CVD Diamond Substrate for Microelectronics

Federal Manufacturing & Technologies

Jan Burden, FM&T, and
Dr. Roy Gat, Applied Science and Technology, Inc.

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AlliedSignal
AEROSPACE

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PROJECT ACCOMPLISHMENT SUMMARY

CVD Diamond Substrate for Microelectronics

BACKGROUND:

Chemical Vapor Deposition (CVD) of diamond films has evolved dramatically in recent years, and commercial opportunities for diamond substrates in thermal management applications are promising. The objective of this technology transfer initiative (TTI) is for Applied Science and Technology, Inc. (ASTeX) and AlliedSignal Federal Manufacturing and Technologies (FM&T) to jointly develop and document the manufacturing processes and procedures required for the fabrication of multichip module circuits using CVD diamond substrates, with the major emphasis of the project concentrating on lapping/polishing prior to metallization. ASTeX would provide diamond films for the study, and FM&T would use its experience in lapping, polishing, and substrate metallization to perform secondary processing on the parts. The primary goal of the project was to establish manufacturing processes that lower the manufacturing cost sufficiently to enable broad commercialization of the technology.

DESCRIPTION:

Major responsibilities for ASTeX: Diamond films were grown at ASTeX using various reactors and formulas. Methods to optimize diamond growth without sacrificing material properties were investigated. Initial diamond films for this project were grown on 2-inch-diameter silicon substrates; all diamond received after the initial shipment was grown on 2-inch-diameter molybdenum substrates.

Major responsibilities for FM&T: Characterization of the diamond films would serve as the basis for the remaining work at FM&T. Understanding the effects of the dimensional and material variations on subsequent processing would be used to further optimize growth conditions at ASTeX. Polishing methods for the diamond would be established to provide smooth surfaces for secondary processing, which includes application of metallization.

Accomplishments: A number of diamond films were produced by ASTeX to characterize the growth process. Variations in deposition rate by changing temperatures and pressures at which the diamond was deposited were studied for the effects on the diamond and substrate quality. Films were grown on silicon and molybdenum substrates and the subsequent diamond attributes compared.

Dimensional inspection revealed warpage or "bow" of the substrate which, in most cases, was too severe for FM&T to conduct polishing or lapping of the diamond. Fluorescent penetrant inspection was performed on the diamond to detect cracks. The dimensional inspections and penetrant work were performed at FM&T and were helpful to ASTeX in revealing size and location of various microcracks.

Diamond which was grown slowly on molybdenum substrates appeared to be the least stressed of the various combinations which were investigated. The slow growth relieved some stress in the diamond, causing less "bow" in the as-grown substrate and diminished cracking.

Diamond films were subjected to production FM&T processes for metallization with good results. ASTeX showed the samples to a number of packaging firms which were impressed with these results. Standard processes for application of Ta_2N, Ti, Pd, and electroplated Au were used to apply an edge monitor pattern. The initial growth side of an as-deposited substrate was used, as the initial growth surface is smooth, mirroring the substrate on which it is grown. (Polished samples of acceptable quality and integrity were not available.) The pattern used had 0.040" pads, and 0.005", 0.002", and 0.001" lines.

Project challenges: The warping of the as-grown diamond was an area of major concern. Significant "bow" in the as-deposited material made most of the samples provided unsuitable for lapping/polishing experimentation. However, the process changes required to alleviate these conditions appear to be those which slow the growth rate and which work inversely with efforts to decrease the cost of manufacturing diamond.

Polishing and lapping work must be conducted in greater detail; however, acceptable as-grown diamond must be available for FM&T with which to do the work.

BENEFITS TO DOE:

Thermal management capabilities in microelectronic packaging technology will be needed for next-generation weapons. This project illustrates the potential of diamond substrate and also points out the need for development in the material science of growing diamond films. Additional work will be required in the diamond growth and processing fields before the advantages of this material can be realized.

ECONOMIC IMPACT:

There is no economic impact generated by this project; rather, the need for additional research is indicated.

PROJECT STATUS: Terminated

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