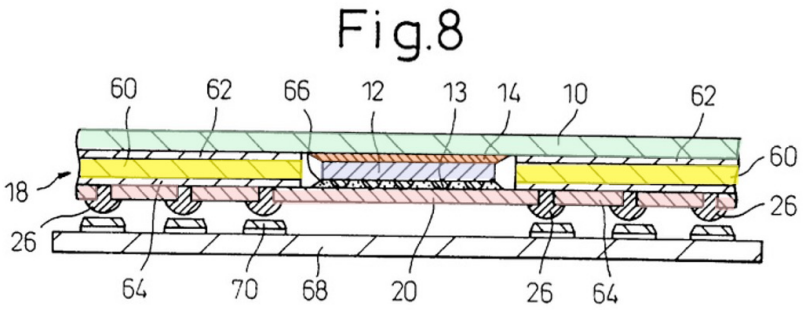


Figure 13: An annotated copy of Figure 8 from Higashi, *(Ex. 1029)* showing the thermally anisotropic graphite sheet (10) in green and surrounding frame that is used to dissipate heat from the semiconductor device in yellow.

6. U.S. Patent 4,849,858 (Grapes, Ex. 1030)

108. Even earlier, in 1986, Grapes and his colleagues at Westinghouse describe a "thermal heat transfer member" or substrate that is made of graphite fibers that are disposed within an insulating material such as an unfilled epoxy resin. The graphite fibers are nominally oriented in the plane of the substrate which has many electrical components mounted to it. The thermal conductivity of the heat transfer member is as high as 311W/mK in the plane of the substrate and less than 1 W/mK in the "transverse" direction. *(Grapes, Ex. 1030)*. This ratio of thermal conductivities corresponds to a thermal anisotropy of about 360. In addition to having excellent thermal transfer properties, the graphite substrate was also lighter in weight compared to conventional PCB materials with an aluminum thermal plane as the core.

109. It should be noted that there is a great deal of similarity between the construction demonstrated in the Grapes patent *(Ex. 1030)* and the Kuo patent *(Ex. 1004)*. The Kuo patent will be described in detail in following sections of this declaration and it will be used as a primary reference when comparing prior art to the asserted claims of the '925 patent.

VII. OVERVIEW OF THE '925 PATENT

110. With this background in mind, I will now review the specification and drawings of the '925 patent.

1. Specification of the '925 Patent

111. The '925 patent is directed to an electronic package assembly including a "composite material panel" that is "configured to provide highly conductive thermal paths" that direct heat flow from electronic devices in the assembly. *(Ex. 1001 at Abstract; 6:26–46)*. In Figure 1B, the inner surface of panel 110 (highlighted in green) of electronic assembly 100 is attached to one end of a support structure 140 (yellow). Support structure 140 is comprised of walls 142 (Fig. 1A) that enclose a space. Support structure 140 may include heat radiating elements 146. *(Ex. 1001, 3:46–49)*. A circuit substrate 102 (red) is attached to another end of the support structure. One or more electronic devices 150 (blue) are mounted to the mounting surface with adhesive material 152. A thermally conductive fill material 154

(orange) is disposed between and physically contacts the electronic devices 150 and the inner surface of panel 110. *(Ex. 1001, 2:53–4:30)*.

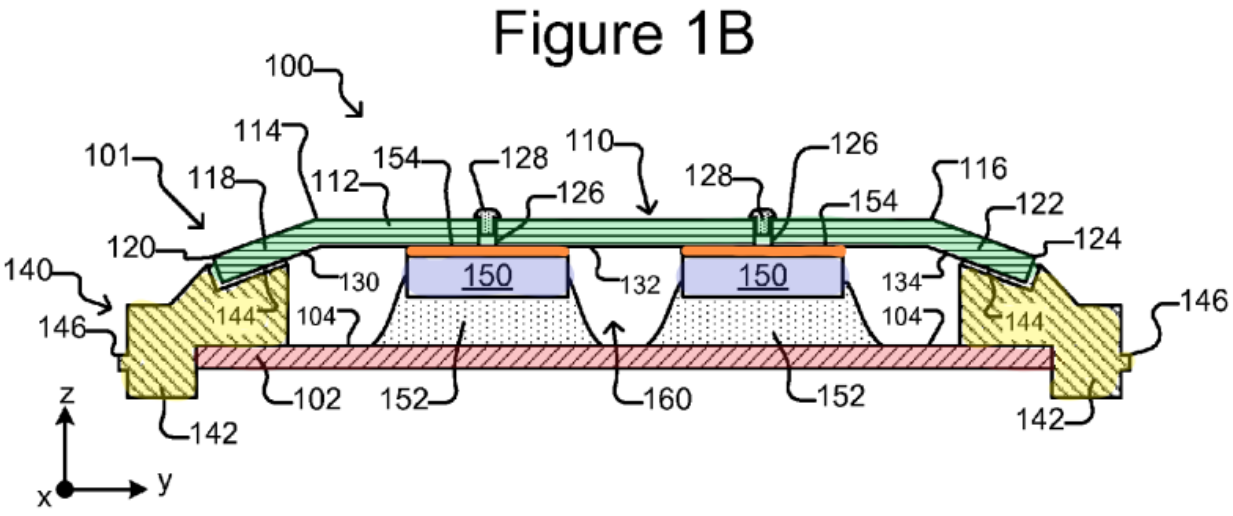


Figure 14: Annotated copy of Fig. 1B from Exhibit 1001 showing the graphite heat spreader in green, the frame in yellow, the thermal interface material in orange the electronic component in blue.

Figure 1A

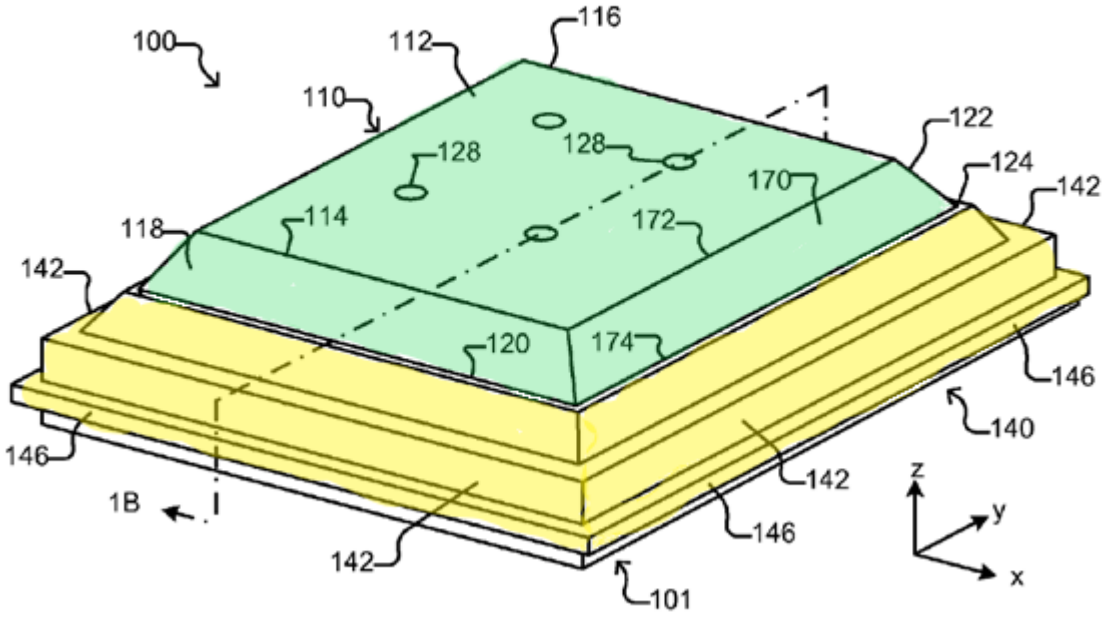


Figure 15: Annotated copy Fig. 1A from Exhibit 1001 showing the graphite heat spreader in green and the support frame in yellow.

112. Electronic devices 150 "can be any type of electronic apparatus, component, circuit element, and/or the like" including, for example, "a semiconductor die comprising one or more integrated electronic circuits, an electronic component (e.g., a resistors (sic), capacitor, inductor, transistor or the like), a diode, or the like." *(Ex. 1001, 3:30–36)*.

113. Panel 110 "can comprise substantially parallel, contiguous sections 112, 118, 122 one or more of which can be angled with respect to each other and/or the mounting surface 104 of the circuit substrate 102." *(Ex. 1001, 4:31–34)*. Three such

sections 112, 118, 122 are shown in FIGS. 1A and 1B. However, the panel may "have more or fewer than the three substantially parallel, contiguous sections 112, 118, 122 shown, and those sections can be oriented (e.g., angled) differently than shown." *(Ex. 1001, 4:35–41)*. The specification states further that "the invention is not limited to use of a panel with any particular number of sections or orientation of sections." *(Ex. 1001, 4:46–48)*. Although the specification describes that "one or more of sections 112, 118, 122 can be angled with respect to each other and/or the mounting surface 104 of the circuit substrate 102," *(Ex. 1001, 5:24–26)*, it attributes no critical significance to the value of the angles of the sections relative to the mounting surface. These angles can vary up to forty-five degrees. *(Ex. 1001, 5:33–44)*.

114. Panel 110 comprises a "composite material" in which "the thermal conductivity is significantly greater" in a first direction that is substantially parallel to the inner surfaces of the sections than it is in a second direction that is substantially perpendicular to the inner surfaces. *(Ex. 1001, 5:45–55)*. This difference in thermal conductivity can vary by up to several hundred-fold. *(Ex. 1001, 5:55–67)*. As a result, the panel 110 can be configured to provide highly conductive thermal paths that are substantially parallel with the inner surfaces of the contiguous sections to direct heat escaping from the top of the integrated circuit devices toward sidewalls

142 of electronic package assembly 100, as illustrated by dashed arrows 302 in Fig. 3:

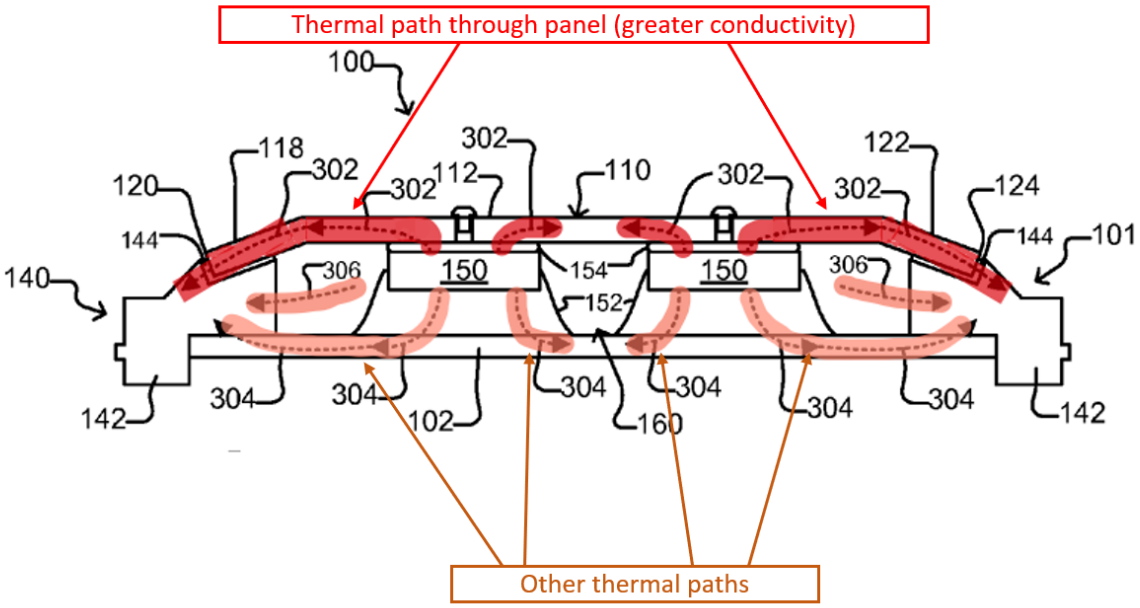


Figure 16: An annotated copy of Fig. 3 from Exhibit 1001 illustrating thermal path 302 as being more conductive than thermal path 304.

According to the specification, the thermal paths 302 through the panel to the outside of the electronic assembly "have a greater thermal conductivity" than any of the other thermal paths to the outside of the electronic assembly, such as the thermal paths depicted by arrows 304, 306. *(Ex. 1001, 6:63–7:3)*.

115. Figure 8 discloses an embodiment which contemplates a plurality of electronic devices 150 of varying heights and with varying spacing between the devices.

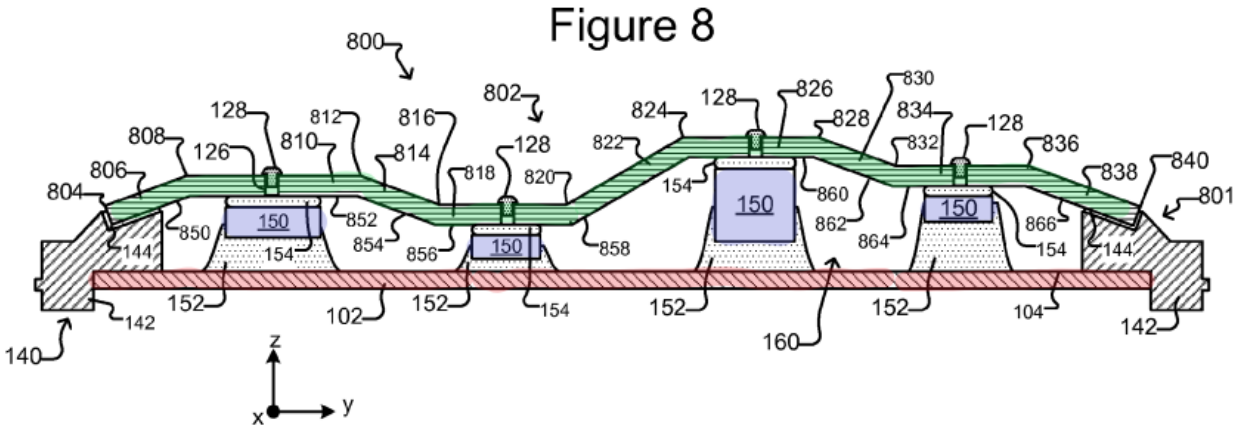


Figure 17: An annotated copy of Figure 8 from Exhibit 1001 showing the graphite heat spreader in green and the insulating substrate in red. Heat generating elements are shown in blue.

116. The ’925 patent explains that the geometry of the heat-spreading panel 802 can “be customized to different sized electronic devices” and that the angles between panel sections and a plane parallel to the mounting surface, as well as the angles between sections, may vary. *(Ex. 1001, 9:66–10:3)*.

2. Prosecution History of the ‘925 Patent

117. I have also reviewed the prosecution history of the ‘925 patent.

118. During prosecution of the ’925 patent, application claims 1–8 and 10–20 were rejected as anticipated and/or obvious in view of Mohammed. *(Ex. 1009)*. At that

time, Claim 1 was the only independent claim, which required a package structure that included a panel having contiguous sections oriented within 25° of the mounting surface. *(Ex. 1002, 184–186).*

119. The examiner found that Fig. 1A of Mohammed (as shown below) included a panel with at least three contiguous sections parallel to the mounting surface of the circuit substrate, which met the requirements of being oriented within 25°.

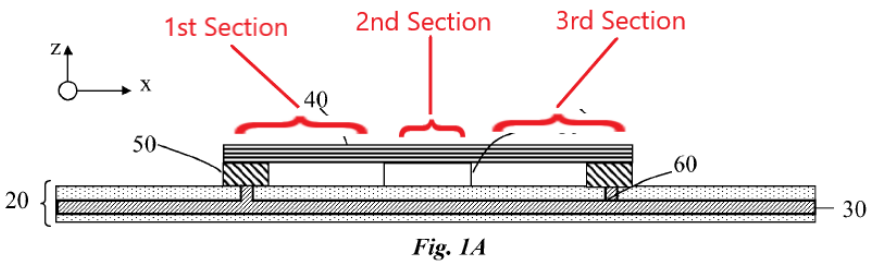


Figure 18: An annotated copy of Figure 1A from Ex. 1009, identifying the three contiguous sections of the panel of Mohammed.

120. In its response, the patent applicant did not dispute the examiner's finding that Mohammed contained a plurality of parallel contiguous sections that satisfied the "oriented within twenty–five degrees of parallel" requirement. Instead, the applicant amended Claim 1 to add the limitation "wherein an angle at a boundary between said inner surface of a first one of said sections and said inner surface of a second one of said sections is greater than or equal to five degrees" and further specifying that "said

second one of said sections is contiguous with said first one of said sections." *(Ex. 1002, 119).*

121. In remarks accompanying the amendment, the applicant argued that Mohammed failed to teach an angle between the inner surfaces of contiguous sections of the panel of Claim 1. *(Ex. 1002, 126).*

122. The examiner then finally rejected application Claim 1 again as anticipated by Mohammed. This time, the examiner relied on Fig. 5 of Mohammed, which shows an embodiment of a heat sinking panel having a curved profile 40. *(Ex. 1009, 0054–0055)*. The examiner asserted that this embodiment of Mohammed disclosed "at least two contiguous sections within 25˚ of parallel to the mounting surface" wherein the angle between said sections was "at least 5˚." *(Ex. 1002, 99–100)*.

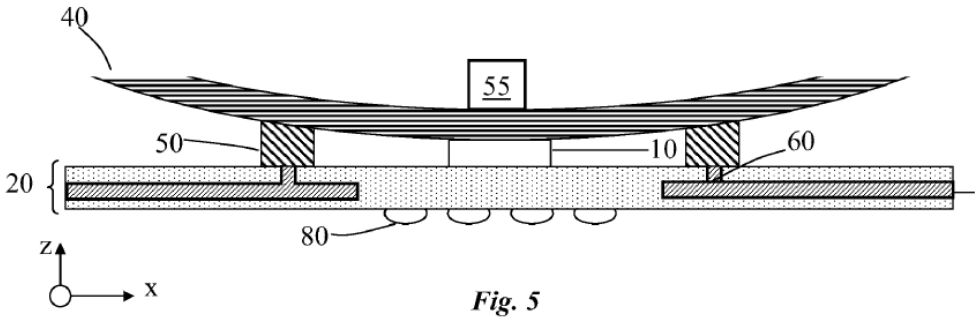


Fig. 5

Figure 19: Figure 5 from Mohammed, *(Ex. 1009).*

123. In the same office action, the examiner indicated that dependent application Claim 3 (which depended from application Claim 1) contained allowable subject

matter because the Claim recited "said first thermal conductivity is at least one–hundred times greater than said second thermal conductivity." *(Ex. 1002, 104)*. In addition, the examiner indicated that dependent application Claim 16 (which also depended from application Claim 1 through other dependent claims) was allowable due to the presence of "a thermally conductive adhesive coupling said outer edge of said outer one of said sections to said support structure." *(Ex. 1002, 104)*.

124. In its next response, the applicant again did not contest the examiner's interpretation of Mohammed. Rather, the applicant made further amendments to avoid the rejection. First, applicant rewrote application Claim 3, which included the allowable subject matter relating to thermal conductivities, as an independent Claim which contained the limitations of originally presented application Claim 1 (but did not include the added limitations relating to the angle between two contiguous sections being greater than or equal to five degrees). *(Ex. 1002, 74)*.

125. In remarks accompanying the amendment, the applicant explained that Claim 3 had been "rewritten in independent form" and that although it did "not include all features of [its] base Claim and/or intervening claims," Claim 3 recited the subject matter the examiner had identified as patentable: "for each said section, said first thermal conductivity is at least one–hundred times greater than said second thermal

conductivity." *(Ex. 1002, 80)*. I understand that, as so amended, application Claim 3 became Claim 3 of the '925 patent.

126. Second, the applicant rewrote application Claim 16 to include limitations relating to thermal conductivities and a thermally adhesive coupling, which the examiner had also indicated was allowable subject matter. *(Ex. 1002, 78).*

127. Similarly, applicant explained in the remarks that application Claim 16 had been re-written to include the thermally adhesive coupling limitation identified as allowable subject matter by the examiner, and thus Claim 16 and its dependent Claim 17, were allowable. *(Ex. 1002, 81)*. I understand that application claims 16-17 became patent claims 15-16 in the issued patent.

VIII. PRIOR ART USED IN DEMONSTRATING OBVIOUSNESS OF THE ASSERTED CLAIMS OF THE '925 PATENT

128. I will now discuss the specific prior art references that demonstrate that the claims of the '925 patent would have been obvious.

1. U.S. Patent No. 7,180,173 ("Kuo", Exhibit 1004)

129. U.S. Patent 7,180,173 *(Kuo, Ex. 1004)* to Kuo discloses an enclosure for a semiconductor integrated circuit device with a metal heat-spreading cover that is very similar to the enclosure of the '925 patent. Kuo discloses that such integrated circuit products produce "lots of heat" which require, inter alia, the use of "heat

spreaders … in order to dissipate the extra heat." *(Kuo, 1:16–19)*. Kuo sought to "provide an improved heat spreader" package design. *(Kuo, 1:59–61)*.

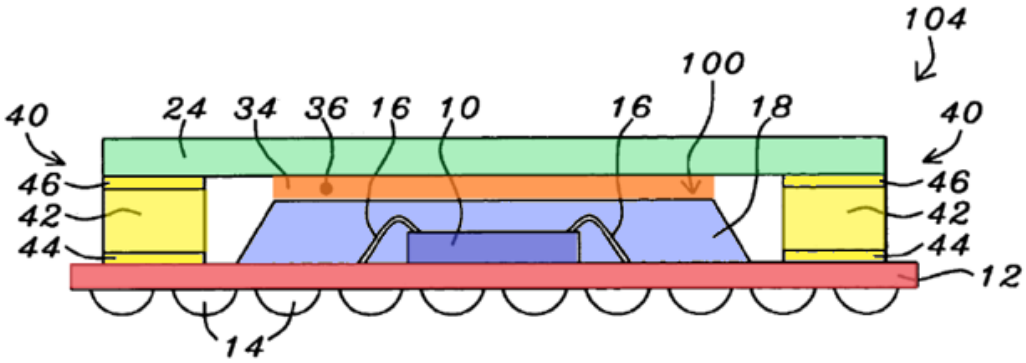


Figure 20: An annotated copy of Figure 2B from Kuo *(Ex. 1004)* showing the heat generating semiconductor die and its mold compound in blue, the thermal interface material in orange, the heat spreader in green and the supporting frame in yellow.

130. As shown in Fig. 2B, Kuo's design includes a heat spreader ball grid array (BGA) package 104 which comprises a "surrounding pillar" 40 (highlighted in yellow) formed around, and spaced apart from, semiconductor chip 10 (blue). The pillar is described as a "square ring" that surrounds the space occupied by chip 100. *(Kuo, 4:47–49)*. Pillar 40 comprises a stiffener portion 42 fixed to a substrate 12 below (red) by epoxy adhesive 44. Stiffener portion 42 is preferably comprised of a metal material, preferably copper. *(Kuo, 4:49–55)*.

131. A heat spreader 24 (green) is fixed to the upper end of pillar 40 by epoxy adhesive 46 so that heat spreader 24 is located over and above chip 100 leaving a

gap 34 between the molding compound 18 that encases the semiconductor chip 10 and the heat spreader 24. Heat spreader 24 is made from the same thermally conductive metal materials as stiffener portion 42 of surrounding pillar 40. *(Kuo, 4:56–64)*.

132. In Kuo, metal heat spreading panel 24 is fixed to the upper end of metal pillar 40 by epoxy adhesive 46. *(Kuo, 4:56–64)*. Kuo does not describe the epoxy material as a thermally conductive material although a POSITA would understand that this is likely to be the case because Kuo's Ball Grid Array (BGA) package is designed to conduct heat away from the semiconductor device primarily through thermal grease 36 to the heat spreader 24 and then from the heat spreader 24 to the support structure 42. The POSITA would have known that epoxy materials used in the assembly of heat spreader components in electronic assemblies at the time of the Kuo invention were typically thermally conductive and it would have been obvious to use an epoxy material 46 that attaches heat spreader 24 to support structure 42 that has thermally conductive properties in order to enable heat transfer to the support structure 42. The properties of various epoxy materials used in electronic assembly are discussed in the background section of this declaration.

133. A "thermal grease" 36 (orange) is inserted into the gap 34 at least between the heat spreader 24 and the molding compound 18. *(Kuo, 5:4–12)*. Thermal grease 36

is a type of Thermal Interface Material described by Kuo as a "silicon[e] rubber" containing heat–conducting particles such as zinc oxide, aluminum oxide, aluminum nitride, boron nitride or ceramic fillers or other materials which have the properties of heat conduction. *(Kuo, 5:13–17)*. The purpose of thermal grease 36 is to transmit heat from the molding compound containing the semiconductor chip to the heat spreader 24 to remove heat from the semiconductor chip and to reduce heat stress in the heat spreader. *(Kuo, 5:29–34)*. The background portion of this declaration describes in more detail the various types of TIMs that were used in the assembly of electronic devices prior to 2013.

2. U.S. Patent App. Pub. No. 2011/0133236 ("Nozaki", Exhibit 1005)

134. Nozaki discloses a package for a semiconductor device (an LED) that uses a heat-spreading material comprised of laminated graphite sheets that conducts heat in a highly anisotropic manner along the plane of the heat-spreading material. The graphite sheets are designed to transfer thermal energy from the semiconductor device to structures that dissipate the heat from the device. Nozaki's package shows "superior heat radiation characteristics." *(Nozaki, 0001)*. Nozaki notes that higher temperatures have deleterious effects on semiconductor light emitting elements and luminous efficiency of the elements decreases. Thus, Nozaki desires "to increase heat radiation efficiency" from the devices. *(Nozaki, 0002)*.

135. In one embodiment shown in Fig. 3, Nozaki discloses a semiconductor light emitting element 3 (highlighted in blue) mounted on an insulating substrate material 2 (red), which in turn is mounted upon a metal substrate 1. Light emitting element 3 is surrounded by fluorescent substance–containing resin layer 4 (orange) which, as shown in Fig. 1(a), resides in a square–shaped cut–out in a "sheet" of "anisotropic heat conduction material 5" (green). *(Nozaki, Fig. 1(a) and 0040)*.

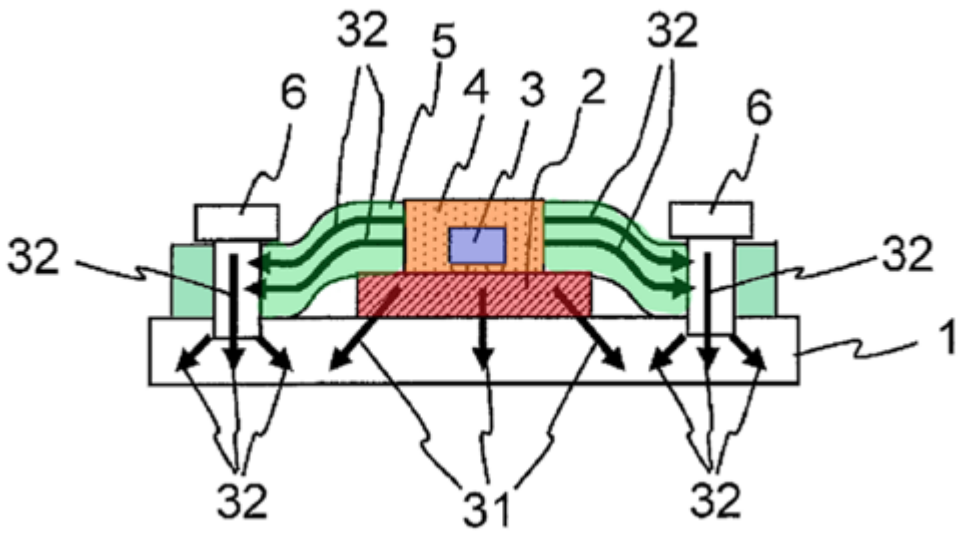


Figure 21: An annotated copy of Figure 3 from Nozaki, *(Ex. 1005)* showing the anisotropic heat spreader in green and heat generating semiconductor die in blue.

136. Nozaki explains that anisotropic heat conduction material 5 has heat conductivity in the main plane direction that is larger than the heat conductivity in the thickness direction. *(Nozaki, 0040)*. The anisotropic heat conduction material 5 conducts heat 32 along the main plane direction and radiates it to the metal substrate

1 as shown by the arrows 32 in Fig. 3. *(Nozaki, 0045 and 0051)*. More specifically, Nozaki teaches that the heat conduction material may be composed of "three layers of graphite sheets . . . [where] [h]eat conductivity of one sheet of the graphite sheet . . . was 4 to 6 W/mK for the thickness direction, or 1200 W/mK for the plane direction." *(Nozaki, 0090)*.

137. In another embodiment shown in Fig. 5, Nozaki teaches use of a "highly conductive adhesion member 52" (purple) for coupling the outer edge of the anisotropic heat conduction material to a "projection member 51." Adhesion member 52 may be "a cured heat conductive paste containing a highly heat conductive metal filler." *(Nozaki, 0058)*. Projection member 51 is formed from the same material as metal substrate 1 and is used for structural support and to conduct heat received from the anisotropic heat conduction material through the adhesion member to substrate 1 and heat sink 40 having fins 41. *(Nozaki, 0058; see id., 0049)*.

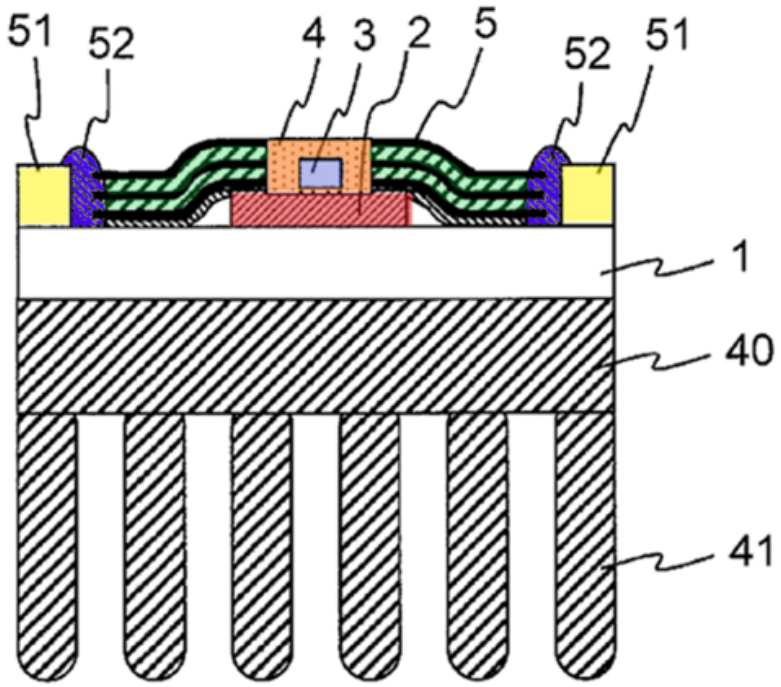


Figure 22: An annotated copy of Figure 5 from Nozaki *(Ex. 1005)* showing the thermal connection of the graphite heat spreader to the heat conductive projection by way of the thermally conductive adhesive shown in dark blue.

138. Nozaki explains that heat from semiconductor device 3 "is highly efficiently conducted along the main plane direction." *(Nozaki, 0059)*. Thereafter, the heat is further conducted from the side of the end of the anisotropic heat conduction material 5 to the projection member 51 via the highly heat conductive adhesion member 52, and conducted from the adhesion member 52 and the projection member 51 to the substrate 1. In this way, "the heat of the semiconductor light emitting element 3 and the fluorescent substance–containing resin layer 4 can be radiated to the substrate 1

at a position remote from the region of the substrate 1 to which the heat is conducted via the insulating substrate 2 (directly under the insulating substrate 2), and free from fear of heat saturation." *(Nozaki, Ex. 1005).*

3. U.S. Patent App. Pub. No. 2005/0039879 ("Hanai", Exhibit 1006)

139. Hanai discloses a pliable, anisotropically heat-conducting graphite sheet used for "the cooling of heat–generating elements" arranged on a circuit substrate, and in particular, for "the cooling of multiple heat–generating elements of different shapes." *(Hanai, 0001)*. Hanai's invention "efficiently cools heat–generating elements when many heat–generating elements of different shapes are mounted at high density." *(Hanai, 0007)*.

As shown in Figure 3, Hanai discloses a printed circuit board 300 with an aluminum heat sink 310 located at one side. Mounted on printed circuit board 300 are a plurality of "heat generating elements" of different heights, shapes and spacings. *(Hanai, 0005, 0019)*.

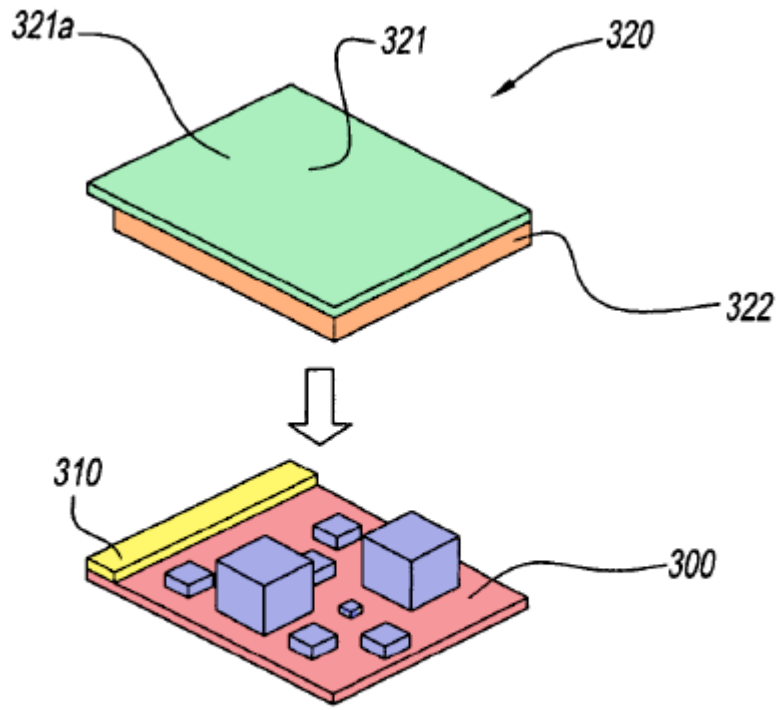


Fig. 3

Figure 23: An annotated copy of Figure 3 from Hanai *(Ex. 1006)* showing the heat generating components in blue, the flexible graphite heat spreader (321) in green and the heat sink (310) in yellow. The thermal interface material (322) is shown in orange and PCB substrate (300) is shown in red.

140. A "heat transmission member" 320 comprised of pliable graphite sheet 321 and flexible heat conducting sheet 322 is a type of TIM and is superimposed over the top of and adheres closely to the heat generating elements 300a, 300b, 300c, 300d, 300e as seen in the exemplary configuration shown in Figure 4, (Hanai, 0021).

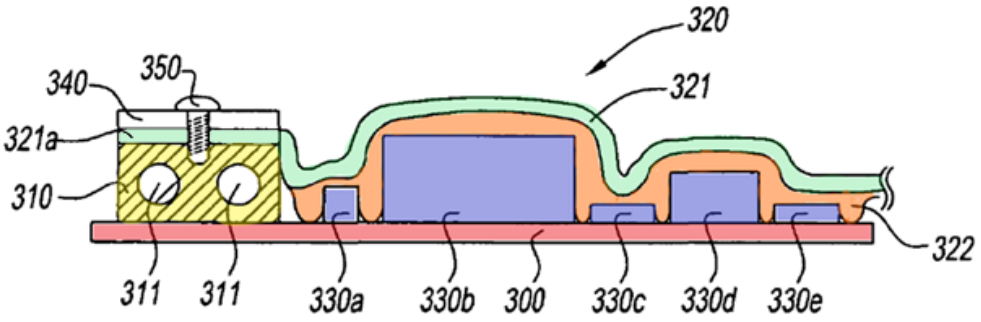


Fig. 4

Figure 24: An annotated copy of Figure 4 from Hanai, *(Ex. 1006)* showing the anisotropic heat spreader in green, the heat generating elements in blue and the heat sink in yellow.

141. As seen in this configuration, the heat–generating elements (highlighted in blue) are of inconsistent shapes and spacings. Graphite sheet 321 (green) and heat conducting sheet 322 (orange) are flexible enough to fit over the top of the heat–generating elements mounted on the printed circuit board substrate (red). *(Hanai, 0020)*. Graphite sheet 321 conducts heat anisotropically. The heat conductivity of the graphite sheet in the c-direction (through the thickness) is approximately 5 W/mK to approximately 20 W/mK and approximately 200 W/mK to approximately 800 W/mK in the ab-direction in the plane of the heat spreader. Heat conducting sheet 322 conducts heat isotropically; that is, approximately at the same rate in all directions. *(Hanai, 1006)*. This heat conducting sheet is a type of Thermal Interface Material that was commonly in use prior to 2013 for efficiently coupling heat from

the heat source into a heat spreader. TIMs are discussed in detail in Section V.3 of this declaration.

142. Graphite sheet 321 is thermally joined to heat sink 310 and "quickly transmit[s] the heat that has been transmitted from heat–conducting sheet 322 to heat sink 310." *(Hanai, 0021)*. As a result, "heat transmission member 320 can efficiently cool these heat–generating elements when many heat–generating elements of different shapes are mounted at high density." *(Hanai, Ex. 1006).* Hanai teaches that the heat conducting sheet 322 is "flexible" enough and graphite sheet 321 is "pliable" enough that this arrangement "can be used as is, even if the placement of heat–generating elements 330 a, etc. changes. As a result, economics and development efficiency are improved when compared to the prior art." *(Hanai, Ex. 1006)*.

IX. APPLICATION OF PRIOR ART TO THE CHALLENGED CLAIMS

143. I will now address two combinations of the above prior art references (Kuo + Nozaki) and (Kuo + Hanai). In my opinion, the POSITA would have been motivated to make these combinations for the reasons I discuss below. In so doing, the POSITA would have had a reasonable expectation of successfully making the "electronic assembly" claimed in each of claims 3, 15 and16 of the '925 patent.

1. Combination of Kuo and Nozaki (Claims 3, 15 and 16 of the '925 patent)

144. The POSITA would have found it obvious to combine the teachings of Kuo and Nozaki to arrive at the structure defined by claims 3, 15 and 16 in the '925 patent.

145. Kuo discloses the basic electronic packaging structure ("electronic assembly") claimed, including a support structure comprising four walls enclosing a space, a circuit substrate coupled to a first portion of said support structure, and a circuit substrate comprising a mounting surface. Kuo also discloses a heat spreading "panel," often called a "lid", intended to dissipate heat from a semiconductor device inside the enclosure. Kuo further discloses a thermal grease (TIM) located between the semiconductor device and the heat spreading lid to facilitate the transfer of heat to the lid. Kuo's heat spreading lid, or panel, is described as made of a metal material, preferably copper. This material spreads heat isotropically; that is, in all directions equally. Kuo does not teach using a material for the heat spreading lid or panel that spreads heat anisotropically as claimed in Claim 3. Kuo also does not teach use of a thermally conductive adhesive coupling the outer edge of the panel to the support structure as claimed in Claim 15.

146. However, the POSITA would have found it obvious to use Nozaki's anisotropic heat-spreading material for the panel of Kuo and employ thermally conductive adhesive as claimed. The POSITA would have been motivated to make

this combination for a number of reasons. The POSITA would have been motivated to combine the teachings of Kuo and Nozaki by substituting Nozaki's anisotropic heat-spreading composite graphite material for Kuo's metal heat-spreading panel 24 to achieve the advantage of more efficient dissipation of heat from the semiconductor device, through the plane of the heat-spreading panel, and into the support structure of Kuo.

147. Nozaki, like Kuo, is directed to a package assembly for semiconductor devices wherein dissipation of heat generated by the semiconductor device is an important consideration. Kuo recognizes that advanced integrated circuit products such as those used in Kuo "produce lots of heat which require the use of heat spreaders." *(Kuo, 1:16–19)*. Nozaki also addresses the "desire[] to increase heat radiation efficiency" from heat-producing semiconductor elements. *(Nozaki, 0002)*. The electronic devices described in both Kuo and Nozaki are designed using similar package design rules and are assembled using similar materials and processes using similar assembly equipment such as die attach, wirebond and encapsulation equipment. Similarly, the assembly of the heat spreaders, TIMs and frames of both Kuo and Nozaki utilize the same equipment and could in fact both devices could be made in the same assembly facility. My prior company, Aspen Technologies, Inc. was one such company and we had numerous clients that contracted with Aspen Technologies to assemble devices such as those described by Kuo and Nozaki.

These references are therefore in the same field and closely related to one another, and the POSITA looking to solve the problem of managing heat in a semiconductor package would have been likely to consult both references.

148. Nozaki teaches that an anisotropic heat-spreading material should be used to increase the heat radiation efficiency from a semiconductor device. The anisotropic heat-spreading material disclosed by Nozaki is a composite material constructed in alternating layers of graphite sheets and an acrylic adhesive. This material conducts substantially more heat along the plane of the sheet than it does through the thickness of the sheet. The exemplary material described in Nozaki has a thermal conductivity in the plane direction of 1200 W/mK and a thermal conductivity in the thickness direction of 4 to 6 W/mK. *(Nozaki, 0090)*. Employing such a material allows heat to be conducted from the semiconductor device along the plane of the heat spreader to the outside frame members of the package assembly, as Nozaki illustrates with arrows 32 in Fig. 3.

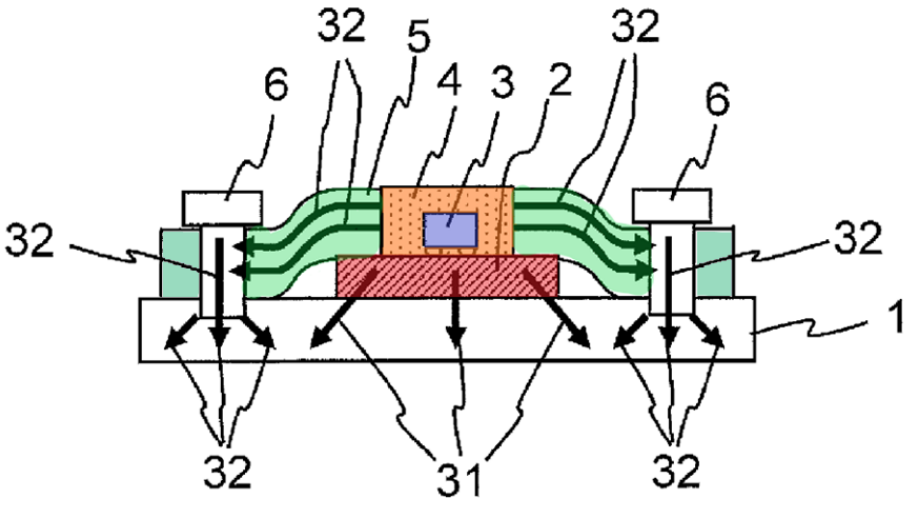


Figure 25: An annotated copy of Figure 3 from Nozaki *(Ex. 1005)* with the anisotropic conductive heat spreader in green, the heat generating element in blue.

149. By using a thermally anisotropic heat spreader, the thermal energy from the heat source *(Nozaki element 3 and Kuo elements 10 and 18)* is more efficiently transferred away from the semiconductor element. In Nozaki, the heat from the anisotropic heat spreader conducts to screw 6 and metal substrate 1, which are preferably made of copper or aluminum. Similarly, in Kuo, the heat from the isotropic heat spreader couples into pillar 40 which is preferably a copper frame attaching the heat spreader to the substrate with an epoxy adhesive. Moving the heat from the source to a copper element benefits the semiconductor device since copper is a very efficient isotropic thermal conductor and will effectively dissipate the heat that is transferred to it. This allows the semiconductor element in both Nozaki and

Kuo to have better performance by keeping it at a lower temperature because the heat has been dissipated away into the copper material of the surrounding package.

150. In Nozaki, heat enters into the edge of the anisotropic heat conduction material 5 from the light emitting semiconductor device. In the combination with Kuo, the POSITA would have understood that heat would enter the anisotropic heat conducting material from the bottom side of the anisotropic heat spreader through thermal grease 36, as I have illustrated below. The thermal grease 36 of Kuo is a type of TIM that is designed specifically to transfer heat from a source into a heat spreader while allowing for dimensional tolerances in the assembly as well as dimensional changes due the different coefficients of thermal expansion (CTE) of the different materials. Kuo describes this TIM as: "The thermal grease 36 is thermally conductive and serves as a thermally conductive interface between the heat spreader…and the mold compound 18." *(Kuo, 5:8)*

151. The thermal grease 36 of Kuo thus serves the same function as the "fill material" 154 in the '925 patent, as it "provides high thermal conductivity and can thus provide high conductivity thermal paths from the electronic devices to the inner surface 132 of section 112 and thus panel 110" *(Ex 1001, 8:14)*.

152. In Kuo's package assembly, as modified to use a lid comprised of the anisotropic heat-spreading graphite material of Nozaki, heat generated by the

electronic device 10 and 18, would enter the panel through the thermal grease. Although the thermal conductivity of the graphite material is relatively low in the c-direction, the thermal grease forms intimate contact with the surface of the graphite heat spreader and minimizes interface gaps which allows thermal energy to be transferred from the heat generating elements. This is because the thermal energy needs to propagate only a short distance from this surface to enter the plane of the heat spreader. Once the thermal energy is in the graphite heat spreader, the high value of thermal conductivity in the ab-direction allows the thermal energy to be shunted to the outside of the package and couple into support pillar 40, which is preferably comprised of copper. This is because the thermal conductivity in the plane of the graphite heat spreader is much greater than in the thickness direction, so the heat flow, as shown by the lateral red arrows in Figure 26, results in the thermal energy being dissipated away from the electronic device. Once the thermal energy reaches the periphery of the heat spreader, some of it couples into the pillar 40 and is dissipated laterally out of the assembly and some of it dissipates laterally out of the assembly from the edge of the graphite head spreader, as illustrated in the figure below.

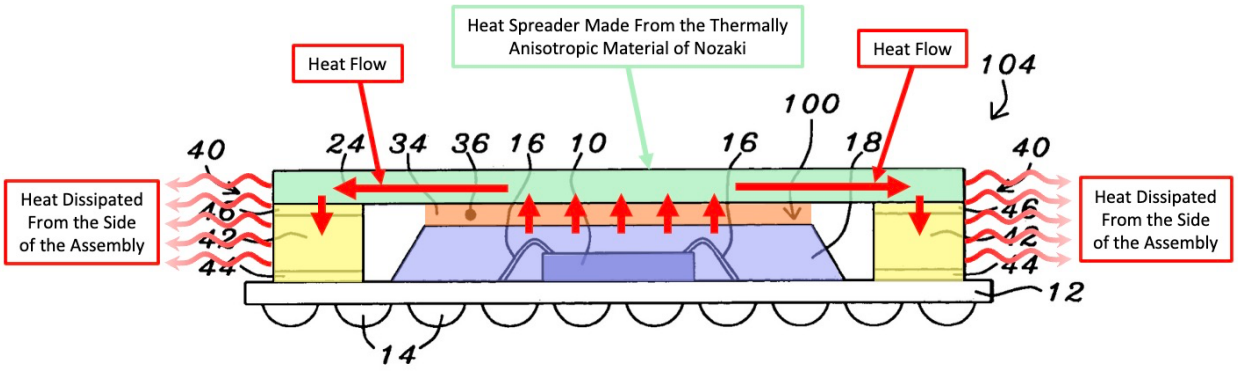


Figure 26: An annotated copy of Figure 2B from Kuo *(Ex. 1004)* showing the path of greatest thermal conductivity in red arrows when the metal lid of Kuo is replaced by the graphite lid of Nozaki *(Ex. 1005)*.

153. The POSITA would have had no difficulty connecting the anisotropic heat spreading panel of Kuo, as modified to use Nozaki's material, with metal support pillar 42. While the panel material is highly anisotropic and thus significant heat would be dissipated from the side of the graphite panel, heat also would be transferred in the perpendicular direction into metal support pillar in the existing design of Kuo. The POSITA would understand that the layer 46 is a thermally conducting material that adheres the heat-spreading panel to the metal pillar. This thermally conductive adhesive would be a commonly available thermally epoxy. This epoxy in fact would likely be the exact same epoxy regardless of whether the lid was made with copper or graphite. In other words, substituting the metal lid of Kuo with the graphite lid of Nozaki would *not* require the thermal epoxy 46 to change. As a POSITA would know, a thermal epoxy that adheres well to copper

would most likely also adhere well to graphite. Epoxy bond lines in electronic assemblies made with such thermally conductive adhesives are typically very thin, on the order of 0.001 inch (25 microns). This typical bond line thickness provides optimal adhesion between the two surfaces while providing a thermal path with low thermal resistance. Alternatively, the POSITA would have known that, if necessary to meet design specifications for heat dissipation, the electronic assembly could be designed such that the edge of anisotropic heat spreader 24 abuts support structure wall 42 in Kuo to facilitate heat transfer, similar to how composite heat spreading material 5 abuts to the screws 6 in Nozaki *(Ex 1005, Fig. 3)*.

154. The POSITA further would have understood that dissipating heat from the source of the thermal energy and spreading it to the side of the package as taught by Nozaki is desirable in many applications. This approach to thermal management could keep the heat generating components inside the package cooler which generally improves their performance. The POSITA would have appreciated the advantage of this approach, particularly in portable electronics such as cell phones or laptops because it reduces undesired "hot spots"; that is, portions of the device that are noticeably hotter than the rest of the device. Not only are hot spots undesired by the user, hot spots can also cause localized mechanical stress due to the hot components expanding more than other cooler components based on their coefficient of thermal expansion (CTE). Different materials used in the electronic device have

different CTEs and thus expand a different amount for a given temperature change. This may lead to stress gradients developing inside the device that can cause functional and reliability failures. Dissipating heat with an anisotropic heat spreader to the sides of the package may also enable further heat dissipation when the sides of the package are placed in contact with other parts of the electronic device or subject to airflow that allows the heat to dissipate even further.

155. The POSITA also would have appreciated another advantage of spreading heat to the support structure in cases where other electronic components that placed over or near the heat generating component must be protected from that heat. The anisotropic heat spreader causes the heat to be transferred to the support structure so the temperature directly above or near the heat generating components does not increase to the point of degrading the performance of the component above or near it. POSITA's had been using this approach in portable devices for many years prior to 2013 as a way to protect, for example, the display portion of the device from having a localized "hot spot" that could adversely affect the display characteristics over the hot spot.

156. By making such a combination, the POSITA would have expected to successfully achieve an electronic packaging assembly having a heat-spreading panel in which the contiguous sections thereof have "a first thermal conductivity

substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section" as claimed. The design and manufacture of such a structure would have been straightforward; the POSITA simply would have replaced the flat heat-spreading panel 24 of Kuo with a flat heat-spreading panel made from Nozaki's composite graphite material. The pillar structure, including the frame and epoxy adhesive holding the heat spreader to the frame, would not have to change.

157. As I have discussed above in Section V, the anisotropic heat-spreading graphite material taught by Nozaki was well known before the priority date of the '925 patent, as were methods to create custom shapes and configurations from this material. No problems would have arisen in making the combination that would not have been addressed through routine experimentation or design choices.

158. I do note that, as shown in Nozaki's preferred embodiments, heat enters into the edge of the anisotropic heat conduction material 5 from a light emitting semiconductor device, which is the exemplary device discussed in Nozaki. In the combination with Kuo, the POSITA would have understood that heat would enter the anisotropic heat conducting material from the device through the thermal interface material (thermal grease 36) in Kuo. The POSITA would have understood that this is a common design used, for example, in Hanai *(Ex. 1006)* as well as in

other applications in the prior art, including *(Smalc, Ex. 1028)*. For example, Smalc describes a thermal interface material as a thermal grease or a graphite-based thermal interface such as described in International Patent Application No. PCT/US02/40238 and/or commercially available from Advanced Energy Technology Inc. of Lake Wood, Ohio as its eGraf Hi-Therm™ line of products that can be interposed between the thermal heat spreader and a heat source to facilitate heat transfer between the heat source and the anisotropic, flexible graphite sheet that Smalc identifies as his "inventive thermal solution." *(Smalc, 4:45-53)*.

159. I will now discuss how the combination of Kuo and Nozaki apply to the specific limitations in claims 3, 15 and 16, taking into account the claims as a whole, which I understand to be the correct analysis.

a. Independent Claim 3 as Obvious over Kuo and Nozaki

i. Preamble: An electronic assembly comprising:

160. I have not been asked to form an opinion as to whether the preamble limits the claim. To the extent the preamble is limiting, Kuo discloses this limitation. Kuo discloses an embodiment of a heat spreader ball grid array package 104 in his Fig. 2B, which is "an electronic assembly" because it is intended to package and house electronic devices such as semiconductor chip 10. Kuo notes that semiconductor

chip 10 is expected to generate "lots of heat" that must be dissipated from the package. *(Kuo, 1:13–18; 4:42–45; Fig. 2B)*.

ii. Limitation 3[a]: a support structure comprising walls enclosing a space;

161. Kuo discloses this limitation. Kuo shows in Fig. 2B a "surrounding pillar" 40 which is in the shape of a "square ring" mounted on substrate 12. Pillar 40 comprises a metal "stiffener portion 42" that is fixed to substrate 12 and provides structural support for the package 104. The POSITA would have understood from this description that the square ring–shaped pillar forms a support structure having four "walls" enclosing a space that includes within it the semiconductor chip 10 encased in molding material 18 as well as gap 34 which includes thermal grease 36 located over the molding material 18. *(Kuo, 4:42–64; 5:4–12; Fig. 2B)*.

162. Furthermore, as a POSITA would know, many different types of semiconductor packages prior to 2013 used support structures comprising walls that enclose a space. For example, as shown in Section VI.5 of this declaration, the patent to Higashi U.S. Patent 6,404,070 shows a "frame surrounding the semiconductor chip."

iii. Limitation 3[b]: a circuit substrate coupled to a first portion of said support structure, said circuit substrate comprising a mounting surface;

163. Kuo discloses this limitation. Kuo discloses that the "ball grid array (BGA) package 104 includes semiconductor chip 10 mounted onto a substrate 12 and is electrically connected to substrate 12 by, for example, lead wires 16. Mold compound 18 encases the semiconductor chip 10 and the lead wires 16. Substrate 12 includes solder balls 14 mounted on the surface opposite the silicon semiconductor chip 10." *(Kuo, 2:42–46)*. Surrounding pillar 40 is coupled to substrate 12 via epoxy adhesive 44. *(Kuo, 4:47–49)*. The POSITA would have understood from this description that substrate 12 is a "circuit substrate" that comprises a mounting surface for semiconductor chip 10 and is coupled to a first portion of a support structure (pillar 40) via the epoxy adhesive.

iv. Limitation 3[c]: an electronic device attached to said mounting surface and disposed within said space; and

164. Kuo discloses this limitation. The '925 patent specification describes an exemplary "electronic device" as "any type of electronic apparatus, component, circuit element, and/or the like" including, for example, "a semiconductor die comprising one or more integrated electronic circuits, an electronic component (e.g., a resistors (sic), capacitor, inductor, transistor or the like), a diode, or the like." *(Ex. 1001, 3:30–36)*. The POSITA would have understood from Kuo's description that semiconductor chip 10 is an "electronic device" as contemplated by the '925 patent *(Kuo, Ex. 1004)*.

v. Limitation 3[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty–five degrees of parallel to said mounting surface,

165. Kuo discloses this limitation. Kuo discloses that heat spreader lid 24 is coupled to a second portion (top portion) of surrounding support structure 42 via epoxy adhesive 46 so as to be located over and above mold compound 18 that encases the semiconductor chip 10. *(Kuo, 4:56–59)*. This heat spreader lid has an inner surface that faces the mounting surface of the circuit substrate.

166. The POSITA would also have understood that Kuo's heat spreader 24 has a plurality of parallel contiguous sections. For example, the POSITA would consider, and as Kuo describes, the portion of heat spreader directly above semiconductor chip 10 and mold compound 18 to be one section, whereas the portions of heat spreader to the left or right of the mold compound (as viewed in cross section in Fig. 2B) to be at least one or more different but contiguous sections. This is shown in the figure below:

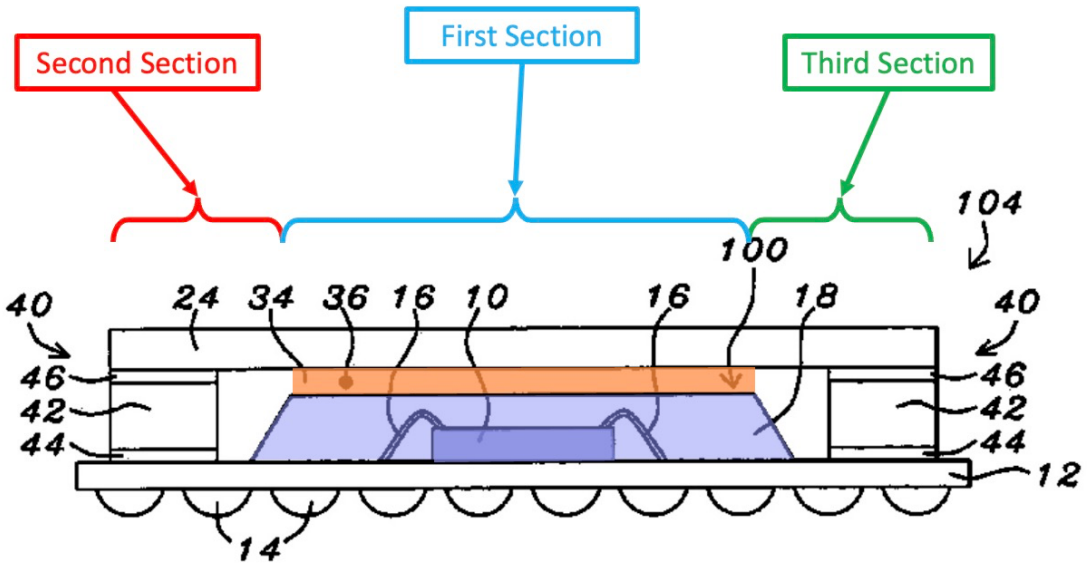


Figure 27: Annotated copy of Figure 2B from Kuo, *(Ex. 1004)* showing the thermal grease (orange) located only above semiconductor die 10 and mold compound 18.

167. The POSITA would have had reason to consider these portions of the Kuo BGA lid or panel to be different but contiguous sections of the heat spreader for a number of reasons. For one, Kuo separates gap 34 into different sections. The First Section of the heat spreader, as taught by Kuo, and as would be understood by a POSITA, is that the portion of heat spreader 24 located directly above the mold compound that encases the semiconductor chip 10. The gap 34 under this First Section of the heat spreader contains a thermal grease 36 (orange annotation) that provides a thermally conductive path for thermal energy to be transferred from the semiconductor chip 10 and its encasing mold compound 18 into the heat spreader 24. *(Kuo, 5:18-21)*. Thus, the First Section of the heat spreader panel is that portion

that absorbs the thermal energy from the semiconductor chip 10 and its mold compound 18 via the thermal grease 36.

168. The POSITA would have understood and Kuo teaches that the Second and Third Sections of the heat spreader do not have thermal grease under them, very specifically for mechanical purposes. As the thermal grease increases in temperature, it expands in volume and since the gap under the Second and Third Sections has no thermal grease, the volume under those Sections can accommodate the volume expansion of the thermal grease from First Section as the temperature increases. "It is preferable that a portion of gap 34 remains once the thermal grease 36 is inserted to allow for the thermal grease to expand to release stress." *(Kuo, 5:6-9)*. The heat absorbed into the First Section is spread laterally away by means of the Second and Third Sections of the heat Spreader. The POSITA would thus have a logical and technical reason to regard the First Section of the panel directly above the thermal grease in Kuo as a separate and distinct section of the panel from the sections of the panel that are not located directly above the thermal grease.

169. In addition, I note that the patent applicant essentially conceded to the examiner's argument that that Fig. 1A of Mohammed, *(Ex. 1009)* which shows a flat heat spreading panel like Kuo, was comprised of at least three contiguous sections. As I observed above, during the patent prosecution the examiner determined that the

flat heat-spreading panel shown in Fig. 1A of Mohammed included a panel with at least three contiguous sections parallel to the mounting surface of the circuit substrate. *(Ex. 1002, 136)*. The examiner further found that the "sections are not differentiated by any particular structural attributes" and that flat "parallel sections" met the requirement that each section be oriented "within 25 degrees of parallel" as claimed.

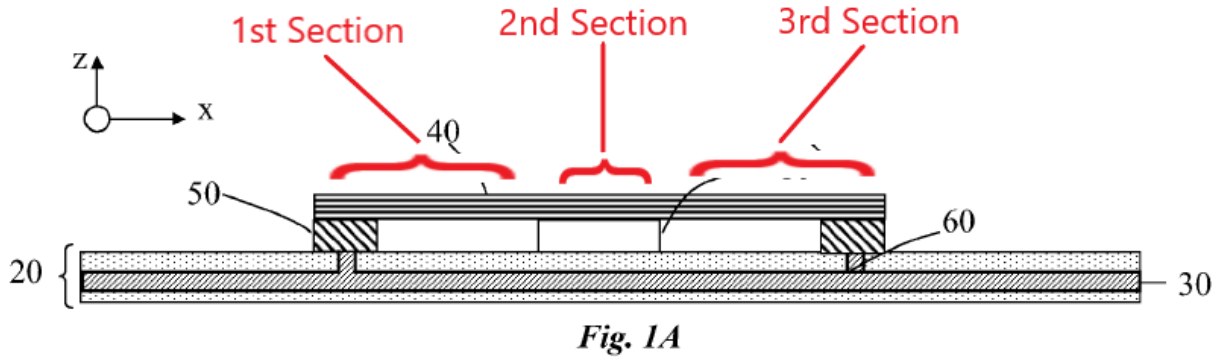


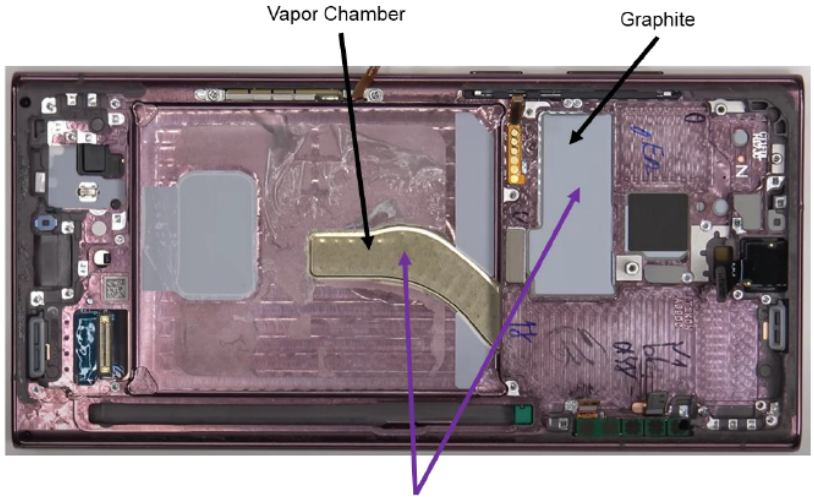
Figure 28: An annotated copy of Figure 1A from Ex, 1009.

170. The patent applicant did not dispute the examiner's interpretation of Mohammed and instead amended Claim 1 to require that there be an angle of at least five degrees between the respective inner surfaces of at least two contiguous sections. *(Ex. 1002, 119)*.

171. I also understand that Redstone Logics LLC, the current owner of the '925 patent, has taken the position in federal district court that is consistent with the examiner's view and the original applicant's view of what constitutes a contiguous

section. I have reviewed the infringement contentions served by Redstone in the parallel district court litigation, and observe that Redstone contends that a flat graphite sheet contained in Samsung's accused smartphones is a "panel comprising contiguous sections, each said section … oriented within twenty–five degrees of parallel to the mounting surface." *(Ex. 1007; Ex. 1008, 8–10)*:

[3d] a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty-five	Each Accused Product comprises a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty-five degrees of parallel to said mounting surface. For example, the Galaxy S22 Ultra contains a vapor chamber and a graphite sheet, each of which has an inner surface facing the mounting substrate and substantially parallel to it. *See, e.g.*:

Claim 3	Accused Products
degrees of parallel to said mounting surface,	 a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty-five degrees of parallel to said mounting surface (the graphite film, vapor chamber and boards are all oriented parallel to the plane of the frame flat surface – and likely within 1 degree of parallel to the mounting surface. The graphite is visible through holes in the flat surface of the frame and covers a larger area on the opposite side of the frame)) Annotated photograph of Galaxy S22 Ultra.

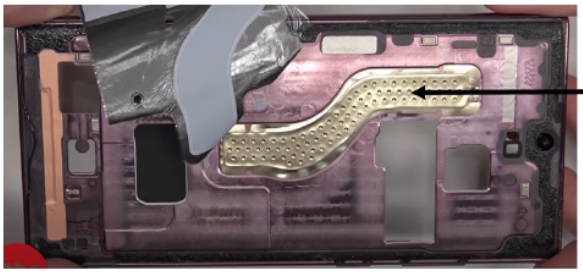
Claim 3	Accused Products
	  (these are views from the opposite side of the frame – to better see how the vapor chamber and graphite film have contiguous sections) Annotated photographs of Galaxy S22 Ultra.

Figure 29: Excerpts from Exhibit 1008

172. Redstone's position indicates that it believes that this limitation of Claim 3 permits an angle between the inner surfaces of contiguous sections to be zero, which is exactly as the examiner read Mohammed and is exactly what is shown by Kuo.

vi. Limitation 3[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section,

173. This limitation would have been obvious based on Kuo in combination with Nozaki. I have already explained above why the POSITA would have been motivated to combine the teachings of Kuo and Nozaki to substitute Nozaki's

anisotropic heat spreading material composed of graphite which, as I have explained above in Section V, it was well known, in place of Kuo's metal heat-spreading panel 24. As calculated in the next section, Nozaki's heat spreading panel has a first thermal conductivity that is parallel to the inner surface and a second thermal conductivity that is perpendicular to the inner surface.

174. Furthermore, as described extensively in the background portion of this declaration, graphite heat spreaders with high degree of anisotropy have been known for many years prior to 2013.

vii. Limitation 3[f]: wherein for each said section, said first thermal conductivity is at least one–hundred times greater than said second thermal conductivity,

175. This limitation is satisfied by Kuo as modified to use the composite heat-spreading material of Nozaki. As I have explained above in Section VIII.2, the exemplary anisotropic heat-spreading material disclosed by Nozaki has a thermal conductivity in the plane (a-b direction) of 1200 W/mK and a thermal conductivity through the thickness (c-direction) of 4 to 6 W/mK. *(Nozaki, 0090)*. Nozaki thus discloses a material whose thermal conductivity in the in-plane direction is 200 to 300 times the thermal conductivity in the thickness direction. Thus, the "first thermal conductivity" of the material in Nozaki is "at least one–hundred times greater" than the second thermal conductivity as required by this claim limitation.

176. As detailed in the background portion of this declaration, thermal anisotropy of graphite exceeded 100 well before 2013. For example, in the Handbook of Carbon, Graphite, Diamond and Fullerenes *(Pierson, pg. 57)*, published in 1993, the thermal conductivity of graphite was listed as being 390 W/mK in the ab-direction while it is only 2 W/mK in the c-direction, with a resulting thermal anisotropy of 145. Also described in Section V.2 of this declaration, the company ThermaCore was offering graphite materials for heat spreaders with a thermal anisotropy of at least 200 as early as 2012.

b. Independent Claim 15 as Obvious over Kuo and Nozaki

i. Preamble: An electronic assembly comprising:

177. The preamble is the same as the preamble in Claim 3. I have explained above how Kuo meets this limitation.

ii. Limitation 15[a]: a support structure comprising walls enclosing a space;

178. This limitation is the same as Limitation 3(a). I have explained above how Kuo meets this limitation.

iii. Limitation 15[b]: a circuit substrate coupled to a first portion of said support structure, said circuit substrate comprising a mounting surface;

179. This limitation is the same as Limitation 3(b). I have explained above how Kuo meets this limitation.

iv. Limitation 15[c]: an electronic device attached to said mounting surface and disposed within said space; and

180. This limitation is the same as Limitation 3(c). I have explained above how Kuo meets this limitation.

v. Limitation15[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty–five degrees of parallel to said mounting surface,

181. This limitation is the same as Limitation 3(d). I have explained above how Kuo meets this limitation.

vi. Limitation 15[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section,

182. This limitation is the same as Limitation 3(e). I have explained above how Kuo meets this limitation.

vii. Limitation 15[f]: wherein said first thermal conductivity is greater than said second thermal conductivity,

183. As I explained with respect to Limitation 3(e), the composite graphite material used by Nozaki conducts heat anisotropically; that is, the material conducts

substantially more heat along the plane of the sheet (ab-direction) than it does through the thickness of the sheet (c-direction). The exemplary material described in Nozaki has a thermal conductivity in the plane direction of 1200 W/mK and a thermal conductivity in the thickness direction of 4 to 6 W/mK. *(Nozaki, 0090)*. The combination of Kuo and Nozaki therefore would result in an electronic package assembly where in each contiguous section, the "first thermal conductivity" in the in-plane ab-direction is greater than "said second thermal conductivity" in the perpendicular c-direction, as claimed. As noted earlier in this declaration, substituting the Nozaki material for the material in Kuo would not require any other change to Kuo. Specifically, the same adhesive used to attach the copper lid of Kuo to the support structure could be used to attach a lid made of the Nozaki material to the same support structure.

viii. Limitation 15[g]: wherein a thermally conductive path from said space enclosed by said walls of said support structure out of said electronic assembly that has a greatest thermal conductivity comprises a thermal path through contiguous ones of said sections of said panel to an outer edge of an outer one of said sections of said panel, and

184. Kuo in combination with Nozaki satisfies this limitation. Nozaki describes the thermal path through which heat escapes from the interior of the electronic assembly through its anisotropic heat-spreading material, and illustrates that path in Fig. 3 of his patent. Heat, indicated by arrows 32, also passes through the anisotropic

heat-spreading composite graphite material 5 to metal screws 6 (in Nozaki's first embodiment) and then to metal substrate 1, as indicated in the annotated Figure 30 below:

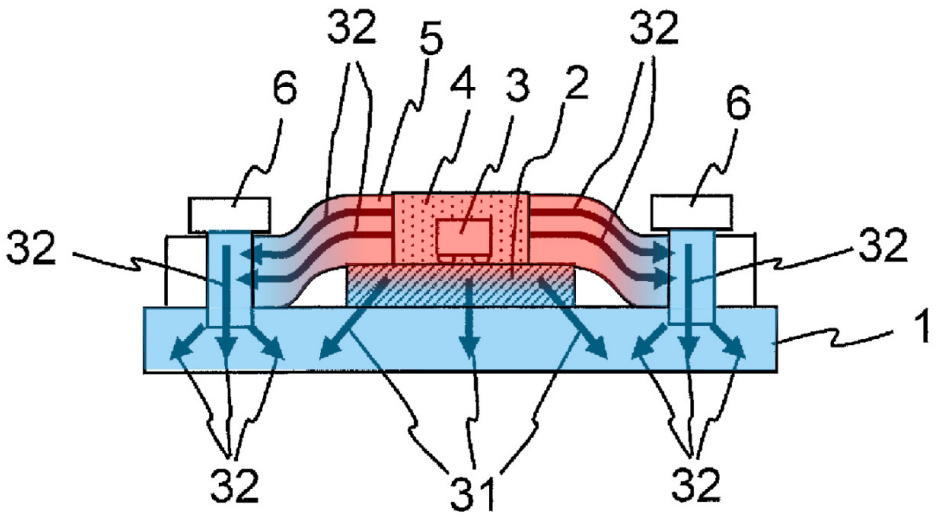


Figure 30: An annotated copy of Figure 3a from Nozaki *(Ex. 1005)* showing the path of greatest thermal conductivity through the graphite heat spreader.

185. While some heat, indicated by the arrows labelled 31, passes through insulating substrate 2 to metal substrate 1 below *(Nozaki, 0049)*, the POSITA would have understood that the heat conductivity of Nozaki's substrate 2 is less than the heat conductivity of the anisotropic heat-spreading composite graphite material in the plane a-b direction. The thermal conductivity of the insulating substrate of Nozaki could be as high as 170W/mK, if it was made of Aluminum Nitride ceramic as Nozaki describes in paragraph [Nozaki, 0046], but this is still much less that the

thermal conductivity in the ab-direction of the anisotropic heat spreader which can be as high as 1200W/mK, and is also less than the thermal conductivity of copper, one of the preferred materials for screws 6 *(Nozaki, 0044)*, which is about 400 W/mK.

186. The POSITA therefore would have appreciated that, in combining Kuo and Nozaki, while some thermal energy would be transmitted through the substrate, the thermally conductive path from the space enclosed by the walls of the support structure out of said electronic assembly that has the greatest thermal conductivity is the thermal path 32 through the contiguous sections of the panel to the outer edges, as claimed.

187. When replacing the copper heat spreader of Kuo with the thermally anisotropic heat spreader of Nozaki, a thermal path that meets this claim limitation is also formed. As illustrated in the Figure 31, the heat from the semiconductor chip 10 and mold 18 is preferably transferred through the thermal grease to the thermally anisotropic lid. Due to this anisotropy, the heat is then transferred laterally due to the greater thermal conductivity it the lateral direction. From there, the thermal energy couples into the pillar structure 40. Kuo, like Nozaki desires to transfer heat efficiently from the space enclosed by the assembly.

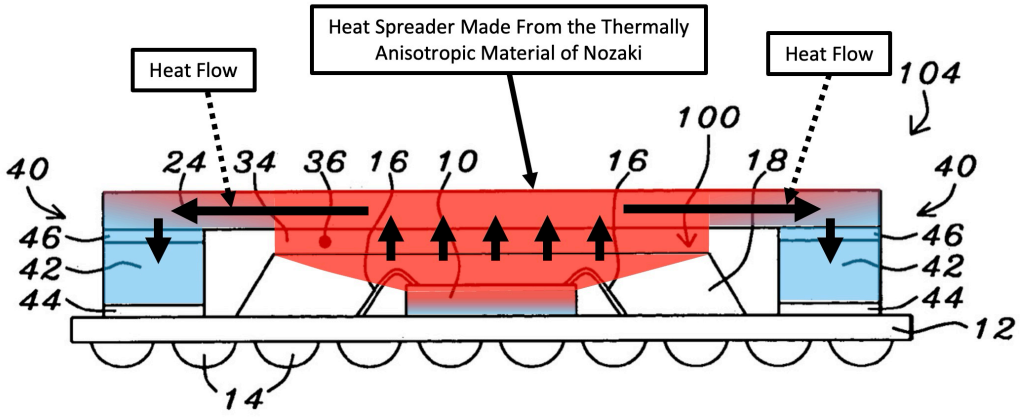


Figure 31: An annotated copy of Kuo, Figure 3a *(Ex 1004)* with the metal lid replaced by the thermally anisotropic lid of Nozaki *(Ex. 1005)*, showing the path of greatest thermal conductivity is through the graphite heat spreader.

188. I note that Kuo does not expressly identify the material from which its substrate 12 is formed. However, the POSITA would have appreciated that it was universally known that BGAs use insulating materials for the substrate such as printed circuit board (PCB) made of laminated organic (FR4, BT resins, etc.) or ceramic materials. This is because these insulating materials allow for electrically conductive traces to be formed on top of, on the underside of and inside the substrate in order to provide electrical connection between the lead wires 16 and the solder balls 14. The thermal conductivity of PCB substrates is typically in the range of 0.5 to 0.3 W/mK. *(Kandasamy, Ex. 1037, Table 1)*.

189. The POSITA would have appreciated that, in implementing the combination of Kuo and Nozaki using the anisotropic graphite heat spreading material for the

panel and an insulating material for the substrate, the thermally conductive path from the space enclosed by the walls of the support structure out of said electronic assembly that has the greatest thermal conductivity would be the thermal path through the contiguous sections of the anisotropic heat-spreading panel to the outer edges, just as is the case with Nozaki, because other possible paths by which heat would escape would go through the insulating material of the substrate which has a lower thermal conductivity.

i. Limitation 15[h]: wherein said electronic assembly further comprises a thermally conductive adhesive coupling said outer edge of said outer one of said sections to said support structure.

190. This limitation would be satisfied by Kuo as modified to use the anisotropic heat-spreading material of Nozaki. In Kuo, metal heat-spreading panel 24 is fixed to the upper end of metal pillar 40 by epoxy adhesive 46. *(Kuo, 4:56–64)*. Kuo does not describe the thermal properties of the epoxy, however, as I have explained above, because Kuo's ball grid array package is designed to conduct heat away from the semiconductor device primarily through thermal grease 36 to heat spreader 24, *(Kuo, 5:29-36)*, and also from heat spreader 24 to support structure 42, which is made of the same material as heat spreader 24, *(Kuo, 4:42-67)*. The POSITA would have understood that Kuo is likely to be using an epoxy material that has a normally thin (about 0.001 inch or 25 microns) bondline and is thermally conductive. Such epoxy

materials, especially when used to join heat-conducting structures, were typically filled with a heat-conducting material such as silver or other metal. Such epoxy materials, especially when used to join heat-conducting structures, were typically filled with a head conducting material such as silver or other metal. These epoxy-based materials are described in more detail in the background section of this declaration. This is likely to be the case in Kuo's Ball Grid Array package is designed to conduct heat away from the semiconductor device primarily through thermal grease 36 to heat spreader 24 and also from heat spreader 24 to support structure 42, which is made of the same material as heat spreader 24. The POSITA therefore would have understood that the epoxy material 46 that attaches heat spreader 24 to support structure 42 was likely to thermally conductive properties in order to enable this heat transfer.

191. The POSITA further would have been motivated to use a thermally conductive epoxy in Kuo, particularly when Kuo is modified to use the anisotropic heat-spreading material of Nozaki. As discussed above in Section IX.1, Nozaki's heat-spreading material allows heat to be conducted from the semiconductor device along the plane of the heat spreader to the outside frame members of Nozaki's package assembly. When modifying Kuo to use the anisotropic heat-spreading material of Nozaki, the POSITA would likewise have been motivated to ensure that heat can be conducted to the outside frame members of Kuo's assembly—i.e.,

copper support structure 42—in order to spread heat away from the heat-generating elements to avoid hot spots or a concentration of heat in a confined space where components are located in close proximity to one another, as explained above.

192. Given that it was well known to use heat-conducting epoxy to join materials to create heat management assemblies, the POSITA would have readily employed such a material here and in fact the same thermally conductive epoxy adhesive could be used to attach a panel to the support structure 42 in Kuo regardless of whether the panel was made of copper of Kuo or the thermally anisotropic graphite of Nozaki.

193. In its Figure 5 embodiment, Nozaki teaches interposing a "highly heat conductive adhesion member 52" (indicated in purple in the annotated figure below) between the outer edge of anisotropic heat-spreading composite graphite material 5 and metal projection member 51. Heat conductive adhesion member may be a "cured heat conductive paste containing a highly heat conductive metal filler such as those of tungsten, carbon, copper, aluminum, silver and gold." *(Nozaki, 0058)*. As described above, these thermally conductive epoxy materials were well known prior to 2013.

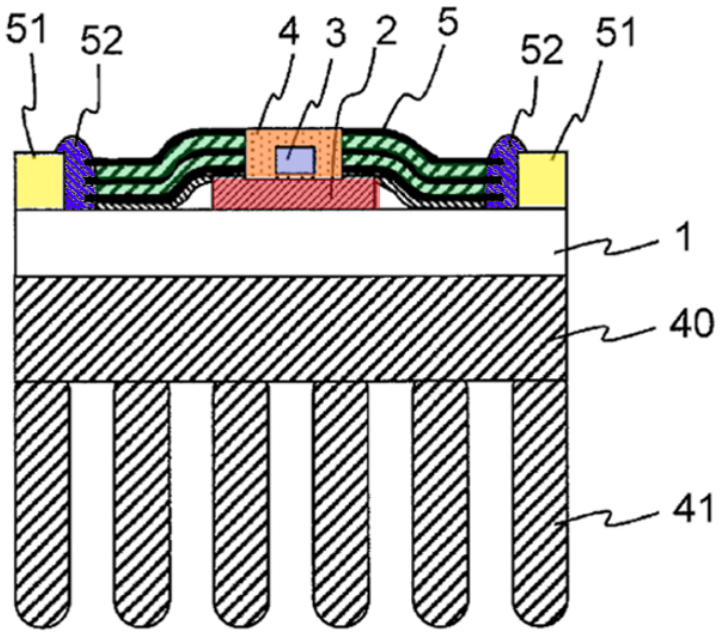


Figure 32: An annotated copy of Figure 5 from Nozaki, *(Ex. 1005)* showing the graphite heat spreader (5) in green, the thermally conductive adhesive (52) in purple and the support frame (51) in yellow.

194. Projection member 51 is made of metal, as is the metal screw 6 used in Nozaki's first embodiment). Thus, projection member 51 has heat-conducting properties greater than the conductivity of the composite graphite material in the perpendicular direction. *(Nozaki, 0058)*. In order to further facilitate heat transfer in the Fig. 5 embodiment, Nozaki teaches to interpose a "highly heat conductive adhesion member 52" (indicated in purple in the annotated figure above) between the outer edge of anisotropic heat-spreading composite graphite material 5 and projection member 51, which have a heat conductivity comparable to or higher than

that of the substrate 1. *(Nozaki, 0058)*. Heat conductive adhesion member may be a "cured heat conductive paste containing a highly heat conductive metal filler such as those of tungsten, carbon, copper, aluminum, silver and gold." *(Nozaki, 0058)*.

195. A POSITA in combining Kuo and Nozaki, would have been motivated to include the thermally conductive adhesive coupling of the type taught by Nozaki to further efficiently conduct heat generated by the electronic device from the anisotropic heat-spreading composite graphite panel to the sidewalls of the electronic assembly, in order to more efficiently conduct heat to the exterior of the assembly as taught by Nozaki.

c. Dependent Claim 16 as Obvious Over Kuo and Nozaki

i. The electronic assembly of Claim 15 further comprising a thermally conductive material disposed between and in physical contact with said electronic device and the inner surface of one of said contiguous ones of said sections of said panel.

196. Kuo teaches the insertion of thermally conductive material in the space between the epoxy–encapsulated electronic device 100 and heat spreader 24 in the form of "thermal grease" 36. Thermal grease is described as a silicone rubber type materials "containing heat–conducting particles such as zinc oxide, aluminum oxide, aluminum nitride, boron nitride or ceramic fillers or other materials which have the properties of heat conduction." *(Kuo, 5:13–17)*. The POSITA would have appreciated that additional heat dissipation efficiency would be achieved from the

presence of the thermal grease in Kuo, which conducts heat from the semiconductor chip 10 and its molded enclosure 18 to heat spreading panel 24.

197. Thermally conductive materials disposed between and in physical contact with the electronic device and the inner surface of the panel are a type of Thermal Interface Material that is described in detail in the background section of this declaration. These types of thermally conductive materials were widely used prior to 2013 and were in regular use at my previous company Aspen Technologies, Inc.

2. Combination of Kuo and Hanai (Claims 3, 15-16 of the '925 patent)

198. In addition, the POSITA would have also found it obvious to combine the teachings of Kuo and Hanai to arrive at the structure defined in Claims 3, 15-16 of the '925 patent.

199. As I have explained above, Kuo discloses the basic electronic packaging structure ("electronic assembly") claimed, including a support structure comprising four walls enclosing a space, a circuit substrate coupled to a first portion of said support structure, and a circuit substrate comprising a mounting surface. Kuo also discloses a heat spreading "panel," often called a "lid," intended to dissipate heat from a semiconductor device inside the enclosure. Kuo further discloses a thermal grease, which is a type of Thermal Interface Material located between the semiconductor device and the heat spreading lid to facilitate the transfer of heat to

the lid. Kuo's heat spreading lid, or panel, is described as made of a metal material, preferably copper. This material spreads heat isotopically, that is, in all directions equally. Kuo does not teach using a material for the heat spreading lid or panel that spreads heat anisotropically.

200. It is also possible that the Board may not agree with my opinion, which as I have explained above was shared by the examiner, the original patent applicant (L-3 Systems) and apparently the Patent Owner, that a flat, planar heat spreader can be viewed as composed of a plurality of contiguous sections oriented within 25° of parallel to the substrate as required in Claim 3.

201. However, the POSITA would have found it obvious to use Hanai's pliable anisotropically heat-conducting graphite sheet for the panel of Kuo. Hanai's pliable graphite sheet follows the topology of multiple electronic devices mounted on a substrate having variable shapes, sizes, heights and spacing, to achieve efficient cooling of those devices.

202. Claims 3, 15-16 of the '925 patent permit the case where more than one electronic component, for example one or more semiconductor integrated circuit chips, are enclosed within an "electronic assembly" as stated in the claims. I understand that it is a bedrock legal rule that the use of the words "a" or "an" to

describe a component in a patent claim means that the claim covers one or more of those components.

203. The POSITA, when confronted with the problem of enclosing multiple devices of different heights, would have been motivated to combine the teachings of Kuo and Hanai by substituting Hanai's anisotropic, pliable graphite sheet material for the metal material of Kuo's heat-spreading panel 24. This modification would enable the POSITA to achieve efficient dissipation of heat from multiple semiconductor devices by designing the sheet material to follow the topology of the devices, as shown in Hanai Figure 4:

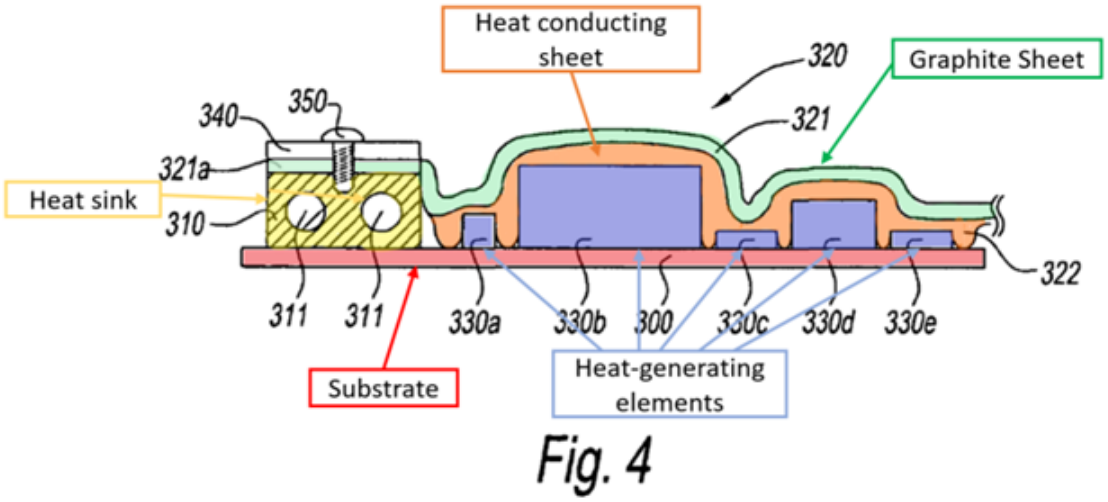


Fig. 4

Figure 33: An annotated copy of Figure 4 from Hanai *(Ex. 1006)* showing the flexible graphite sheet 321 in green and the heat generating elements in blue. The thermal interface material is shown in orange.

Configurations in which electronic substrates contain multiple electronic devices having variable shapes, sizes, heights and spacing are common. For example, portable electronic devices such as cell phones and laptop computers use semiconductor chips that are enclosed in packages. These packaged chips, or integrated circuits (ICs) are of different size, height and shape due to the specifics of each integrated circuit and how it is made. Furthermore, due to the desire to keep the cell phone or laptop as small as possible, each of the components is individually designed to be as short and as close together as possible.

204. Microprocessors for example, are usually larger components that are often packaged in what is called a Ball Grid Array (BGA). (The structure of Kuo is a BGA). These packages can have hundreds or thousands of connections to the substrate. Ball grid array packages have different heights based on the size of the balls and the thickness of the BGA package itself. The package size, height and shape of the BGA is optimized for the semiconductor chip that is mounted inside and the height is also dependent on how electrical connection is made between the chip and the package itself.

205. Conversely, memory integrated circuits can have fewer connections to the substrate and are therefore smaller, but they too can also generate a great deal of heat. Memory ICs often come in packages where the semiconductor chips are

stacked on top of each other or on top of a microprocessor. Thus, the size, height and shape of a memory integrated circuit package is optimized for this configuration of stacked semiconductor chips and how those chips are electrically connected to the package.

206. As yet another example, portable electronic devices usually contain radio frequency ICs (RFICs) that support communication standards such as Wi-Fi and Bluetooth. These RF semiconductor components generate heat and are likewise packaged in a manner that optimizes the RF performance while minimizing height and size. The package height of the RFIC is not necessarily the same height as either a BGA or memory IC, yet all can benefit from an anisotropic heat spreader.

207. Furthermore, the spacing between integrated circuits and between other components is an important design criteria. Components that must communicate with each other using high frequency signals are often located close to each other to preserve the integrity of the communication by minimizing the distortion of the signals as they pass through the substrate. Conversely, RF IC's might be located some distance from the microprocessor or memory integrated circuits so that the RF signals do not interfere with the high frequency communication between the microprocessor and the memory.

208. A detailed description of these design choices and the impact on the possible angles of the graphite heat spreader is provided in Section IX.2.a.v which uses the BlackBerry Playbook from 2011 as a commercially available example. The POSITA would have been motivated to combine the teachings of Kuo and Hanai by substituting Hanai's anisotropic pliable sheet material for the metal material of Kuo's heat spreading panel 24 to achieve efficient dissipation of heat from multiple semiconductor devices having variable shapes, sizes, heights and spacing. In this way, the POSITA would have achieved the advantage of conducting heat through the plane of the heat spreading panel, and into the support structure of Kuo. This is true for a number of reasons.

209. Hanai teaches that to achieve efficient cooling of multiple electronic devices mounted on a substrate having variable shapes, sizes, heights and spacing, it is important that the heat spreading element located above the devices be flexible enough to closely follow the topology of the devices because for a given thermal conductivity, heat transfers better through a thin volume than it does through a thicker volume. Hanai further teaches that it is advantageous to employ a material that spreads heat anisotropically; that is, a material that conducts heat more efficiently in the plane parallel to the surface. This way, the heat can be effectively transferred to the side of the device as disclosed by Hanai.

210. It should be noted that the anisotropic heat spreader of Nozaki also transfers heat to the side of the device.

211. I have explained above in Section IX.1 why a POSITA would have been motivated to transfer heat to the side of the device. Dissipating heat from the source of the thermal energy and spreading it to the side of the package, as a POSITA would understand, is important for several reasons. Typically, the exterior of an electronic device is at a lower temperature than the interior of the device and the sides of the package have more area than the central portion of the package, so the thermal energy is spread over a larger area which results in lower overall temperature of the component inside the package as well as the package itself.

212. A POSITA would have understood this approach is important in particular for portable electronics since it reduces undesired "hot spots", portions of the device that are noticeably hotter than the rest of the device. Not only are hot spots undesired for tactile reasons by the user, but hot spots can also cause localized mechanical stress due to the hot components expanding more than cooler components based on their coefficient of thermal expansion (CTE). Hot spots are further undesired because different materials used in the electronic device have different CTEs and thus expand a different amount for a given temperature change. This leads to stress gradients developing inside the device which can cause functional and reliability

failures. If the overall temperature change is lower, the difference in expansion for the different materials is lower, thus stresses are lower resulting in greater reliability.

213. Dissipating heat with an anisotropic heat spreader to the sides of the package can also be important as the sides of the package can be placed in contact with other parts of the electronic device to dissipate the heat even further.

214. Another advantage of spreading heat to the support structure that would have been obvious to a POSITA is that this approach is important when other electronic components that are placed over or near the heat generating component must be protected from that heat. The anisotropic heat spreader causes the heat to be transferred to the support structure so the temperature directly above or near the heat generating components does not increase to the point of degrading the performance of the component above or near it. POSITA's have been using this approach in portable devices for many years prior to 2013 as a way to protect the display portion of the device from having a localized "hot spot" which would cause the display characteristics over the hot spot to be different than the surrounding cooler portions of the display.

215. By making such a combination, the POSITA would have expected to successfully achieve an electronic packaging assembly having a heat-spreading panel in which the contiguous sections thereof have substantially parallel sections

oriented at the angles specified in the claims. The design and manufacture of such a structure would have been straightforward; the POSITA simply would have replaced the flat heat-spreading panel 24 of Kuo with the pliable heat-spreading graphite sheet taught by Hanai. As I have discussed above in Section V, the anisotropic heat-spreading graphite material taught by Hanai was well known before the priority date of the '925 patent, as were methods to create custom shapes and configurations from this material. No problems would have arisen in making the combination that would not have been addressed through routine experimentation or design choices.

216. Furthermore, the substitution of Hanai's thermally anisotropic heat spreader with the metal heat spreader of Kuo would not have required any other change to the Kuo invention. The same adhesive 46 would be used to attach the heat spreader to the support structure and the same thermal grease 36 would be used with both the Hanai and Kuo heat spreading lids.

217. I will now discuss how the combination of Kuo and Hanai applies to the specific limitations of Claim 3.

a. Independent Claim 3 as Obvious Over Kuo and Hanai

i. Preamble: An electronic assembly comprising:

218. To the extent the preamble is limiting, Kuo discloses this limitation as explained with in Section IX.1.a.i above.

ii. Limitation 3[a]: a support structure comprising walls enclosing a space;

219. Kuo discloses this limitation for the reasons explained with respect to this limitation in IX.1.a.ii above.

iii. Limitation 3[b]: a circuit substrate coupled to a first portion of said support structure, said circuit substrate comprising a mounting surface;

220. Kuo discloses this limitation for the reasons explained with respect to this limitation in IX.1.a.iii above.

iv. Limitation 3[c]: an electronic device attached to said mounting surface and disposed within said space; and

221. Kuo discloses this limitation for the reasons explained with respect to this limitation in IX.1.a.iv above. I understand that use of the article "an" in this limitation includes one or more such electronic device.

v. Limitation 3[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty–five degrees of parallel to said mounting surface,

222. This limitation would have been obvious based on Kuo in combination with Hanai. Electronic devices contain many different components with different heights and with different spacings between them. Considering a portion of the graphite heat spreader that is over two components with different heights, one can define three sections of a heat spreading panel as shown in the Figure below. The First Section of the graphite heat spreader is shown in red and is above "Component B" This First Section has an inner surface that is parallel to the mounting surface or substrate. The Third Section is shown in blue and is above "Component A" and it too has an inner surface that is parallel to the mounting surface. The Second Section, shown in green is contiguous with both the First and Third Sections and the Second Section spans between Component A and Component B. The angle of this Second Section can be calculated using the definition of the tangent of an angle. The tangent of an angle is defined as the length of the opposite side of a triangle divided by the length of the adjacent side. In this example, the opposite side of this triangle is equal to the difference in the height of the two components ($\Delta H = H3 - H1$). The adjacent side is simply the space (S1) between the two components. Claim limitation 3[d] requires each of the sections to be within 25 degrees of parallel to the mounting surface. The tangent of 25 degrees is approximately 0.466. Thus, as long as a section of the graphite heat spreader spanning between two components has the dimensions such that the ratio of the Height Difference (ΔH) to the Spacing (S1) is

less than 0.466, then the claim limitation is met. A POSITA would understand this to be a simple design feature of a heat spreader for an electronic device, not a unique claim element. As will be shown in the next portion of this declaration, commercial devices existed and were sold in the US prior to 2013 the year that the '925 patent was filed.

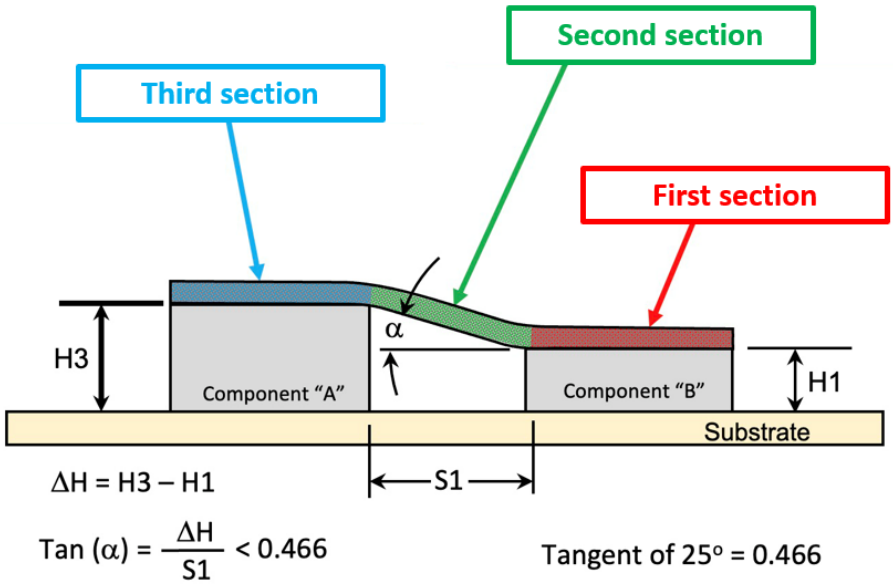


Figure 34: An illustration showing how the angle of a contiguous section of a graphite heat spreader would be calculated.

223. For example, one device that existed well before 2013 and that used a graphite heat spreader was the BlackBerry PlayBook, a thin tablet-style device that the user interacts with primarily through a capacitive touch screen along with a forward-facing and rear-facing camera. The BlackBerry PlayBook was manufactured by the company RIM and released for sale in the US in April 2011 *(Exhibit 1038,*

https://www.theguardian.com/technology/2011/mar/22/blackberry-playbook-launch-date-price-specs)

224. A teardown report for the BlackBerry PlayBook is available from the iFixit.com website, a common website for this type of technical analysis of electronic devices. A recent screen capture of the home page of the teardown is shown in Figure 35. The teardown itself was published on April 19, 2011 and can be found in Exhibit 1031.

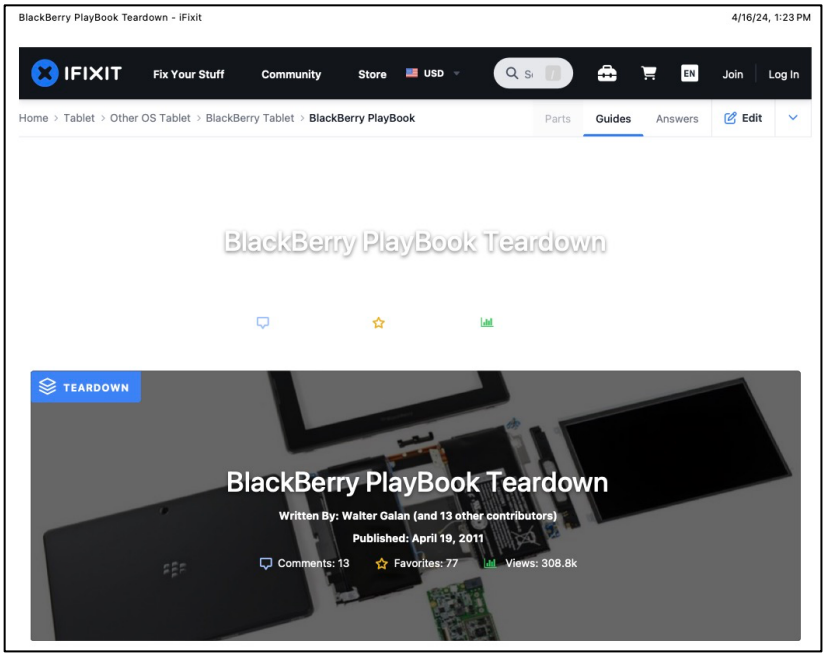


Figure 35: A screen capture of the opening web page of the BlackBerry Playbook teardown from iFixIt.com. *(Ex. 1031).*

225. When the BlackBerry PlayBook is opened and the rear case is removed, the motherboard and graphite heat spreader become visible. This can be seen in Step 5

of the teardown and an annotated screen capture of this step is shown in Figure 36 where the graphite heat spreader is shown in blue annotation.

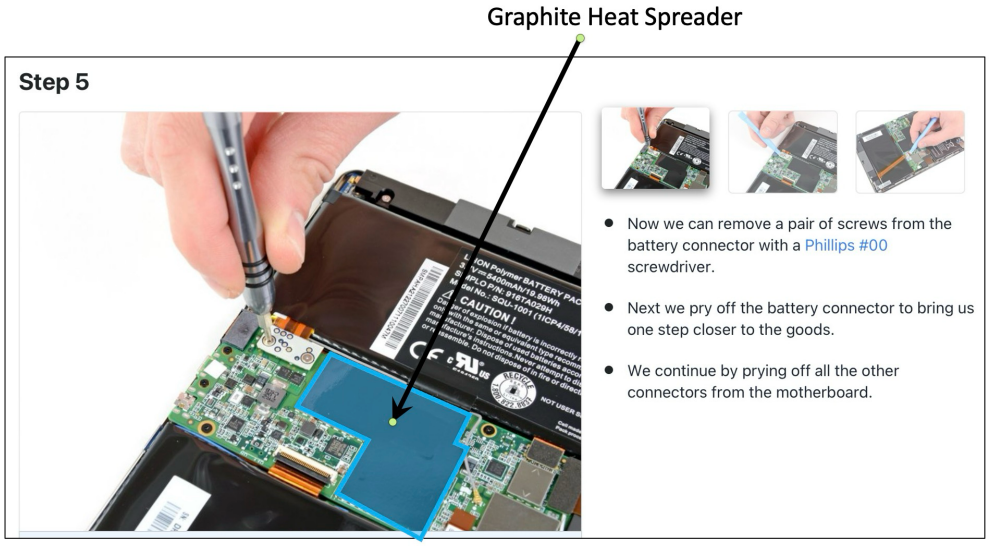


Figure 36: An annotated screen capture of a web page from the iFixIt.com BlackBerry Playbook teardown showing the anisotropic graphite heat spreader highlighted in blue. *(Ex. 1031).*

226. The website iFixit.com helps consumers and others understand the repairability of the devices its technicians analyze. As such, this website does not explicitly identify the thermally anisotropic graphite heat spreader. We can however identify this by looking at Appendix E of the Freescale Thermal Management Application Note AN4579 where the graphite heat spreader is identified and described as "Cool(ing) the CPU and Memory", spreading the heat "into other components" *(Ex. 1023)*. A second graphite heat spreader is "used to shield heat from reaching the back cover."

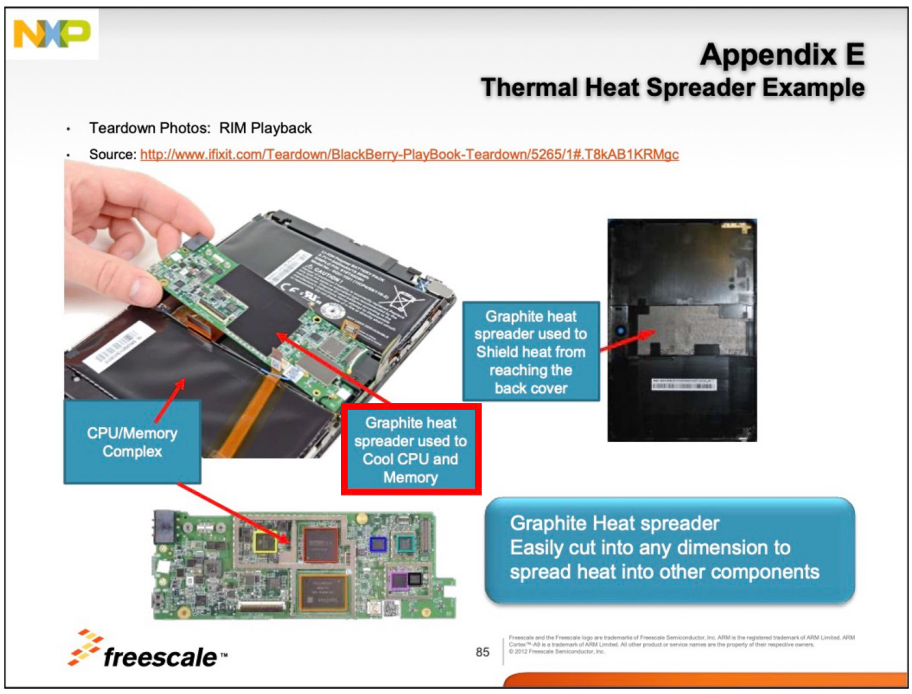


Figure 37: An annotated image from the Freescale Thermal Management Application Note identifying the graphite heat spreader in the Blackberry PlayBook. Label is shown in the red outlined blue text box. *(Ex. 1023).*

227. The Freescale document also references the iFixit.com teardown and uses an image from Step 7 of the iFixit.com teardown report. That image is shown in Figure 36 below which not only shows the components on the substrate, but also lists the components that are under the heat spreader.

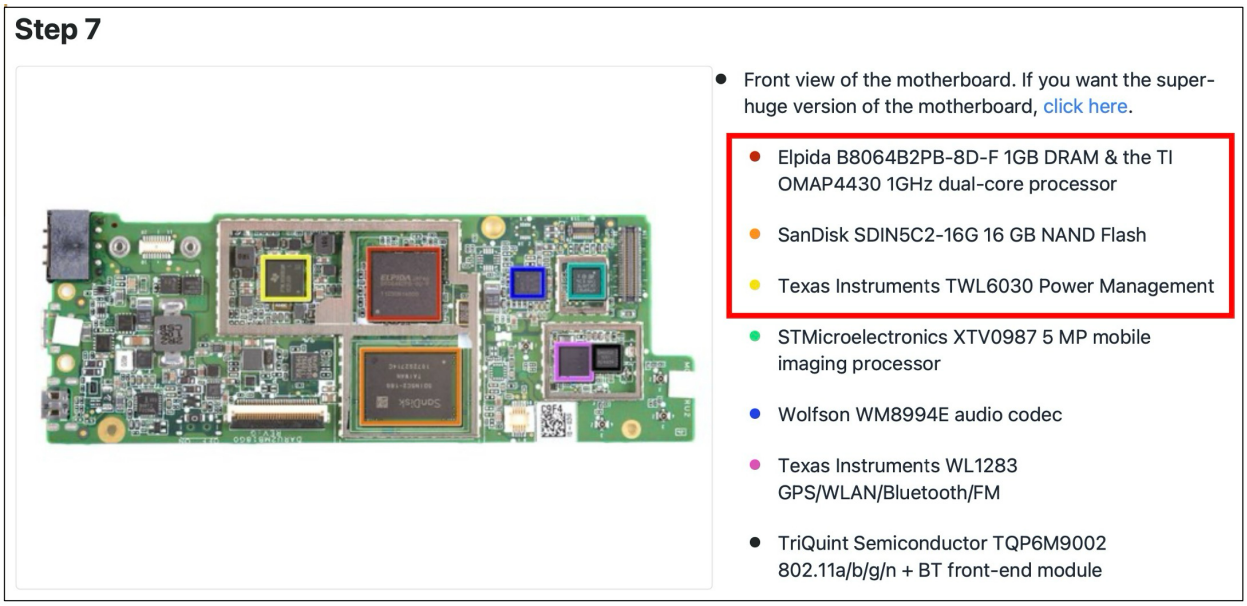


Figure 38: Annotated screen capture from the iFixit.com teardown of the BlackBerry PlayBook listing key components as well as showing their location on the printed circuit board substrate *(Exhibit 1031).*

228. By examining the electronic components that generate heat and that are under the thermally anisotropic graphite heat spreader and by analyzing their mounting position on the substrate, calculations can be made as to the maximum angle that the graphite heat spreader might have to contact these components which have different heights from the mounting surface.

229. The CPU component in the BlackBerry PlayBook is the Texas Instruments OMP4430 dual core processor. This chip is packaged in a 12mm x 12mm Ball Grid Array (BGA) package that has a maximum height of 0.9mm from its mounting surface.

230. The package that this CPU is housed in has a unique "Package-On-Package" (PoP) configuration that allows a packaged system memory chip to be mounted directly on top of the CPU package. The system memory chip is the Elpida B8064B2BPB which is a one Gigabyte Dynamic Random Access Memory (DRAM). The DRAM chip is also housed in a 12mm x 12mm BGA package that has a maximum height of 1.0mm from its mounting surface. Since the DRAM is mounted on top of the CPU package, the package heights add, leading to a total component height from the mounting surface to the top of the PoP configuration of about 1.9mm.

231. The assembly of the CPU/DRAM PoP configuration is described in the Texas Instruments "TI OMAP4xxx POP SMT Design Guideline" document *(Ex. 1032)*. Pages from that document are shown in the following figures which show images of the components, as well as drawings that show package dimensions and heights from the mounting surface.

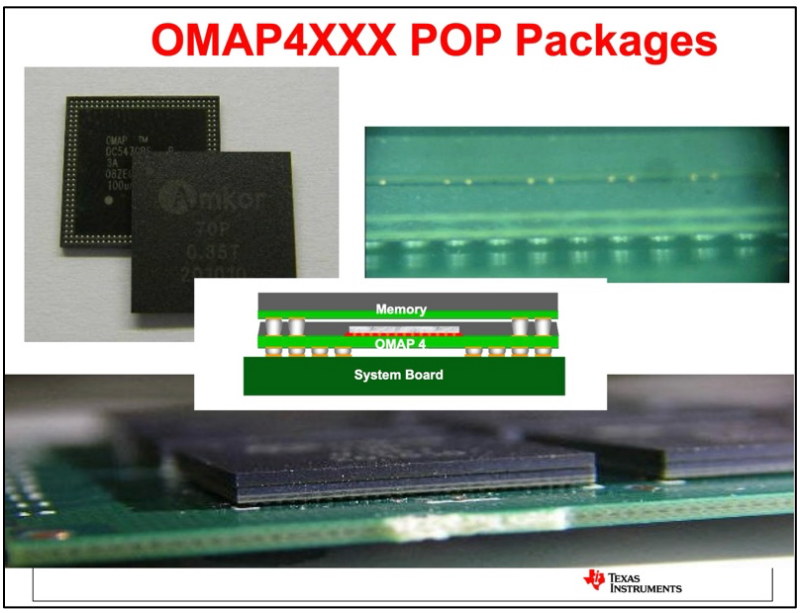


Figure 39: Image showing the CPU and memory components that are used in the Package-On-Package configuration *(Ex. 1032).*

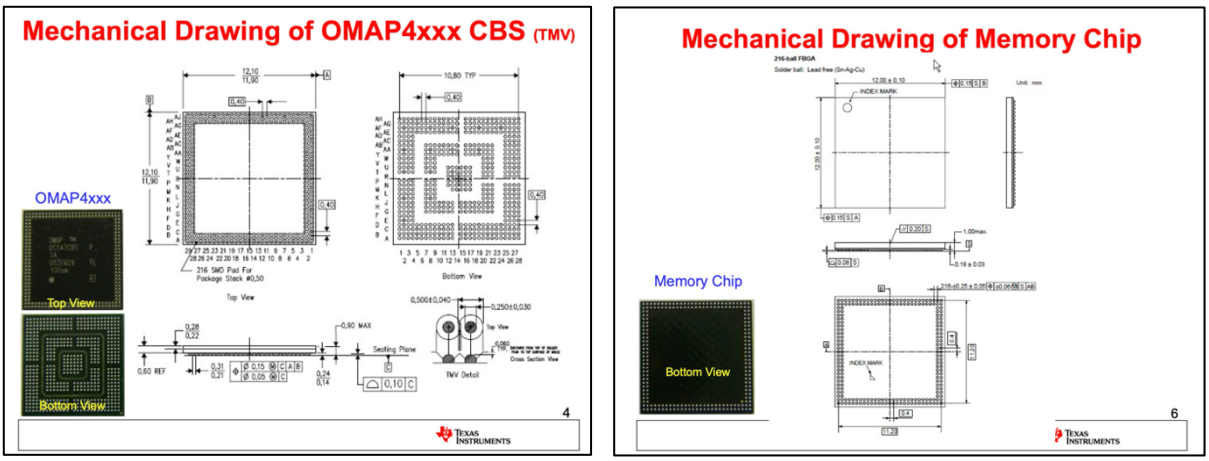
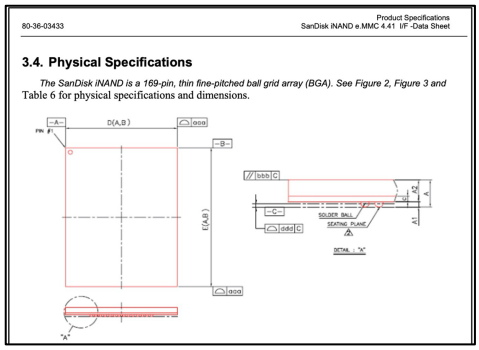


Figure 40: Package outline drawings of the CPU and memory components used in the BlackBerry Playbook from the TI application note. *(Ex. 1032).*

232. Two other components that are under the graphite heat spreader are packaged in a more conventional manner. The SanDisk SDIN5C2-16G is a Flash Memory

component that is packaged in a BGA package that measures 12 x 16 x 1.2mm high. The Power Management Component from Texas Instruments, the TWL6030, is a BGA that measures 7 x 7 x 1.0mm high. The datasheets for both components are shown in the figures below:



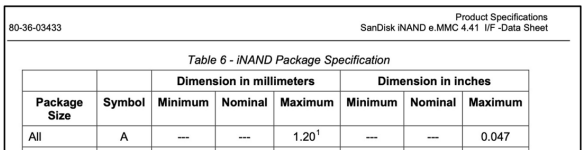
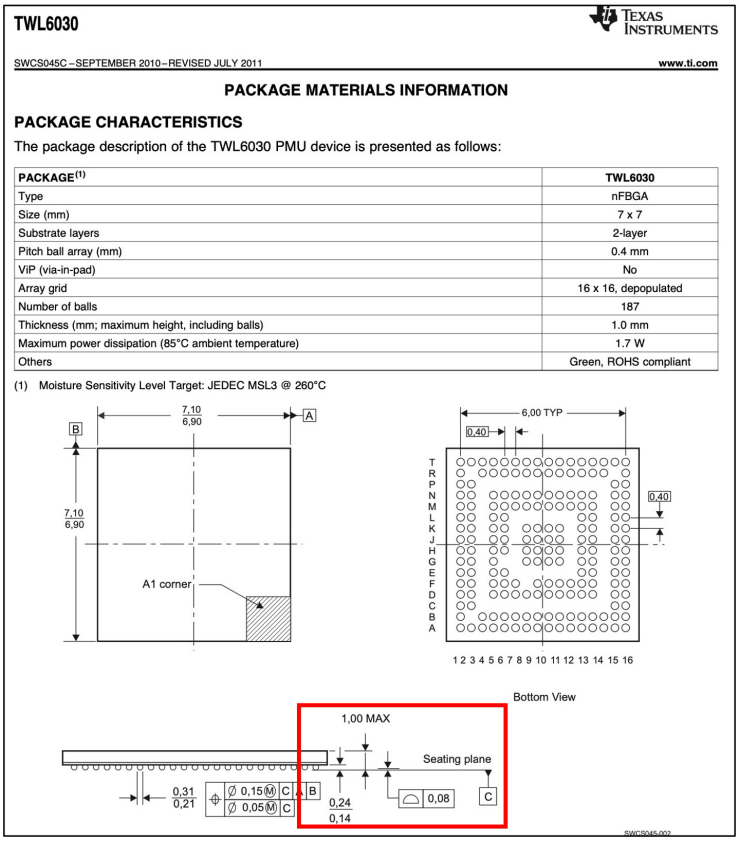


Figure 41: Drawings from the 2010 datasheet of the SanDisk Flash memory used in the BlackBerry Playbook *(Ex. 1033)*.



TWL6030

TEXAS INSTRUMENTS

SWCS045C – SEPTEMBER 2010 – REVISED JULY 2011 www.ti.com

PACKAGE MATERIALS INFORMATION

PACKAGE CHARACTERISTICS

The package description of the TWL6030 PMU device is presented as follows:

PACKAGE(1)	TWL6030
Type	nFBGA
Size (mm)	7 x 7
Substrate layers	2-layer
Pitch ball array (mm)	0.4 mm
ViP (via-in-pad)	No
Array grid	16 x 16, depopulated
Number of balls	187
Thickness (mm; maximum height, including balls)	1.0 mm
Maximum power dissipation (85°C ambient temperature)	1.7 W
Others	Green, ROHS compliant

(1) Moisture Sensitivity Level Target: JEDEC MSL3 @ 260°C

Figure 42: An annotated package outline drawing from the datasheet of the TI Power Management component TWL6030 used in the BlackBerry Playbook *(Ex. 1034)*.

233. By examining the layout of the printed circuit board from the of the BlackBerry PlayBook iFixit.com teardown and understanding the size of the three components under the graphite heat spreader, a reasonable estimate of the distance between the components can be made. This estimate is shown in Figure 41 where the distance between the Power Management component and the CPU/Memory PoP is about 8.5mm and the distance between the Flash Memory component and the CPU/Memory PoP is about 3.5mm.

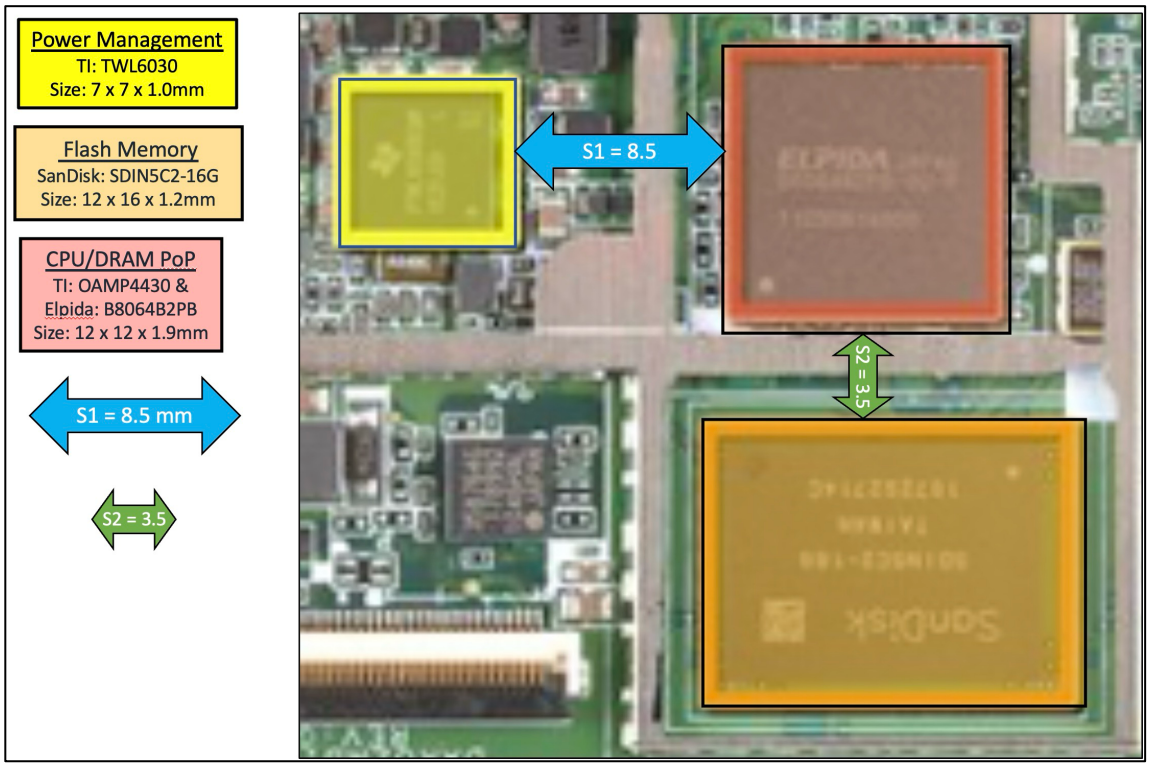


Figure 43: An annotated image of the circuit board used in BlackBerry Playbook with the color-coded electronic components and calculated spacing between them. *(Ex. 1031).*

234. The graphite heat spreader in the BlackBerry PlayBook has at least five contiguous sections. Three of the sections are parallel to the mounting surface and are over each of the three components described above: CPU/DRAM PoP, the Flash Memory package, and the Power Management component. The section of the heat spreader spanning between the CPU/DRAM PoP and the Power Management package can be considered as the fourth section, while the section of the heat

spreader spanning between the CPU/DRAM PoP and the Flash Memory package can be considered the fifth section.

235. The tangent of an angle is equal to the length of the opposite side divided by the length of the adjacent side. This formula can be used to calculate the possible angle of the section of the graphite heat spreader that spans from one component to the other relative to the mounting board substrate. The angle of the fourth section of the graphite heat spreader which spans from the CPU/DRAM Package on Package component to the Power Management component would be about 6 degrees. Using the same formula, the angle that the section of graphite heat spreader that spans from the CPU/DRAM Package on Package to the Flash Memory component would be 11.3 degrees. These calculations are shown in the figure below.

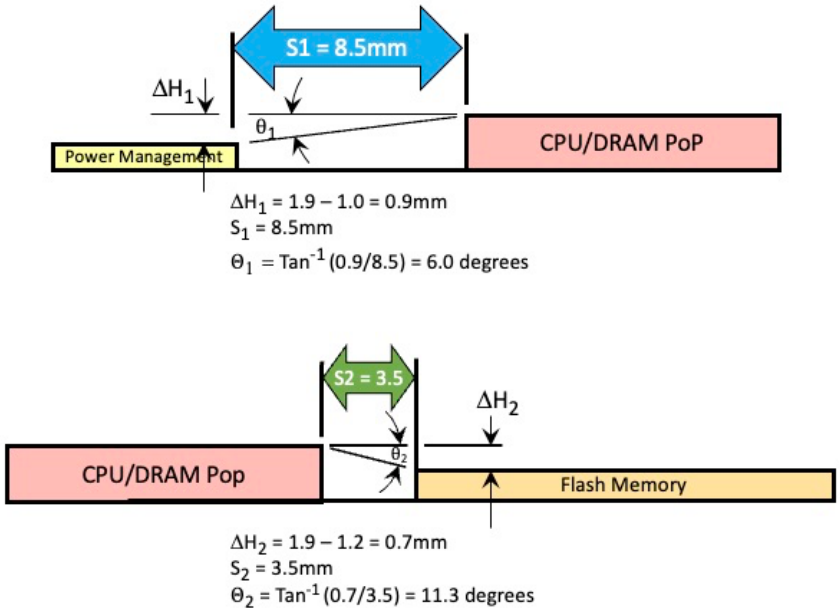


Figure 44: Calculations of the angle that contiguous sections of the graphite heat spreader might have as it spans between components in the BlackBerry PlayBook.

236. The three sections of the graphite heat spreader that are directly over the three components would have a surface that is nominally parallel to the mounting surface. While those contiguous sections of the same graphite heat spreader that span between one component and another could be at an angle that is not parallel to the mounting surface. As this example illustrates, the angle of the heat spreader sections that span between components is dependent on the difference in component height and the spacing between them and since different products use different components with different spacing, graphite heat spreaders could contain sections that are at angles other than parallel to the mounting surface, but yet well within 25 degrees from the mounting surface.

237. In addition, the POSITA would have noted that the ’925 patent specification does not ascribe any particular significance to the number of contiguous sections or the exact values of the angles between the inner surfaces of the contiguous sections, both with respect to one another and with respect to the mounting surface. The ’925 specification states that the panel may “have more or fewer than the three substantially parallel, contiguous sections 112, 118, 122 shown, and those sections can be oriented (e.g., angled) differently than shown,” *(Ex. 1001, 4:35–41)*, and that

"the invention is not limited to use of a panel with any particular number of sections or orientation of sections." *(Ex. 1001 ,4:46–48)*. The specification further states that the angles between the inner surfaces of the sections and a plane parallel to the mounting surface:

> *"can be less than or equal to forty-five degrees, thirty degrees, twenty-five degrees, fifteen degrees, ten degrees, or five degrees. Put another way, in various embodiments, the angles 204 and 206 can be greater than zero but less than or equal to forty-five degrees, thirty degrees, twenty-five degrees, fifteen degrees, ten degrees, or five degrees. In fact, all of the inner surfaces 130, 132, 134 of the all of sections 112, 118, 122 of the panel 110 can be with forty-five degrees, thirty degrees, twenty-five degrees, fifteen degrees, ten degree, or five degrees of parallel to each other and/or the mounting surface 104 of the circuit substrate 102." (Ex. 1001, 5:33–44; see also id, 9:53–65) (describing Figure 8 embodiment having a plurality of electronic devices within the package assembly).*

238. Hanai's teaching that the pliable, anisotropic heat-spreading graphite sheet "adhere[s] closely to heat–generating elements 330a, etc.," *(Hanai, 0021)*, and thus conforms to the topology of the plurality of semiconductor devices on the substrate mirrors the '925 patent specification's statement that, in the case of multiple devices, the heat-spreading panel can "be customized to different sized electronic devices" as shown in Fig. 8. *(Ex. 1001, 9:66–10:3, Fig. 8)*. No problems would have arisen in making the combination that could not have been addressed through routine experimentation or design choices made by the POSITA.

vi. Limitation 3[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section,

239. Kuo in combination with Hanai satisfies this limitation. The pliable graphite sheet 321 of Hanai conducts heat anisotropically. The heat conductivity of the graphite sheet is approximately 5 W/mK to approximately 20 W/mK in the direction of its thickness and approximately 200 W/mK to approximately 800 W/mK in the direction of the plane of the surface. *(Hanai, 0019)*. The combination of Kuo and Hanai thus would result in an electronic package assembly in which each contiguous section "has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section," as claimed.

vii. Limitation 3[f]: wherein for each said section, said first thermal conductivity is at least one–hundred times greater than said second thermal conductivity,

240. Kuo in combination with Hanai satisfies this limitation. The thermal conductivity of Hanai's graphite sheet 321 is approximately 5 W/mK to approximately 20 W/mK in the direction of its thickness (c-direction) and approximately 200 W/mK to approximately 800 W/mK in the direction of the plane of the surface (a-b direction). *(Hanai, 0019)*. The thermal anisotropy of a graphite heat spreader is defined as the thermal conductivity in the a-b direction divided by

the thermal conductivity in the c-direction. The POSITA would have appreciated that these values provide a range of thermal anisotropy ranging from 10 (200 W/mK divided by 20 W/mK) to 160 (800 W/mK divided by 5 W/mK).

241. I observe that the '925 Patent ascribes no particular importance or criticality to the range of values contained in this claim limitation. To the contrary, the specification makes clear that the value can vary widely: "the first thermal conductivity can be significantly greater (e.g., two times or more, five times or more, fifty times or more, one-hundred times or more, or five hundred times or more) than the second thermal conductivity." *(Ex. 1001, 5:59–65)*.

242. Moreover, in implementing the combination, the POSITA would have understood that selection of the precise thermal conductivity characteristics of the graphite material in Hanai was a design choice. In many cases, the POSITA would have been inclined to choose a thermal conductivity difference between the in-plane and perpendicular directions toward the higher end of the range 10x to 160x in order to maximize heat dissipation efficiency for those applications in which such maximization was important and the cost of doing so was within budget. On the other hand, in applications where cost was more important than thermal performance, a lower cost heat spreader with a lower thermal anisotropy might be chosen.

243. The POSITA further would have been aware that examples existed of graphite material having the claimed thermal conductivity properties not only through the teachings of Hanai, but also through, e.g., the teaching of Nozaki of graphite materials having a thermal conductivity difference of more than 100x in the in-plane vs perpendicular directions. See explanation of Limitation 3(f) in IX.1.a.vii above.

244. Furthermore, as described previously in this declaration, graphite heat spreaders with thermal anisotropy of greater than 100 were well known and commercially available well before 2013.

b. Independent Claim 15 as Obvious Over Kuo and Hanai

i. Preamble: An electronic assembly comprising:

245. The preamble is the same as the preamble in Claim 3. I have explained above how Kuo meets this limitation.

ii. Element 15[a]: a support structure comprising walls enclosing a space;

246. This limitation is the same as Limitation 3(a). I have explained above how Kuo meets this limitation.

iii. Element 15[b]: a circuit substrate coupled to a first portion of said support structure, said circuit substrate comprising a mounting surface;

247. This limitation is the same as Limitation 3(b). I have explained above how Kuo meets this limitation.

iv. Element 15[c]: an electronic device attached to said mounting surface and disposed within said space; and

248. This limitation is the same as Limitation 3(c). I have explained above how Kuo meets this limitation.

v. Element 15[d]: a panel coupled to a second portion of said support structure, said panel comprising contiguous sections, each said section comprising an inner surface facing said mounting surface of said circuit substrate and oriented within twenty-five degrees of parallel to said mounting surface,

249. This limitation is the same as Limitation 3(d). I have explained above how Kuo meets this limitation.

vi. Element 15[e]: wherein each said section has a first thermal conductivity substantially parallel to the inner surface of said section and a second thermal conductivity substantially perpendicular to the inner surface of said section,

250. This limitation is the same as Limitation 3(e). I have explained above how Kuo meets this limitation.

vii. Element 15[f]: wherein said first thermal conductivity is greater than said second thermal conductivity,

251. This limitation would be satisfied by Kuo as modified to use the anisotropic heat-spreading graphite sheet of Hanai. The heat conductivity of Hanai's graphite

sheet 321 is approximately 5 W/mK to approximately 20 W/mK in the direction of its thickness and approximately 200 W/mK to approximately 800 W/mK in the direction of the plane of the surface. *(Hanai, 0019)*.

252. As described earlier, thermal anisotropy is defined as the ratio of thermal conductivity in the ab-direction to the thermal conductivity in the c-direction with the ab-direction being the direction of the plane and the c-direction through the thickness of the heat spreader. The specific thermal anisotropy of a heat spreader is a design choice that the thermal engineer would specify. The POSITA would have appreciated that the values of thermal conductivity provided by Hanai cover a range of thermal anisotropies from 10 (200 W/mK divided by 20 W/mK) to 160 (800 W/mK divided by 5 W/mK). *(Hanai, 0020)* In every case, the first thermal conductivity (in-plane) is greater than the thermal conductivity perpendicular to plane.

viii. Element 15[g]: wherein a thermally conductive path from said space enclosed by said walls of said support structure out of said electronic assembly that has a greatest thermal conductivity comprises a thermal path through contiguous ones of said sections of said panel to an outer edge of an outer one of said sections of said panel, and

253. This limitation would be satisfied by Kuo as modified to use the anisotropic heat-spreading material of Hanai. By substituting Hanai's thermally anisotropic lid with Kuo's metal lid, the thermally conductive path from the components in the

space enclosed by the walls of the support structure is through thermal grease to the thermally anisotropic heat spreader of Hanai, to the walls of the support structure.

254. In Hanai, heat is designed primarily to flow through pliable graphite sheet 321, which conducts heat anisotropically to an aluminum heat sink 310 located at the side of PC board 300. This heat flow path is illustrated by the red arrows in the Figure 43 below.

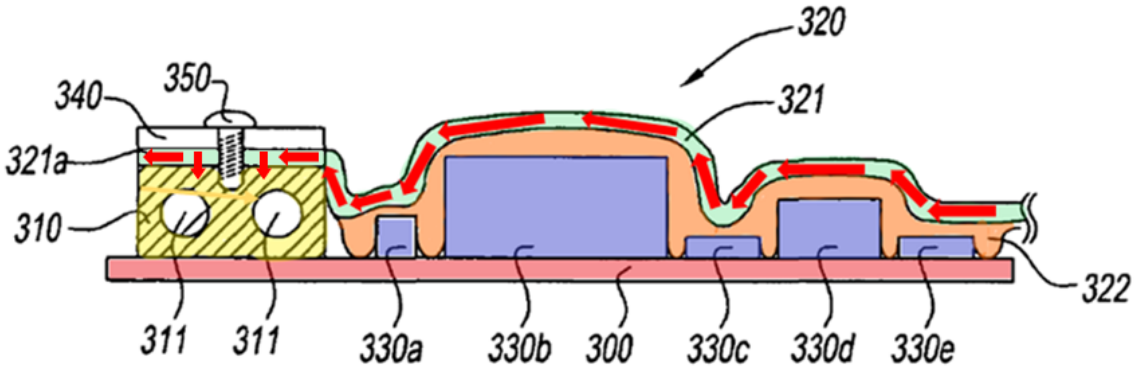


Fig. 4

Figure 45: Annotated copy of Figure 4 from Hanai *(Ex 1006)* with the red arrows indicating the flow of heat in the thermally anisotropic heat spreader.

255. The POSITA would have understood that the thermal conductivity through the graphite sheet toward the heat sink of Hanai is the path of greatest thermal conductivity because the thermal conductivity in the a-b direction of the Hanai heat

spreader is much greater that the thermal conductivity through the substrate to heat sink 310, which is designed to quickly remove heat from the system through coolant flowing through fluid flow path 311. *(Hanai, 0020)*. The anisotropic heat-spreading graphite material of sheet 321 is intentionally designed to conduct heat preferentially in the ab-direction away from the heat generating elements. Hanai uses a Printed Circuit Board for a substrate and this material would have a smaller value of thermal conductivity much less than the thermal conductivity of the anisotropic heat spreader in the a-b direction.

256. When replacing the copper heat spreader of Kuo with the thermally anisotropic heat spreader of Hanai, a thermal path that meets this claim limitation is formed. As illustrated in the Figure 44, the heat from the semiconductor chip 10 and mold 18 is preferably transferred through the thermal grease to the thermally anisotropic lid. Due to this anisotropy, the heat is then transferred laterally due to the greater thermal conductivity it the lateral direction. From there, the thermal energy couples into the pillar structure 40.

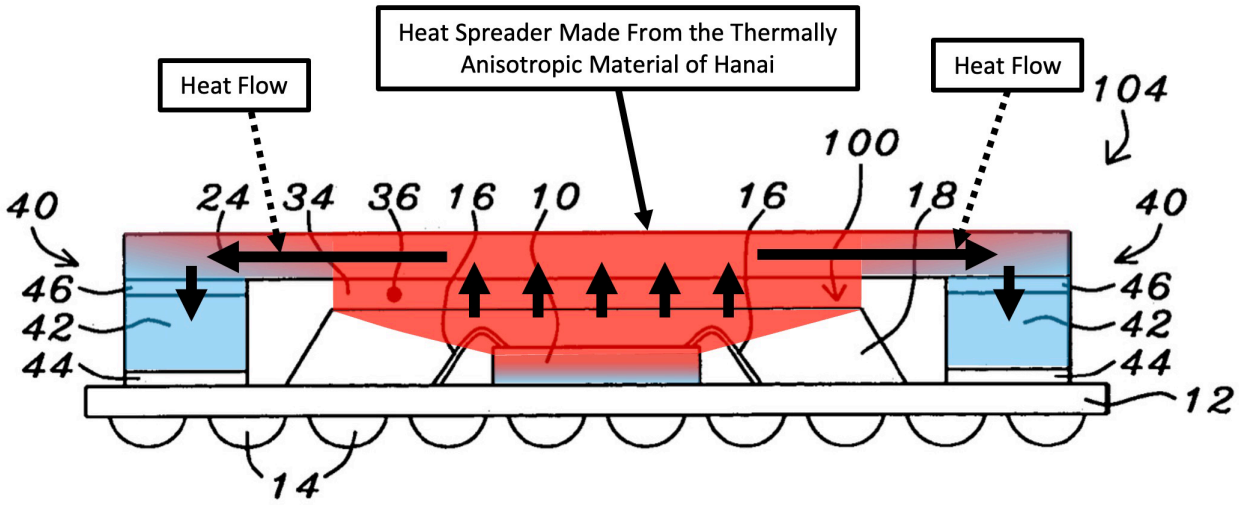


Figure 46: An annotated copy of Figure 3a from Kuo *(Ex. 1004)* as modified by *Hanai (Ex. 1006)* showing the path of greatest thermal conductivity through the graphite heat spreader.

257. The POSITA further would have appreciated that, in making the combination of Kuo and Hanai using the anisotropically heat-conducting pliable graphite sheet for Kuo's heat-spreading panel 24, the thermally conductive path from the heat-generating elements in the space enclosed by the walls of the support structure having the greatest thermal conductivity would be the thermal path through the contiguous sections of the panel to the outer edges of the assembly. Kuo, like Hanai, desires to transfer heat efficiently from the space enclosed by the assembly. Kuo as modified by Hanai would do so by transferring heat in the ab-direction of the graphite sheet to the copper sidewall support structure of Kuo in a similar fashion to Hanai. The thermal conductivity of Hanai's heat spreader in the ab -direction is 200 to 800 W/mK and when used in the Kuo assembly, it would create the path of

greatest thermal conductivity since the other thermal path is through the insulating substrate which is made of PCB material**.** The thermal conductivity of a PCB material, such as that used for the substrate in a BGA like Kuo, typically ranges from 0.5 to 0.3 W/mK. *(Kandasamy, Table 1)*. Kuo as modified by Hanai would do so by transferring heat along the plane of the graphite sheet to the copper sidewall support structure 42 of Kuo in a similar fashion to how Hanai transfers heat along pliable graphite sheet 321 to heat sink 310.

ix. Element 15[h]: wherein said electronic assembly further comprises a thermally conductive adhesive coupling said outer edge of said outer one of said sections to said support structure.

258. This limitation would have been obvious based on Kuo in combination with Hanai. In Kuo, the metal heat-spreading panel 24 is fixed to the upper end of metal pillar 40 by epoxy adhesive 46. *(Kuo, 4:56–64)*. Kuo does not describe the thermal properties of the epoxy, however, as I have explained above, because Kuo's ball grid array package is designed to conduct heat away from the semiconductor device primarily through thermal grease 36 to heat spreader 24, *(Kuo, 5:29-36)*, and also from heat spreader 24 to support structure 42, which is made of the same material as heat spreader 24, *(Kuo, 4:42-67)*, the POSITA would have understood that Kuo is likely to be using an epoxy material that has a normally thin (about 0.001 inch or 25 microns) bondline and is thermally conductive. Such epoxy materials, especially when used to join heat-conducting structures, were typically filled with a heat-

conducting material such as silver or other metal. These epoxy-based materials are described in more detail in the background section of this declaration. This is likely to be the case in Kuo's Ball Grid Array package is designed to conduct heat away from the semiconductor device primarily through thermal grease 36 to heat spreader 24 and also from heat spreader 24 to support structure 42, which is made of the same material as heat spreader 24. The POSITA therefore would have understood that the epoxy material 46 that attaches heat spreader 24 to support structure 42 was likely to thermally conductive properties in order to enable this heat transfer.

259. The POSITA further would have been motivated to use a thermally conductive epoxy in Kuo, particularly when Kuo is modified to use the anisotropic heat-spreading material of Hanai. As discussed above with respect to Kuo and Nozaki in Section IX.1, Hanai's heat-spreading material allows heat to be conducted from the semiconductor device along the a-b direction of the heat spreader to the outside heat sink. *(Hanai, Ex. 1006)*. When modifying Kuo to use the anisotropic heat-spreading material of Hanai, the POSITA would likewise have been motivated to ensure that heat can be conducted to the outside frame members of Kuo's assembly—i.e., copper support structure 42—in order to spread heat away from the heat-generating elements to avoid hot spots or a concentration of heat in a confined space where components are located in close proximity to one another, as explained above in Section IX.1.

260. Given that it was well known to use heat-conducting epoxy for this purpose, the POSITA would have readily employed such a material here and in fact the same thermally conductive epoxy adhesive could be used to attach a panel to the support structure 42 in Kuo regardless of whether the panel was made of copper of Kuo or the thermally anisotropic graphite of Hanai.

261. Furthermore, as a POSITA would understand, the thermal grease 36 of Kuo and the heat conducting sheet 322 are both "Thermal Interface Materials" and they serve identical purposes. When substituting the thermally anisotropic heat spreader of Hanai for the metal plate of Kuo, the thermal grease (TIM) of Kuo would not have to change.

c. Dependent Claim 16 as Obvious Over Kuo and Hanai

i. The electronic assembly of Claim 15 further comprising a thermally conductive material disposed between and in physical contact with said electronic device and the inner surface of one of said contiguous ones of said sections of said panel.

262. Kuo teaches the insertion of thermally conductive material in the space between the epoxy-encapsulated electronic device 100 and metal heat spreader 24 in the form of "thermal grease" 36. As described previously in this declaration, thermal grease is a type of material in the general class of materials referred to as a TIM. The thermal grease of Kuo is a TIM that is described as a silicone rubber type materials "containing heat-conducting particles such as zinc oxide, aluminum oxide,

aluminum nitride, boron nitride or ceramic fillers or other materials which have the properties of heat conduction." *(Kuo, 5:13-17)*. The POSITA would have understood that additional heat dissipation efficiency would be achieved from the presence of the thermal grease between the epoxy-encapsulated electronic device and the heat-spreading composite graphite panel in Kuo as modified by Hanai. Hanai teaches a similar concept of using a TIM in the form of flexible heat-conducting sheet 322 to transfer heat from the electronic components to the graphite heat spreader. The POSITA would have understood that the TIM of Hanai serves the same purpose as does thermal grease 36 in Kuo; that is, to facilitate the heat transfer from the heat-producing IC elements into anisotropic pliable graphite sheet 321 to enable further dissipation of heat to the side of the assembly.

X. SUMMARY

263. Claims 3, 15 and 16 of the '925 patent describe electronic package technologies and materials that existed long before it's 2013 filing date. This is evidenced by publications prior to 2013. Graphite materials and their use in electronic packages had become a standard solution in particular for mobile devices that needed to be small and thin yet had thermal management challenges. My personal, hands-on experience with this type of assembly prior to 2010 further bolsters this opinion.

264. In addition, a review of the patent literature shows that any attempt at defining a unique feature or claim element in claims 3, 15 and 16 of the '925 patent would fail due to obviousness to a POSITA as of the filing date of the '925 patent.

265. A simple substitution of the Nozaki graphite lid for the copper lid of Kuo meets the limitations of the asserted claims. No other change to Kuo is required; the same thermally conductive epoxy can be used to attach the lid and the same thermal interface material between the heat generating components and the heat spreader can be used.

266. Likewise, a simple substitution of the Hanai graphite lid for the copper lid of Kuo meets the limitations of the asserted claims. No other change to Kuo is required; the same thermally conductive epoxy can be used to attach the lid and the same thermal interface material between the heat generating components and the heat spreader can be used.

267. Due to both an abundance of technical and commercial prior art along with an extensive body of prior patent filings shows that the asserted claims of the '925 patent would be obvious to a POSITA as of the filing date of the '925 patent.

Appendix A

Curriculum Vitae of Leland J. Spangler

SAMSUNG EX. 1003 - 150/163

LELAND "CHIP" SPANGLER, Ph.D.

312 Sutherland Place
Manitou Springs, CO 80829

(719) 440-5753
chip@aspenmicrosystems.com

SUMMARY OF QUALIFICATIONS

* * * More than thirty years of experience in the design, development and/or manufacture of over 350 different products that use IC and sensors in new and innovative ways for automotive, medical, industrial and commercial applications. Specific products include: inertial, seismic, pressure, chemical and gas sensors, microphones, ultra-high resolution optical displays, electronic switch arrays, RF, IR, ultrasonic and LED products, optical telecom and communication products, implantable and diagnostic medical devices, DNA analysis products, microfluidic devices as well as thyristors, microwave, power and SOI transistors.

* * * Deep practical expertise in all aspects of semiconductor and electronic devices, fabrication, packaging and reliability including materials, fabrication technologies, transistors, circuits, sensors, MEMS, and optical devices along with wafer-level and die-level packaging and package assembly processes including hermetic, plastic, substrate, PCB and panel-level packaging.

* * * Excellent oral and written communication skills along with a deep knowledge of patent and intellectual property issues. Inventor or co-inventor on fifteen U.S. and international patents. Provides IP and Expert Witness services with trial experience at the US Int. Trade Commission and Federal District Court.

WORK EXPERIENCE

President, Aspen Microsystems, LLC, Manitou Springs, CO — Sept. 2011 to present

- Created and executed product development plans in conjunction with the client for IC's, MEMS and sensor products including: pressure sensors, LEDs, optical sensors, gas and water quality sensors, inertial sensors, timing devices and oscillators, power semiconductor devices, thyristors, fiber optic communication devices, DNA analysis chips, implantable neuro-stimulators for pain management and Vagus nerve stimulators as well as medical diagnostic hemodynamic sensors.
- Provide consulting services for dozens of microelectronic customers in areas including materials, wafer fabrication, IC design and layout, semiconductor reliability, and device packaging, PCB design and electronic reliability. Conduct multi-day seminars in all aspect of circuit and device design, fabrication and packaging of ICs, MEMS, optical devices and sensors for customers throughout the world.
- Provide successful expert witness services for multiple clients including technical construction analysis and evidence gathering, on-site inspections of defendant's manufacturing facilities, technical research and consulting, support for Markman hearings, claim construction, expert report writing, deposition and courtroom testimony.

Principal Engineer, Treehouse, Inc. Colorado Springs, CO — Jan. 2011 to Oct. 2011

- Development of an ultra-high-precision 6DoF force/torque sensor for orthopedic surgical robot. Developed custom optical communication system for pulse power. Developed Vagus nerve stimulator electronics.

President & CTO, Aspen Technologies, LLC, Colorado Springs, CO — Sept. 2001 to Jan. 2011

- Serving in a variety of positions leading up to President, built a customer base along with engineering, manufacturing and support teams. In a five-year span increased revenue by 6X while sustaining >60% gross margin and >18% net profitability.
- Transformed the company from a prototype IC and MEMS packaging shop to a product development and manufacturing organization with a focus on products with difficult engineering challenges. Sold Aspen Technologies in January of 2011.

SAMSUNG EX. 1003 - 151/163

WORK EXPERIENCE (cont.)

- Responsible for sales, marketing, engineering, manufacturing and quality activities for a wide range of products including ICs, RF devices, MEMS, down-hole sensors, displays, microphones, photonics, biomedical and microfluidic devices, DNA sequencing chips. Sustained yields of >95% across many products and customers with an on-time delivery record of >99%.
- Lead the development of an ultra-high resolution (64M) laser-based display system. Developed packages and assembly processes for DNA analysis, telecom switch arrays and precision integrated circuits and electronic assemblies. Transferred products to high volume production at overseas locations.

Principal Engineer, Coventor, Inc., Colorado Springs, CO Jan. 2001 to Sept. 2001

- Designed optical MEMS devices and packages for RF and telecom applications including the integration of photonic, optical, electrical components, windows and optical coatings to meet electrical, mechanical, optical, cost and reliability requirements.

Analog IC Design Engineer, Intel Corp. and Ford Micro., Inc., Colo. Spgs., CO April '98 to Dec. 2000

- Designed charge pump and interface circuits for Flash memory chips as well as baseband circuits for wireless devices (200kHz 3rd order filter, AGC and 12-bit DAC). Designed amplifiers, oscillators, comparator, and level-shift circuits, slew controlled I/O interface circuits and ESD protection used in 2.1 volt, mixed-signal CMOS integrated circuits for automotive applications.
- Developed a novel lateral BJT in a CMOS process for use in a negative voltage ESD isolation circuit (first pass success).

Principal Egr. Mgr., Corp. Tech. Specialist, Ford Microelectronics, Colo. Spgs., Feb. '93 to April '98

- Responsible for the design, development and qualification of three silicon automotive accelerometers (>7M/yr production) including the world's first plastic packaged surface mount airbag accelerometer.
- Hired and managed a product development staff of 15 engineers. Managed a $5M/yr. operating and $2M/yr. capital budget.
- Lead corporate engineer on Ford's worldwide safety system development team. Created and implemented sensor product and wafer fabrication roadmaps for inertial and pressure sensors, GMR position, temperature and mass air flow sensors.

Product Design Supervisor, Corp. Tech. Specialist, Ford Electronics, Dearborn, MI Nov. '89 to Feb. '93

- Initiated an automotive MEMS program by writing funding proposals, business, technology and product plans. Secured $23M in internal funding to establish a MEMS development and manufacturing capability at Ford Microelectronics, Inc.
- Assisted in the design & development sensors, circuits and electronic modules for safety & engine control systems including oxygen, pressure and mass air flowt sensors.

Member Scientific Staff, Bell Northern Research, Ann Arbor, MI April '88 to July '89

- Designed database processor and associative memory IC for TCP/IP-based networks for precursors to the Internet.

Director Research and Development, Integrated Microsystems, Inc., Ann Arbor, MI Sept. '85 to April '88

- Hardware, software and fabrication technology development for neural recording probes and blood oxygen sensors.
- Developed glass substrate pressure and temperature sensors, CMOS and bipolar SOI circuits and their fabrication processes.

EDUCATION

Ph.D.	April 1988,	The University of Michigan, Ann Arbor, MI ('84-'85 IBM Research Fellow)
M.S.E. (E.E.)	Dec. 1983,	The University of Michigan, Ann Arbor, MI
B.S.E. (E.E.)	April 1982,	The University of Michigan, Ann Arbor, MI

PROFESSIONAL and BOARD MEMBERSHIPS

Associate Editor IEEE Journal of Microelectromechanical Systems (JMEMS) (2006 - 2019)
Board Member - Transducers Research Foundation (2008 - 2020)
Institute of Electrical and Electronics Engineers (IEEE), Senior Member (1980 - present)
Surface Mount Technology Association, Member (2018-2020)
International Steering Committee Member - Transducers Conference (2004 - 2012)

UNITED STATES and INTERNATIONAL PATENTS

Janik, J., Brindley, R., Tang, E., Dunlop, J., Spangler, L., *Implantable electrode array assembly including a carrier with packaged control modules,* US Patent 10,525,258.

Janik, J., Brindley, R., Tang, E., Dunlop, J., Spangler, L., *Implantable electrode array assembly with an array substrate,* US Patent 10,342,971.

Janik, J., Brindley, R., Tang, E., Spangler, L., *Sensor Assembly and Method for Measuring Forces and Torques*, European Patent Application 18190347.7-1001.

Janik, J., Brindley, R., Tang, E., Spangler, L., *Sensor assembly and method for measuring forces and torques,* US Patent 10,048,145.

Janik, J., Brindley, R., Tang, E., Dunlop, J., Spangler, L., *Implantable electrode array assembly with an array substrate, electrodes and integrated circuits, the integrated circuits being attached to package substrates,* US Patent 10,046,158.

Janik, J., Brindley, R., Katragadda, R., Tang, E., Dunlop, J., Spangler, L., *Implantable Electrode Array Assembly Including a Carrier for Supporting the Electrodes and Control Modules for Regulating Operation of the Electrodes Embedded in the Carrier and Method of Making the Same.* WO 2011/017426 A2, August 4, 2010.

Brindley, R., Janik, J., Tang, E., Dunlop, J., Spangler, L., *Method of manufacturing an implantable electrode array by forming packages around the array control modules after the control modules are bonded to substrates*, US Patent 9,950,154

Brindley, R., Janik, J., Tang, E., Dunlop, J, Spangler, L, *Implantable electrode array assembly including a carrier with embedded control modules contained in packages…*, US Patent 9,770,582.

J. Janik, R. Brindley, E. Tang, and L. Spangler, *Sensor Assembly and Method for Measuring Forces and Torques*, U.S. Patent 9,274,104.

L. Spangler, K. D. Wise, *Photon Triggered Silicon Controlled Rectifier*, U.S. Provisional Application No. 61/883,789

J. Janik, R. Brindley, R. Katragadda, E. Tang, J. Dunlop, L. Spangler, *Implantable Electrode Array Assembly Including a Carrier, Superstrates Mounted to the Carrier and Electrodes Disposed on the Superstrates,* US Patent 8,554,340.

J. Janik, R. Brindley, J. Dunlop, L. Spangler and E. Tang, *Implantable Electrode Array Assembly with Electrodes that are Integral with the ASICs that Source/Sink current to the Electrodes*, Publication No. EP2512585 A1.

J. Janik, R. Brindley, E. Tang, J. Dunlop, JR., L. Spangler, *Implantable Electrode Array Assembly with an Array Substrate, Electrodes and Integrated Circuits, the Integrated Circuits Being Attached to the Package Substrates*, Application No. 20120330393.

J. Janik, R. Brindley, E. Tang, J. Dunlop, L. Spangler, *Implantable Electrode Array Assembly Including a Carrier for Supporting the Electrodes and Control Modules for Regulating Operation of the Electrodes Embedded in the Carrier, and Method of Making Same*, Application No. 20120310316.

P. Stevenson, C. Stephan, A. Samman, L. Spangler, *Acceleration Sensing Module with a Combined Self-Test and Ground Electrode*, U.S. Patent 5,731,520.

P. Stevenson, C. Stephan, A. Samman, L. Spangler, *Accelerometer with a Combined Self-Test and Ground Electrode*, U.S. Patent 5,587,518.

UNITED STATES and INTERNATIONAL PATENTS (Continued)

L. Spangler, C. Kemp, M. Graf, *Integrated Silicon Automotive Accelerometer and Single-Point Impact Sensor*, U.S. Patent 5,495,414

L. Spangler and M. Graf, *Method and Apparatus for Self-Testing a Single-Point Automotive Impact Sensing System*, U.S. Patent 5,433,101.

L. Spangler, *Boron Doped Silicon Accelerometer Sense Element*, U.S. Patent 5,404,749.

L. Spangler, and K.D. Wise, *Single-Crystal Silicon-On-Insulator Process for Sensors and Circuits*, U.S. Patent 5,343,064.

L. Spangler, *Method for Calibrating a Single-Point Impact Sensor*, U.S. Patent 5,337,260.

PUBLICATIONS and PRESENTATIONS

M.J. George, MD; J. Litvinov, PhD; K. Aroom, MS; L. J. Spangler, PhD, H. Caplan, MD; C. E. Wade, PhD; C. S. Cox Jr., MD; B. S. Gill, MD, *Microelectromechanical System Measurement of Platelet Contraction: Direct Interrogation of Myosin Light Chain Phosphorylation*, Int. J. Molecular Science, Vol. 22, No. 12, June 16, 2021.

M. Gaitan, L. Spangler, et.al., *2019 iNEMI Roadmap for MEMS and Sensors*, International Electronics Manufacturing Initiative, Morrisville, NC, USA, July 2019.

L. Spangler, *Commercialization Opportunities for Printed, Flexible, Stretchable and Functional Fabric Sensors and Sensor-Based Systems for IoT and-Wearables*, 2018 Sensors Expo, San Jose, CA, June 27, 2018.

M. Gaitan, L. Spangler, et.al., *2017 iNEMI Roadmap for MEMS and Sensors*, International Electronics Manufacturing Initiative, Herndon, VA, USA, May 2017.

L. Spangler, *MEMS Packaging for IoT Applications*, Enabling the Internet of Things, 13th Annual MEPTEC MEMS Technology Forum, San Jose, California, May 20, 1015.

L. Spangler, *Wafer-Level Packaging for MEMS and Microsystems*, IWLPC 2014, San Jose, California, Nov 13, 2014

L. Spangler, *35 years of Microsystem Packaging from Automotive to Mobile Electronics and Beyond*, Int. Wafer-Level Packaging Conference: IWLPC 2013, San Jose, California, Nov. 2, 2013.

L. Spangler, *Microfluidic Device Packaging*, IMAPS 2013, Orlando Florida, October 2, 2013.

L. Spangler, *Microsystem Packaging: From High Volume to Specialty Products*, Commercialization of Micro-Nano Systems Conference: COMS 2010, Albuquerque, New Mexico, Sept. 2, 2010.

L. Spangler, *Packaging and Assembly Issues in MEMS, Microsystems and Sensor Products*, Sensors Expo and Conference, Chicago, IL, June 8, 2009

L. Spangler, *Microsystem Packaging, From High Volume to Specialty Products*, BSAC Industrial Advisory Board Meeting, Berkeley, CA, March 12, 2008.

L. Spangler, C. Cleveland, *Material Considerations in MEMS, Microsystem and Photonic Packages*, Material Research Society November 27, 2007.

B. Winkler, L. Spangler, et. al., *An Optical Microsystem for Displays*, 2006 Solid-State Sensor & Actuator Workshop, Technical Digest, Hilton Head, SC, June 2006.

L. Spangler, *Factors Influencing the Design of Microsystems*, 2004 Custom Integrated Circuits Conference, Orlando Florida, October 3-6, 2004. (Invited paper)

L. Spangler, *Assembly Process Issues and Reliability in Microsystem Packaging*, Proceedings of SPIE, Vol. 5343, January 27, 2004, pg 5343-14. (Invited paper)

L. Spangler, *Solutions to Semiconductor and MEMS Packaging Challenges*, Proceedings IMAPS Technical Meeting, Boulder, Colorado, February 5, 2003.

PUBLICATIONS and PRESENTATIONS (Continued)

L. Spangler, C. Kemp, L. Starr, *IC Design for Sensor Interfaces in the Harsh Automotive Environment*, Proceedings of the 8th NASA Symposium on VLSI Design, Albuquerque, New Mexico, October 20-21, 1999.

L. Spangler, *A Delta-Sigma Modulator Circuit*, IEEE Solid State Circuits Society, Workshop on MEMS Interface Circuits, Arlington, VA, October 14-15, 1999.

S. Cunningham, S. Tatic-Lucic, J. Carper, J. Lindsey and L. Spangler, *A High Aspect Ratio Accelerometer Fabricated with Anodic Bonding, Dissolved Wafer and Deep RIE Processes*, Tech. Digest of the IEEE, 10th Int. Conf. on Solid State Sensors and Actuators, Transducers '99, Sendai, Japan, June 7-10, 1999.

L. Spangler, *Integrated Circuit Package Technology for Accelerometers*, NEPCON West '99, Anaheim, CA, February 23, 1999.

L. Spangler, *Plastic Packaging Considerations for Accelerometers*, IMAPS Advanced Technology Workshop, Ojai, CA, January 26-28, 1998.

W. Marc Stalnaker, L. Spangler, et. al., *Plastic SMD Package Technology for Accelerometers*, ISHM '97, 30th International Symposium on Microelectronics, Philadelphia, Pennsylvania, October 12, 1997.

L. Spangler, W. Marc Stalnaker, *Reliability Considerations in SMD Packages for Automotive Sensors*, 4th CDF-AEC Reliability Workshop, Colorado Springs, Colorado, October 9, 1997.

L. Spangler, *Accelerometers for Automotive Passive Restraint Systems*, The Massachusetts Institute of Technology, VLSI Seminar (Invited Speaker), November 19, 1996.

L. Spangler, C. Kemp, *ISAAC (Integrated Silicon Automotive ACcelerometer)*, Sensors and Actuators A, Vol. 54, 1996, pp 523-529.

L. Spangler, C. Kemp, *A Smart Automotive Accelerometer with On-Chip Airbag Deployment Circuits*, 1996 Solid-State Sensor & Actuator Workshop, Technical Digest, Hilton Head, SC, June 1996.

C. Kemp, L. Spangler, *A Delta-Sigma Sensor Interface Circuit*, Ford Automotive Components Division Tech Notes, Spring 1996, pg 15.

L. Spangler, *Smart Sensors for Automotive Applications*, SPIE 1996 Smart Structures and Materials Conf., San Diego California, February 28-29, 1996.

L. Spangler and C. Kemp, *ISAAC (Integrated Silicon Automotive Accelerometer)*, Technical Digest of the IEEE 8th International Conference on Solid State Sensors and Actuators, Transducers '95 Stockholm, Sweden, June 25-29, 1995.

C. Kemp, L. Spangler, *An Accelerometer Interface Circuit*, 1995 Custom Integrated Circuits Conference, Santa Clara, California, May 1-4, 1995.

L. Spangler, *Silicon as a Smart Material*, United States Department of Energy Smart Materials Workshop Report, D. Smyth, Editor, Snowmass, Colorado, August 4-8, 1990.

L. Spangler and K.D. Wise, *A New Silicon-On-Glass Process for Integrated Sensors*, 1988 IEEE Solid-State Sensor and Actuator Workshop, Technical Digest, Hilton Head, SC, June 1988, pg. 140.

L. Spangler, *A Single-Crystal Silicon-On-Insulator Process for Sensors and Circuits*, The University of Michigan Ph.D. Thesis, March 1988.

L. Spangler and K.D. Wise, *A Technology for High-Performance Single-Crystal Silicon-On-Insulator Transistors*, IEEE Electron Device Letters, Vol. EDL-8, No. 4, April 1987.

L. Spangler, *Polysilicon Thin Film Transistors on Glass*, Research Report No.359, GM Research Laboratories, Warren, Michigan, January 1985.

L. Spangler and K.D. Wise, *Pressure and Temperature Sensors for Automotive Applications*, Final Research Report to Ford Motor Company, The University of Michigan, Ann Arbor, November 1984.

CONFERENCE COMMITTEES

Organizing Committee Member, 2016 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2016.

Local Arrangements Chair, 17th Int. Conf. on Solid State Sensors & Actuators, Transducers '15, Anchorage, AK, June, 2015.

Organizing Committee Member, 2014 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2014.

Local Arrangements Chair, 14th Int. Conf. on Solid State Sensors & Actuators, Transducers '09, Denver, CO, June, 2009.

General Chair, 2008 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2008.

Technical Program Chair, 2006 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2006.

TPC Member, 2007 IEEE MEMS Conference Tucson, AZ, Jan. 2007.

TPC Member, 2004 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2004.

Short Course Coordinator, IEEE 11th Int. Conf. on Solid State Sensors & Actuators, Transducers '03, Boston, Mass., June, 2003.

Organizing Committee, 2002 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2002.

TPC Member, 2000 Solid-State Sensor and Actuator Workshop, Hilton Head, SC, June 2000.

TPC Member, IEEE 9th Int. Conf. on Solid State Sensors and Actuators, Transducers '99, Sendai, Japan, June 7-11, 1999.

Short Course Coordinator, IEEE 8th Int. Conf. on Solid State Sensors & Actuators, Transducers '97, Chicago, IL, June 15, 1997.

TPC Member, SPIE Symp. on Micromachining and Microfabrication Process Technology, San Jose, CA, October 22, 1998.

TPC Member, SPIE Symp. on Micromachining and Microfabrication Process Technology, Austin, TX, October 14-15, 1997.

TPC Member, SPIE Smart Structures and Materials Conference, San Diego, CA, March 3-6, 1997.

TPC Member, SPIE Symp. on Micromachining and Microfabrication Process Technology, Austin, TX, October 13-14, 1996.

PROFESSIONAL DEVELOPMENT COURSES TAUGHT

MEMS Products and Technologies, One-day class taught at a Fortune 500 company October 4, 2019.

Integration of Sensors for Flexible, Hybrid, Printed Systems, half day short course at the MEMS and Sensors Technical Congress, Flex 2019, Monterey, CA, Feb. 18, 2019.

Challenges and Solutions for Integration of Sensors with Flexible, Hybrid, Printed Systems, half day short course at the MEMS and Sensors Technical Congress, Flex 2018, Monterey, CA, Feb. 12, 2018.

MEMS Products and Technologies for Emerging Markets, two-day public class taught in Singapore, October 5-6, 2017.

MEMS Products and Technologies for Emerging Markets, two-day public class taught in Penang, Malaysia, October 2-3, 2017.

Microfluidic Packaging, half-day class taught at a major US University, April 4, 2017.

Wafer-Level Packaging for the Functional Integration of MEMS and ICs, half-day class at the 2016 Int. Wafer Level Packaging Conf. (IWLPC), Oct 20, 2016.

MEMS Markets, Product Design and Production, Three-day class at a European government laboratory, Feb 10-13, 2016.

PROFESSIONAL DEVELOPMENT COURSES TAUGHT (Continued)

Wafer Level Packaging for MEMS and Microsystems, Technologies for Size and Cost Reductions, half-day class at the 2015 Int. Wafer Level Packaging Conf. (IWLPC), Oct 15, 2015.

Wafer Level Packaging for MEMS and Microsystems, Challenges and Opportunities, half-day Class at the 2014 Int. Wafer Level Packaging Conf. (IWLPC), Nov. 13, 2014.

Practical Aspects of MEMS and Microsystems Packages, half-day class at the IMAPS Int. Symp., Orlando, Oct. 3, 2013.

MEMS Packaging and Assembly Processes, two-day class at a major US equipment manufacturer, October 22-23, 2012.

Appendix B

Expert Witness History of Leland J. Spangler, Ph.D.

Summary of Expert Witness Engagements

Leland "Chip" Spangler, Ph.D.

Summary of Experience:

I have supported clients as an Expert Witness since September 2013 with matters including patent infringement, trade secret misappropriations, contract disputes, damages claims and injunction hearings.

In the area of patent infringement, I have supported clients at the International Trade Commission, Federal District Court as well as the US Patent Trial and Appeal Board. My clients include both Petitioners as well as Patent Owners. I have supported clients in *Inter Partes* Reviews, including swear behind cases as well as Markman Hearings and Federal District Court matters involving attempts to obtain a Temporary Injunction due to alleged patent infringement.

In the area of contract disputes, I have assisted a client to enforce a settlement agreement and testified at the International Court of Arbitration. I have also supported a client by preparing a cost model for use in a Damages Claim/Lost Profits case. I have also supported a client in US District Court in Trade Secret misappropriation matter.

I also have deep experience in device testing and work with teardown labs evaluating exemplar devices, developing technical construction analysis protocols and interpreting their results. I have performed on-site video inspections to gather information to support my client's position related to patent cases that involved method claims.

Summary of Expert Witness Activity:

Number of Sworn Court Testimonies: 3
Number of Sworn Depositions: 5
Number of Expert Reports filed: 9
Number of Cost Models developed: 1

Detailed Case History

Type: Patent litigation, Temporary injunction, Appeal
Case No.: 2:21-cv-00332-GMN-EJY United States District Court, Nevada
Client: Innova Electronics Corporation (Defendant)
Adverse: Power Probe Group, Inc. (Plaintiff)
Period: October 2021 – December 2023
EW Role: Expert Witness for Non-infringement, Markman support, Court testimony

Type: Patent litigation
Case No.: US ITC 337-TA-1356, International Trade Commission
Client: Lutronic Corporation (Respondent)
Adverse: Serendia, LLC (Complainant)
Period: April 2023 – November 2023
EW Role: Expert witness, Expert report, Deposition, ITC Testimony documentation

Type: Patent litigation
Case No.: US District Court Eastern Texas 2:22-cv-233
Client: ImberaTech, LLC (Plaintiff)
Adverse: Samsung Electronics and Semiconductor (Defendant)
Period: July 2022 – January 2023
EW Role: Consulting expert witness

Type: Patent litigation
Case No.: US District Court West Texas 6:21-cv-00374-ADA (W.D. Tex.)
Client: Western Digital Technologies, Inc (Defendant)
Adverse: Katana Silicon Technologies LLC (Plaintiff)
Period: November 2021 – January 2022
EW Role: Consulting expert witness

Type: Damages claim/Lost profits
Case No.: 16-932C United States Court of Federal Claims
Client: Spectre Corporation (Plaintiff)
Adverse: United States of America (Defendant)
Period: February 2020 – May 2023
EW Role: Expert Witness, Expert declarations, Deposition, Cost model development

Type: Patent litigation
Case No.: US District Court Eastern Texas, Marshall Div. c.a. 2:20-cv-00048
Client: Texas Instruments (Defendant)
Adverse: Bell Semiconductor (Plaintiff)
Period: July 2020 – September 2020
EW Role: Consulting expert witness

Type: Contract dispute
Case No.: 24206/MK, International Court of Arbitration
Client: Nichia Corporation (Complainant)
Adverse: Koninklijke Philips, N.V. (Respondent)
Period: June 2019 – June 2021
EW Role: Expert Witness, Expert Declarations, Deposition, Court testimony

Type: Patent litigation
Case No.: US District Court Delaware. No.1:19-cv-00861-RGA
Client: Invensas Corporation/Xperi (Plaintiff)
Adverse: NVIDEA Corporation (Defendant)
Period: August 2019 – October 2019
EW Role: Consulting expert witness

Type: Trade secret misappropriation
Case No.: US ITC 337-TA-1186, International Trade Commission
Client: Knowles Electronics (Complainant)
Adverse: Bellsing Acoustic Technology (Respondent)
Period: November 2019 – February 2021
EW Role: Expert witness for both invalidity and infringement,

Type: Patent litigation, IPR
Case No.: IPR2020-00708, US Patent Trial and Appeal Board
Client: Tessera Advanced Technologies, Inc. (Plaintiff)
Adverse: NVIDIA Corporation (Defendant)
Period: September 2019 – June 2020
EW Role: Consulting expert witness

Type: Patent litigation, IPR, Swear behind
Case No.: IPR2019-00625, US Patent Trial and Appeal Board
Client: Curt Manufacturing, LLC (Respondent)
Adverse: Horizon Global Americas, Inc. (Complainant)
Period: January 2019 – March 2020
EW Role: Expert Witness for IPR and Swear Behind filings, Filed Expert Reports, Deposition

Type: Patent litigation
Case No.: US District Court Southern California ‘18CV0968 GPCKSC
Client: GoPro, Inc., Robert Bosch (Defendant)
Adverse: American GNC Corp. (Plaintiff)
Period: May 2018 – January 2019
EW Role: Expert witness for both invalidity and infringement,

Type: Patent litigation
Case No.: US District Court Eastern Texas 1:17-cv-00670
Client: Xperi Corporation (Plaintiff)
Adverse: Samsung Semiconductor (Defendant)
Period: November 2017 – November 2018
EW Role: Consulting expert witness

Type: Patent litigation
Case No.: US District Court Eastern Texas, Marshall Div. c.a. No. 16-cv-1453-JRG
Period: September 2017 – 2018
Client: Nichia Corporation (Plaintiff)
Adverse: Vizio, Inc, et. al. (Defendant)
EW Role: Testifying expert, Markman declaration, IPR preparation, Construction analysis

Type: Patent litigation
Case No.: US ITC 337-TA-1010, International Trade Commission
Client: Tessera, Inc. (Complainant)
Adverse: Broadcom, et.al. (Respondent)
Period: March 2016 – December 2017
EW Role: Consulting expert witness

Type: Enforcement of settlement agreement
Case No.: US District Court Northern Illinois, C.A. No. 06 C 6213
Client: Knowles Electronics (Plaintiff)
Adverse: American Audio Component, Inc., et. al. (Defendant)
Period: May 2017 – November 2017
EW Role: Consulting Expert Witness. Construction analysis, Opinion on Interrogatories

Type: Patent litigation
Case No.: US ITC 337-TA-888, International Trade Commission
Client: Knowles Electronics (Complainant)
Adverse: GoerTek (Respondent)
Period: September 2013 – May 2014
EW Role: Testifying Expert for infringement, Consulting Expert for invalidity. Trial testimony, deposition, expert report, video site inspections, functional and construction analysis

* * * *

I declare under penalty of perjury under Section 1001 of Title 18 of the United States code that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true.

Dated: May 30, 2024

Leland J. Spangler, Ph.D.

Leland J. Spangler, Ph.D.

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