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DIAMOND HEAT SINKS FOR ELECTRONIC CIRCUITS*

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Progress Report, September 1990

Abstract and Executive Summary:

During the interim stage of this Phase I R&D, a useful metallizing procedure for bulk diamond has been developed, with natural diamond chips, granules, and polished wafers from two vendors. Small-scale statistical experiments were designed and executed by systematically varying several material and processing variables including: metallizing and brazing compositions, processing temperature and time, ambient control, and other procedural changes.

Under selected combinations of these variables, metallizing of these diamond samples was achieved. Surface wetting appears to be excellent. The metallized surfaces were brazed or soldered to metal for future heat sink uses in high-power electronic circuits.

These results clearly demonstrate the proof of the principle that is our main objective in Phase I.

The remainder of the Phase I work will be directed to metallizing and brazing polished diamond wafers to metal (copper and/or Kovar) substrates; detailed sample characterization inlcuding SEM, microstructural and microprobing analyses; thermal conductance measurements of mounted diamond wafers; and analyzing all results for the final report.

*This project is sponsored by SDIO/IS and managed by ONR Contract Number N00014-90-C-0143

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Additional Metallizing Process Development

Single-step metallizing and brazing is high desirable because it simplifies processing, minimizes diamond damage, and improves product quality, yield, and cost. Single-step diamond metallizing and brazing directly to copper substrate was tried and also successful. Copper does not statically match common semiconductor materials as well as Kovar. But the former has much higher thermal conductivity, which is needed for superior heat sinks. As to matching, Lintel's previous work has shown that dynamic matching is far more important than the conventional static matching criterion. The softness and thermal conductivity of copper is very efficient in minimizing dyanmic mismatch stresses and strains. An invited paper on "Graded Metal-Ceramic Microjoints in Parallel", with emphasis on graded copper alloy preforms for electronic and high T_C superconductor packages, is to be given by the PI at the Detroit 1990 AIME Fall Meeting on October 9, A.M. See enclosed abstract of the paper. With our many new approaches, Lintel has already made a variety of highly "unmatched" metal-ceramic joints that are exceptioanally strong and thermomechanically shock-resistant.

Special Equipment

A special equipment has been made for mounting the diamond chip or wafer brazed or soldered onto metal substrate, applying heat on the top diamond surface, and continuously monitoring the absolute temperatures and temperature differential between the substrate and top surface. For sensitivity, mil-size Constantan-Copper thermocouples have been prepared for these measurements.

Phase II Project

Because of the short duration of this Phase I work, our diamond metallizing/brazing processes almost certainly could be further substantially improved, both in product quality and process reproducibility. Our detailed sample characterization in Phase I will guide us in such improvements. In addition, interactions with potential military and commercial users will supply product specifications for different electronic circuits. We await further development in our Phase II for more and larger-scale systematic experimentation, comprehensive product characterization with iterative feed-backs, testing of new ideas such as microcomposite bonding regions for extra strength and thermal resistance, and material/process fine-tuning and optimization.

Invited Paper
For the 1990 AIME Fall Meeting
Metal-Ceramic Joining Symposium

In Journal of Metals, July 1990, p. Fall Meeting 31

ABSTRACT

GRADED METAL-CERAMIC MICROJOINTS IN PARALLEL*: C.H. Li

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A basic worldwide problem in metal-ceramic joining is the mismatch in thermal expansion coefficient. This problem limits the use temperature of joints to 600^{o}C. The commonly used mismatch expansion criterion relates to the static case, and does not apply in most actual service. Computed results show that dynamic mismatch, not static mismatch, usually leads to joint failures. To minimize dynamic mismatch stresses, we have designed microjoints in parallel which are graded laterally, namely,from the center to the periphery of the bonding interface region, in stiffness, thermal conductivity, and/or thermal expansion coefficient. All present graded seals, microjoints in series, vary only the expansion coefficient axially from metal to ceramic, to reduce static mismatch stresses. Our laterally graded seals are useful for mounting fragile Si, GaAs and high T_c superconductors onto metal substrates for improved performance, bond strength, & heat transfer.

*DOE contract DE-AC02-86ER80382 partly supported work.