Large Volume Manufacture of Dymalloy

RECEIVED

MAR 03 1999

Project Accomplishments Summary CRADA No. TSB-1167-95

OSTI

Date: June 22, 1998

Revision: 4

A. Parties

The project was a relationship between the Lawrence Livermore National Laboratory (LLNL) and Spectra-Mat, Inc.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550

Spectra-Mat, Inc.
100 Westgate Drive
Watsonville, CA 95076

B. Background

The application of high power density electronic components such as fast microprocessors and power semiconductors was often limited by an inability to maintain the device junctions below their maximum rated operating temperature. The junction temperature rise was determined by the thermal resistance from junction to the ambient thermal environment. Two of the largest contributions to this thermal resistance were the die attach interface and the package base. A decrease in the thermal resistance allowed increased component packing density in MCMs, reduction of heat sink volume in tightly packed systems, the use of higher performance circuit components, and improved reliability.

The substrate for a multichip module or device package was the primary thermal link between the junctions and the heat sink. In 1995 at the start of this CRADA, high power multichip module and single chip package designs used substrate materials such as aluminum nitride and copper tungsten alloys that had thermal conductivity in the range of 200 W/mK. A copper alloy and diamond-powder composite material that had a thermal conductivity of 420 W/mK was developed at LLNL. This composite material, Dymalloy, had a coefficient of thermal expansion, nominally 5.8 ppm/C, that was similar to silicon and gallium arsenide. The thermal expansion match allowed the use of hard die-attach methods that reduced the thermal resistance.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LLNL and Spectra Mat had specific scientific and commercial reasons in establishing Dymalloy as a marketable product.

Dymalloy employed a unique process for bonding diamond powder into a copper-silver matrix material. This process involved coating diamond powders in size ranges from 1 to 100 mm, pressing the coated powder into a porous monolith, sintering the porous monolith, and infiltrating with the desired copper alloy. Various parts of the Dymalloy process found unique applications in the materials needs of other programs at LLNL. A modified Dymalloy process was used to fabricate a revolutionary type of porous electrode for solid oxide fuel cells. This technology, described in invention disclosure IL-9451, was the central technology in several energy and transportation proposals. The laboratory-scale equipment developed for coating diamond powder was modified to develop a process for fabricating beryllium fuel capsules for ICF experiments at the National Ignition Facility (NIF) at LLNL.

Developing Dymalloy to its full potential required the knowledge of the diverse thermal transport mechanisms between phonon and electronic conduction in ceramics and metals. Understanding these phenomena became more apparent when estimates of the composite thermal conductivity were 1.5 to 2 times larger than the measured thermal conductivity. This discrepancy implied a research opportunity that would be viewed more favorably if Dymalloy were a successful commercial product.

A second scientific optimization problem was to determine the parameters that enhanced the manufacturing techniques of producing high thermal conductive Type 1 diamond powders. This basic research included measuring the physical properties of powder material and verifying scaling laws for powder physical properties. The research efforts in this area would be enhanced if Dymalloy were commercially available.

C. Description

The purpose of this research was to test the commercial viability and feasibility of Dymalloy, a composite material to measure thermal conductivity.

Dymalloy was developed as part of a CRADA with Sun Microsystems. Sun Microsystems was a potential end user of Dymalloy as a substrate for MCM's. Sun had no desire to be involved in the manufacture of this material.

The goal of this small business CRADA with Spectra Mat was to establish the high volume commercial manufacturing industry source for Dymalloy required by an end-user such as Sun Microsystems. The difference between the fabrication technique developed during the CRADA and this proposed work related to the mechanical technique of coating the diamond powder.

Mechanical parts for the high-volume diamond powder coating process existed; however, they needed to be installed in an existing coating system for evaluation.

Sputtering systems similar to the one required for this project were available at LLNL. Once the diamond powder was coated, both LLNL and Spectra Mat could make and test the Dymalloy composites. Spectra Mat manufactured Dymalloy composites in order to evaluate and establish a reasonable cost estimate on their existing processing capabilities. This information was used by Spectra Mat to define the market and cost-competitive products that could be commercialized from this new substrate material.

LLNL and Spectra Mat established the following goals for this cooperation:

1. Establish the manufacturerability for Dymalloy
2. Collaborate and investigate techniques that would reduce the laboratory process of making Dymalloy into a suitable manufacturing process
3. Advance the state-of-the-art in thermal management of high power microelectronics components
4. Open new markets for this technology

Division of Responsibilities Between The Lab and Its Partner

The division of labor took advantage of each partners' relative strengths at the beginning of this project.

LLNL planned to demonstrate the capability of coating large volumes of diamond powder, 10 to 100 grams per batch. LLNL and Spectra Mat wanted to evaluate this high-volume prototype powder coating process and the fabrication steps needed to establish base costs for manufacturing Dymalloy.

Spectra Mat identified practical problems and facility issues associated with the manufacture of Dymalloy, and both LLNL and Spectra Mat applied technical solutions to solve those issues. Spectra Mat, with multi-customer contacts and the ability to provide prototype material samples, verified the commercial need for Dymalloy and estimated the potential market demand for this product and related products manufactured by the Dymalloy process.

<u>Task</u>	<u>Responsibility</u>
1. Install powder coating prototype in existing Sputter coating system	LLNL
2. Test and Demonstrate large volume diamond coating capability	LLNL and Spectra Mat
3. Build Dymalloy composite from coated diamond	LLNL and Spectra Mat
4. Evaluate potential market	Spectra Mat

D. Economic Impact

Dymalloy substrate material had potential markets in space based electronic components, high performance microwave circuits, personal computers, automobile computers, and other military and private industry applications.

Industrial Partner

Spectra Mat is a small high-tech company that was committed to developing new products such as Dymalloy to utilize existing manufacturing capabilities created by changes in market opportunities for their current products. Spectra Mat was the ideal industrial partner for commercializing Dymalloy technology because they were primarily involved in the manufacture of high-tech products. They had underutilized manufacturing capacity. They manufactured porous tungsten components, and they had experience infiltrating porous materials. Our initial contact with Spectra Mat resulted from a description of the Dymalloy technology provided in a press release.

Dymalloy represented a new product for Spectra Mat. The company produced ion sources, tungsten copper products for substrate materials and heat sinks, custom engineering of porous ceramics, and high temperature furnaces for brazing applications. The products provided by Spectra Mat made it a prime candidate for the commercialization and manufacture of Dymalloy.

The U.S. Economy

The microelectronics industry is a very competitive worldwide industry. In 1995, Japan was the dominant vendor for microelectronics thermal management material, controlling 95% of the market. The continuing trend in the microelectronics industry was building faster and more powerful microelectronics circuits. High performance circuit design was limited by the capability to remove heat generated at the electronic device junction. An improvement in the ability to cool junction temperatures would significantly impact the microelectronics industry.

We believed Dymalloy was a substrate material that would meet the physical demands to cool device junctions. The aerospace and automobile industries also had immediate uses for this material. If Dymalloy became commercially available through U.S. manufacturers, the immediate impact would be related to the microelectronics and aerospace industries. The number of jobs directly related to the manufacture of Dymalloy substrates depended on the demand. Typical estimates for the substrate material ranged from 100,000 per year to 100,000 per month for the electronics industry depending on substrate costs, and 40,000 to 60,000 per year for the automobile industry. Other jobs in the microelectronics industry relating to device package design, development, and manufacture probably remained the same or possibly increased because of the use of Dymalloy. Helping these industries had a positive effect on the U.S. economy.

We believed the Dymalloy technology could be applied to develop other composites and materials that would have potential future use, such as porous fuel cells. One application for fuel cells was in the electric car that is the leading replacement the present gasoline powered vehicle. Fuel cells with these unique porous electrodes would have a direct impact on the automobile industry in the U.S.

E. Benefits to DOE

The development of Dymalloy composite was a materials related problem. The development relied on the capabilities of the Chemistry and Materials Department Physical Vapor Deposition group. The effort produced Dymalloy, single layer diamond grinding tool, porous electrodes for solid oxide fuel cell studies, and beryllium fuel capsules for ICF experiments at NIF. We believed improvements in the physical properties of Dymalloy could involve research in the relation between phonon and electronic heat transport in interface regions. Subsequent samples would produce from results of interface improvements would be tested at LLNL.

The Spectra Mat project was not the success that we envisioned. Although we had the equipment here at LLNL to demonstrate large production of coated diamond powder, and we readily set it up, the physics and chemistry of the process did not work as expected. The project used a wheel, similar to a clothes dryer, to lift the powder up and then the powder would drop through a plasma region, generated by our sputter coating gun, to coat the powder with a tungsten or other carbide formers. We did not anticipate that the powder would charge and be pushed out horizontally from its free fall path. This problem slowed our progress and made it difficult to make a large quantity of powder. By the time we discovered and verified this problem we had invested over three man-months of effort into the project. This effort equaled the amount of money given to us by SBA. Spectra Mat did the market research and was setting up to braze samples that we planned to supply them from our powder coating process. Companies were eager to test the product

but our present design did not produce the quantities needed. We thought of alternate techniques but could not find the funding to pursue the new ideas.

F. Industry Area

We believed the technology would have benefited these industries:
Microelectronics, aerospace, electronics, microwave, computers, automotive

G. Project Status

This project was completed in May 1996.

H. LLNL Point of Contact for Project Information

LLNL was represented by John Kerns, (Principal Investigator, L-287
925/422-9586; 925/422-6747 from the Engineering Directorate.

I. Company Size and Point(s) of Contact

Spectra Mat, Inc. was represented by Jim Abendscham, President, 408/722-4116
x-304 and Richard Petznick 408/722-4116 x- 331; 408/722-4172 (fax for both).
Company sales are approximately \$5.0 million, and the company employs
<100 people.

J. Project Examples

Technical information about the properties studies and a final report were
developed and delivered.

K. Subject Inventions

This small value contractual mechanism did not anticipate any generation of Intellectual Property (IP) including subject inventions.

L. Release of Information

I certify that all information contained in this report is accurate and releasable to the best of my knowledge.

fr Norma E Dumpice
Karena McKinley, Director
Industrial Partnerships
and Commercialization

2/10/99
Date

Release Of Information

I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

Jim Abendscham
Jim Abendscham, President
Spectra-Mat, Inc.

21 Jan 99
Date

Ms. Mckinley Please
send ~~me~~ a signed
copy for our files.

Also is a return if
we post some or part of
this information on
our web page?

1-21-99

"An Employee Owned Company"

SPECTRA-MAT, INC.

Jim Abendschan
President

MATERIALS • COMPONENTS • EQUIPMENT
ELECTRONICS AND AEROSPACE INDUSTRIES
100 Westgate Drive, Watsonville, CA U.S.A. 95076
Phone: 831.722.4116 Ext. 304 / FAX: 831.722.4172 / Pager: 408.682.5975
Web: www.spectrimal.com E-Mail: jpa@jimmed.com