

Public Abstract

First Name:Paul

Middle Name:Edward

Last Name:Mason

Adviser's First Name:Mark

Adviser's Last Name:Prelas

Co-Adviser's First Name:

Co-Adviser's Last Name:

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Title:Large-Area Single-Crystal Diamond Films Via Hot Filament Chemical Vapor Deposition

Production advances have spurred further investigation into identifying properties of synthetic diamond films in high-purity form. These properties have provided evidence that films of exceptionally high quality can be used as a heat sink, as a sensor material in electro-chemistry, and as a neutron sensor. This discussion focuses on purposing a diamond film production method that may be used as a sensor material. To be utilized as a sensor material competitive with existing neutron detectors, these diamond films must be single crystals that are nearly completely free of lattice defects; possess high electron and hole mobility; demonstrate a high response rate to neutron interactions; and be comprised of sufficient cross section to interact with a large number of incident neutrons.

The notion of producing diamond films for this purpose is gaining significant ground. As can be seen in the recent experiments at CERN (European Organization for Nuclear Research), Element Six® diamond crystals were used as detection media during the Higgs Boson experiments. Other sensors have been created in which small diamond wafers were multiplexed into a larger detection cross-section through parallel wire bonding. Aside from multiplexing, which is challenging from a cost and fabrication perspective, the resulting cross sectional area is the most significant limitation with using these wafers as sensors. Realistically, the largest diamond film that can be purchased commercially as a neutron detector is a square chip 3.5 mm by 3.5 mm by 0.5 mm thick. However, while prohibitively expensive for commercialization, there are crystals with cross sections as large as 1 cm². Improving the probability of interaction of diamond with neutrons can be accomplished by increasing the cross sectional area of the film. The current research effort is aimed at producing a single-crystal diamond wafer that is 5 cm in diameter by 200 μm thick utilizing Hot Filament Chemical Vapor Deposition (HFCVD). This is a twenty-fold increase in cross-sectional area and therefore, an increase by the same amount in the probability of interaction with incident neutrons. Two hundred micrometers is estimated as the minimum thickness required for a resultant semiconductor grade wafer that can be used as a substrate in Microwave Plasma-Assisted Chemical Vapor Deposition (MPACVD).

The use of Hot Filament Chemical Vapor Deposition (HFCVD) resulted in a large-area single-crystal diamond wafer measuring 4.4 cm in diameter, 370 μm thick by using a 90/10 platinum/iridium foil substrate coated in a mixture of 0-2 μm and 5-8 μm natural diamond powder. This was covered with a 5 cm diameter boron nitride ring to alter the incoming gas flow to the optimum velocity necessary for growth. Diamond nucleation and subsequent homoepitaxial growth formed on the diamond seed crystals. Growth began near the ring and progressed symmetrically and radially inward. Coalescing nucleation points from the Pt/Ir foil and seed crystals merged without visible distinction between the individual structures. Diamond growth mimicked the surface topography of the foil and piping (μm-sized holes) was present in the final film. Optical and microanalysis were used to determine that the entire 4.4 cm diameter underside of the film is one crystal.