Towards Low Stress, Quantum Grade Diamond Grown via Chemical Vapor Deposition

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1. Introduction

The performance of nitrogen-vacancy (NV) center diamond is fundamentally based on the crystalline properties of the substrate and N-doped epitaxial layer. The crystallinity of the substrate and epi-layer in terms of lattice curvature, extended defect concentration and chemical purity determines the baseline characteristics of the final devices, which have immense potential to impact a variety of magnetic field and electric field sensing applications. Nitrogen-doped diamond sensing technologies are enabled by the negatively charged NV- center in diamond which has a spin state that can be optically probed and manipulated. The extreme sensitivity of this spin-state to magnetic fields allows for unprecedented capabilities in magnetic and electric field sensing.

In this presentation, we report on the growth and characterization of high purity (Type IIa) diamond substrates and N-doped epitaxial layers for quantum applications. Free-standing substrates grown using microwave plasma-assisted chemical vapor deposition (CVD) technique are assessed using cross-polarized and quantitative birefringence, x-ray diffraction and x-ray topography. Results are compared to the starting seed substrates, produced using the high-temperature, high-pressure method (HPHT). Quantitative birefringence shows a strain of 200 kPa (optically detected magnetic resonance broadening of 750 Hz) over essentially an entire 4 mm x 4 mm x 0.16 mm epitaxial CVD layer containing 5 parts per million (ppm). X-ray topography shows no signatures of newly formed extended defects in the 5 ppm epi-layer relative to the diffraction grade HPHT substrate. Micro x-ray diffraction mapping shows a radius of curvature over 1 km for a 1 mm thick plate. Together the results demonstrate that GLCT's CVD substrates are equivalent or better than the HPHT seeds in terms of lattice curvature and extended defect concentration.