Institute of Physics of the Czech Academy of Sciences

SEMINAR

Department of Functional Materials

23. 06. 2022 at 10:00

Main hall of the FZU building, Na Slovance 1999/2, Prague 8

Oliver A Williams

Cardiff School of Physics and Astronomy, Condensed Matter and Photonics Group, UK

Diamond – material of last resort?

Diamond has several extreme properties such as the highest Youngs modulus, thermal conductivity, electrical resistivity of all materials etc, that make it very attractive for a plethora of applications ranging from cutting tools to single photon sources. Unfortunately, due to the phase diagram of carbon, diamond forms under pressures higher than 100K bar and temperatures greater 2000K within the Earth. These conditions have been reproduced under laboratory conditions but are almost impossible to scale up to the large areas required for many applications. Diamond remains one of the hardest materials to grow synthetically.

Chemical Vapour Deposition of diamond was first accomplished around the same time as high pressure synthesis. This technique dissociates hydrogen and methane under high temperature plasmas to create atomic hydrogen and methyl radicals. The methyl radical acts as a building block for diamond growth, with non-diamond carbon being suppressed by the extremely aggressive atomic hydrogen background. This is a metastable process that can be difficult to control. However, thin diamond films can now be produced on substrates such as silicon with Young's modulus as high as 1100 GPa and with unrivalled high thermal conductivity.

In this work the production of high-quality diamond films for Micro-Electro-Mechanical Systems and Surface Acoustic Wave (SAW) devices will be demonstrated. Nucleation of diamond on foreign substrates, control over the CVD growth process, Chemical Mechanical Polishing and device fabrication will be discussed. Integration with materials such as AlN and GaN will be discussed as well as the production of single photon centres based on colour centres such as NV and SiV. Superconducting and non-superconducting MEMS / SAW devices will be demonstrated with frequency-Q products as high as 10^{14} Hz.

***Professor Oliver A Williams** established the Cardiff Diamond Foundry, the largest diamond growth group in the UK. His group focuses on MEMS, superconductivity, single photon sources, high frequency filters, thermal management and anything that exploits the extreme materials properties of diamond. He currently holds a Personal Chair in Experimental Physics.*

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Cardiff School of Physics and Astronomy, Condensed Matter and Photonics Group, UK

An overview of Chemical Mechanical Polishing of Diamond

Advances in growth technologies have made it possible to grow nanocrystalline diamond (NCD) over large area on non-diamond substrates. NCD films are polycrystalline in nature, but retain all the superlative properties of single crystal diamond such as superhardness, superconductivity, high thermal conductivity and biocompatibility. Such properties make NCD an excellent material for fabricating ultrasensitive and quantum devices, e.g., MEMS and SQUIDs for a variety of applications. However, the downside of NCD is its inherent surface roughness, which can lead to reduced sensitivity. While the polishing of single crystal diamond or thick polycrystalline film is well developed, these techniques cannot be used to polish NCD. This is primarily due to wafer bow due to large differences in thermal expansion coefficients between NCD and the substrate (e.g., Si). To get around this problem we have developed a chemical mechanical polishing technique capable of generating smooth NCD surfaces. The process is based on a similar process used in the silicon industry for polishing metal interconnects. In this process NCD is polished using a silica based slurry in contact with a soft polyurethane pad. Using this process, we were able to reduce the roughness from 18.3 nm to 1.7 nm RMS over an area of 25 μm^2 on a 360 nm thick NCD film. Furthermore, this technique can remove polishing tracks from both (100) and (111) single crystal diamond. Initial experiments were carried out using silica-based slurries and following experiments with other oxide (ceria and alumina) based slurries. Both slurries were able to polish thin NCD films. We observed that the pH of the slurry has minimal effect on polishing, while an inverse relationship exists between the abrasive particle diameter and polishing rate. A loss in superconductivity in boron doped diamond after mechanical polishing has previously been reported, however in this reported technique no loss in superconductivity was observed.

Finally, to study chemical aspects of the technique, we explored the effects of the addition of strong redox agents to the polishing fluid on the roughness reduction rate of NCD films. A series of NCD films were polished for 4 h and the roughness monitored by AFM after each hour. The base slurry used for polishing was colloidal silica SF1 from Logitech, which could reduce a nominal as-grown NCD RMS roughness of ~24 nm to ~2 nm RMS over 25 μm^2 within 4 hours of polishing. Various redox agents such as hydrogen peroxide, ferric nitrate, potassium permanganate, oxalic acid and sodium thiosulfate were added to SF1 to study their effect on polishing rates. Oxalic acid produced the fastest polishing rate while hydrogen peroxide had very little effect on polishing possibly due to its volatile nature. XPS after polishing revealed little difference in the surface oxygen content, this is a possible indication that the addition of redox agents does not increase the density of oxygen containing species on the surface, but rather accelerates the process of attachment and removal of Si or O atoms on the diamond surface.

__Dr Soumen Mandal__ is a Post-Doctoral Research Associate working in School of Physics and Astronomy at Cardiff University, U.K. in the group of Prof. Oliver Williams. His current research interest is the study of diamond as a material for device applications.