

### **349c Electronic Properties of (Ultra) Nanocrystalline Diamond Films**

*Oliver A. Williams*

Nanocrystalline diamond (NCD) films and Ultrananocrystalline diamond (UNCD) films are unique forms of carbon with grain sizes of less than 500nm. NCD is generally considered to be a form of poly/microcrystalline diamond grown with a high nucleation density to allow the preparation of thin coalesced films with small grain sizes. Thus this material maintains its columnar structure, but can be extremely smooth if the films are grown thin. UNCD has no analogy with conventional columnar structured diamond due to the very high renucleation rate of its growth process, which results in very small (3-5nm) grain sizes.

Both of these materials have applications in Micro/Nano-Electromechanical Systems (MEMS/NEMS), microfluidics, SAW devices, electrochemical electrodes, low friction tribological coatings, optical coatings etc where the high roughness of thick polycrystalline material is undesirable. For many of these applications the control of electrical conductivity and associated optical properties is vital for the commercial exploitation of these films.

This work addresses two mechanisms of conductivity. As NCD is basically conventional diamond, it can be p type doped by the addition of boron in to the gas phase. This results in an activation energy of 0.37eV, and can be controlled from intrinsic to metallic conductivity. UNCD films can be made n type and conductive by the addition of nitrogen into the gas phase. However, this process is not a form of conventional doping and is related to mid gap states in the diamond film. Transmission studies of boron doped NCD and nitrogenated UNCD show very high adsorbtion within the bandgap of nitrogenated UNCD and very high transmission in boron doped NCD. Hall Effect measurements confirm nitrogenated UNCD as n type with very low activation energy and the boron doped films as p type. Both mechanisms can control conductivity form near intrinsic to metallic behaviour.

These two very different materials have equally different applications. For instance, nitrogenated UNCD can be used in a heterostructure to make a highly stable rectifying contact whereas thin boron doped NCD can yield highly conductive optical coatings with high visible transmission on quartz.