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Project Accomplishment Summary

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Sandia National Laboratories
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Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1573.106)

between **Sandia National Labs** and **Lockheed Martin Corporation**

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Sol-Gel Processing for High Power Fiber Arrays (CE&T) SV

Final Abstract:

This document serves as the final report for the Lockheed Martin Shared Vision project – "Sol-Gel Processing for High Power Fiber Arrays." The goal of the program was to establish an inorganic replacement for epoxy used to bond high optical power fiber optic assemblies. Sandia considered four distinct chemistries as possible bonding agents, and evaluated each against the system requirements and constraints as relayed by Lockheed Martin. Of the solutions we investigated, we chose an alkali-silicate based glass system. This chemistry offered adequate structural bonding using a simple deposition method. In addition, material characterization showed good thermal stability and optical properties. The similarity of the silicate bonding process to the current epoxy method and the off-the-shelf availability of the precursor combined to make the silicate chemistry the best inorganic choice as a bonding agent for these high power fiber optic assemblies.

Background:

The goal of this program was to establish an inorganic replacement for the epoxy used to bond high power optical fiber assemblies. For low power applications organic epoxy is commonly used to bond fibers. The concern was that under high power operating conditions absorption in the organic epoxy would lead to heating, charring and eventual failure of the bond. By switching to an inorganic bond the possibility of charring is reduced. Furthermore, several silica (SiO_x) based chemistries exist, with the potential of creating a bonding material with similar optical properties as the optical fiber. Sandia was tasked with identifying several possible inorganic boding agents and identifying the optimal chemistry for use in this high power application.

The fibers have a 400-micron cladding OD surrounded by a fluoro-acrylate coating. The acrylate coating has a maximum temperature of 80 °C before it begins to degrade, so this places a limit on possible processes used in array bonding. In operation, the temperature around the coating must also be kept below 80 °C, however, local temperatures around the area of the bond could be as high as 120 °C. The bonding agent must be able to join the silica fiber to the holder. Furthermore, the bonding agent must fill or at least accommodate the void space formed around the fiber.

Description:

The goal of the program was to establish an inorganic replacement for epoxy used to bond high optical power fibers. Sandia considered four distinct chemistries as possible bonding agents, and evaluated each against the system requirements and constraints as relayed by Lockheed Martin. Of the solutions we investigated, we chose an alkali-silicate based glass system. This chemistry offered adequate structural bonding using a simple deposition method. In addition, material characterization showed good thermal stability and optical properties. Dense cured films of potassium silicate have an index of refraction at 1064 nm of 1.470 while dense cured films of sodium silicate have an index of refraction of 1.462. Commercially available, off-the-shelf solutions of alkali silicates can be diluted with water in a 1:1 ratio, and applied directly to the fiber array, and dried at room temperature to yield good bond strength. The silicate bond can be further cured for extended times at 70 °C in order to provide increased resistance to bond failure at elevated temperatures. The bonds do show evidence of micro-cracking and porosity, observable by eye as a clouding of the bond. This clouding is most pronounced in thick areas of the film, but can be controlled to some degree by controlling the amount of silicate used. It should be noted, however, that in all of our qualitative fiber bond strength tests, not a single fiber de-bonded regardless of the degree of clouding. The similarity of the silicate bonding process to the current epoxy method and the off-the-shelf availability of the precursor combined to make the silicate chemistry the best inorganic choice as a bonding agent for these high power fiber optic assemblies.

Although the conclusion of this report is that the alkali silicate solution is the best choice as an inorganic replacement for the organic epoxy, this does not mean that the other solutions we considered will not work. In fact the lines distinguishing the techniques begin to blur when the bonding mechanisms are analyzed on the microscopic scale – in every method, we are attempting to get the O-Si-O monomers in the fibers fibers to connect via O-Si-O monomers supplied in solution. To some, a solution with 1-5 nm silica particles is considered a colloidal solution, while others refer to it as a solution with 1-5 nm aggregates of silicate dissolved in solvent. It is possible that a less compressed program could yield a hybrid bonding approach, combining the strengths of each of these chemistries to yield a bond with superior qualities to the straight silicate solution, but it will be difficult to surpass the preparation, deposition and bond strength of commercially available alkali silicates.

Benefits to the Department of Energy:

This project met its goals on time and within budget. The broader joint SNL Lockheed Martin Shared Vision program has established benefits to the DOE. Since this program is a part of that larger program, it carries with it the same benefits. More specifically to the work performed, the project allowed SNL material expertise developed under DOE work to be leveraged by Lockheed Martin for potential WFO.

Economic Impact:

Because this was a feasibility study for replacing organic bonding agents with inorganic bonding agents as a risk mitigation step, quantifying the economic impact is difficult. The final product is years away from market and aside from developing this small material answer, SNL was/is not involved in the system level product.

Project Status:

The Sol-Gel Processing for High Power Fiber Arrays project is complete. A final report and presentation on our findings was delivered to Lockheed Martin prior to the close of the program.

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

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Company Size and Points of Contact

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CRADA Intellectual Property

None

Technology Commercialization

Since this was a feasibility study involving commercially available materials, no commercialization effort is intended.

Project Examples

No examples exist. We did file a final report.

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Cooperative Research and Development Agreement (SC99/01573.106)
between **Sandia National Laboratories** and **Lockheed Martin Corporation**

This summary has been approved for public release by Sandia and Lockheed Martin Corporation

Sandia National Laboratories

By______________________________ 4/23/2013
Bruce Burckel Date
Principal Investigator

Sandia National Laboratories

By______________________________ 4·15·13
Manager Date
WFO/CRADA Agreements

Lockheed Martin Corporation

By______________________________ 6/13/13
Title: LM Principal Investigator Date

In order to expedite the process, if we do not receive your signed reply by 06/23/2013 we will assume your concurrence for the release of this document to the public.