Lattice strain analysis of superconducting boron doped diamond

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In heavily boron-doped diamonds with boron concentration of more than $10^{21}cm^{-3}$, lattice strains appear prominently and once the doped diamond film reaches a certain thickness, relaxation of the lattice strain caused by in-plane stress begins to occur [1]. Cross-sectional transmission electron microscope (TEM) observation of heavily boron doped (111) diamond film have shown high density of planar defects such as stacking faults in boron doped diamonds with a thickness of over 500 nm (Fig. 1(a): right) . These stacking faults could be the origin of this relaxation layer. In type II superconductors, strong and sharp angular dependent magnetic flux pinning can occur at planar defects such as stacking faults. In this study, we evaluated the introduction process of stacking faults caused by lattice mismatch by cross-sectional TEM and X-ray diffraction, estimated the structure of stacking faults by magnetic flux pinning.

Heavily boron-doped superconducting diamond films were synthesized onto High Pressure and High Temperature (HPHT) Ib (111) diamond substrate using Micro-wave Plasma enhanced Chemical Vapor Deposition (MPCVD) method. Fig.1(a) shows a cross-sectional TEM image of boron-doped diamond films with before and after lattice relaxation introduction. The structure of stacking faults was estimated to be upside down tetrahedron structure (Fig.2(b)). The calculated angle between the ridge line and the vertical axis becomes 35.3° and the angle between one of three inclined planes (shaded plane in Fig. 1(b)) and the vertical axis is 19.5°, these values correspond to the angles in TEM image (30°, 20°). To verify this estimation, we researched the magnetic field angular dependence of resistivity. First, magnetic flux pinning was observed only diamond films with stacking faults, so stacking faults were suggested to cause flux pinning. Fig.2 shows the magnetic angular dependence of the resistivity. Φ was in-plane direction angle and 0° was set to be the angle at which the graph becomes symmetrical, θ was vertical direction angle and 0° was set to be the angle which paralleled to the [111] direction. Graph Φ= 0°, 60° showed symmetric sharp resistivity dips (θ= 23.25°, -21.75°) and these angles correspond to the calculated angles (±22°). On the other hand, graph Φ= 30° shows asymmetric resistivity dips (θ= 18.75°, -31.25°) and these angles correspond to the calculated angles (θ= 19.5°, -35.3°), which also correspond to the angle in Fig.1(a).

This study suggests that angular dependent magnetic flux pinning in superconducting diamond is caused by stacking fault, reveals the three fold symmetry of magnetic flux pinning like shown Fig.2.

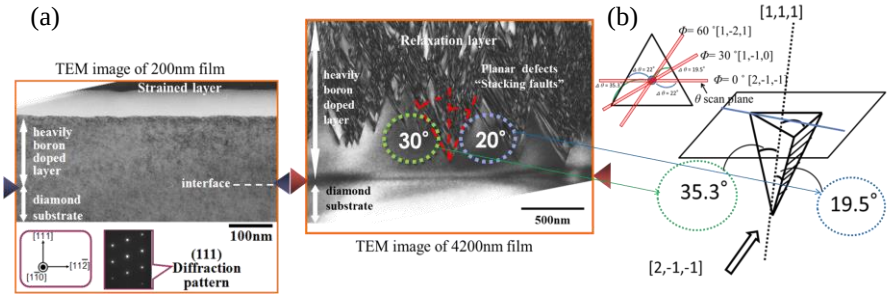

Fig.1 (a) Cross sectional TEM image of superconducting diamond. In initial growth (left), there is no defect. After sufficient growth (right), there are high density of stacking faults.
(b) Schematic view of upside down tetrahedron structure of stacking faults

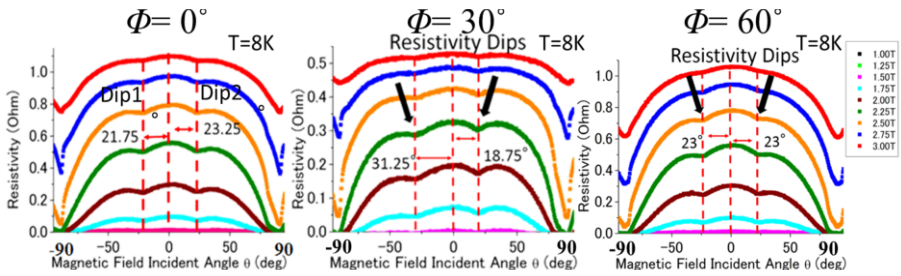

Fig.2 Magnetic field angle dependence of resistivity of lattice relaxed superconducting diamond

Reference:

[1] S. Kitagoh, H. Kawarada *et al.*, *Physica C*, **470** S610-S612 (2010).