Nucleation, Growth and Doping of Nanocrystalline Diamond Films

Williams O.A.

Institute for Materials Research, Hasselt University, Belgium
and IMEC vzw, Division IMOMEC, Belgium

Nanodiamond or nanocrystalline diamond are broad terms used to describe a plethora of materials. It is generally accepted that nanocrystalline diamond (NCD) consists of facets less than 100 nm in size, whereas a second term “ultrananocrystalline diamond” (UNCD) has been coined to describe material with grain sizes less than 10nm. The key difference in these materials originates in the growth process, where NCD films are grown with conventional hydrogen rich plasmas and UNCD with hydrogen poor chemistrys. Reducing the concentration of hydrogen in the plasma leads to re-nucleation processes, allowing for smaller grain sizes, but with the inevitable trade off of higher sp^2 levels.

The contrasting surface to volume ratios of these two kinds of nanodiamond have profound effects on the carrier transport phenomena. NCD films with larger grain sizes and lower grain boundary volume fractions show transport characteristics very similar to that of microcrystalline and monocrystalline diamond films. When undoped they are highly resistive and transparent. Doping with boron leads to conventional valence band conduction followed by hopping and metallic conduction at high boron levels. At very high boron levels this material can be superconductive at very low temperatures (<4K). Very heavily doped NCD is significantly more absorbing and small sp^2 bonding contributions are visible in the Raman spectra.

UNCD films demonstrate considerably different conductivity behaviour due to their significant sp^2 concentrations. UNCD is an absorbing material, and its optical signature betrays its complicated band structure. Intrinsic UNCD can be highly resistive, but not of the order of NCD. When grown with added nitrogen, the conductivity increases dramatically due to an increase in the desnity of states associated with π bonding.

In this work we will compare the growth and contrasting properties of these two complimentary materials. We will demonstrate ultra high nucleation densities by seeding substrates with a monodisperse nanodiamond colloid. This allows the growth of films thinner than 50 nm with no pinholes or voids. The possible applications of each type of nanodiamond will be discussed.