Synthesis and Electrical Characterization of $n$-Type Nanocrystalline Diamond Films by Microwave Plasma-Enhanced Chemical Vapor Deposition

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Nanocrystalline diamond (nanodiamond) films are composed of three different carbon phases: the diamond phase in form of nano-sized grains, trans-polyacetylene segments, and amorphous carbon. They are typically formed under C$_2$-rich conditions by CVD in Ar-rich/CH$_4$ plasmas. $n$-type conductivity in nitrogen-incorporated nanodiamond films is attributed to the formation of electronic states associated with carbon and nitrogen in the grain boundary. However, the origin of the high $n$-type conductivity still remains unclear. The authors investigate structure and electrical properties of $n$-type nanodiamond films prepared from a microwave Ar-rich/N$_2$/CH$_4$ plasma. The authors also investigate the rectification properties of $p - n$ diodes using $n$-type nanodiamond films. The plasma was characterized by strong emission from C$_2$ radicals. The room-temperature resistivity of the films decreased exponentially by three orders of magnitude with deposition temperature and was saturated at $\sim 10^{-2}\Omega$ cm. The electron concentration increased up to $10^{20}$ cm$^{-3}$, while the mobility was between 1 and 10 cm$^2$V$^{-1}$s$^{-1}$. Arrhenius plots of the conductivity showed a transition from semiconducting to quasi-metallic conduction with deposition temperature. The amount and clustering of the sp$^2$ phase were found to affect strongly the electrical conduction properties.

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