Electrical Evaluation of Defects and Dopants in Diamond

Rafi Kalish and Cecile Saguy

Physics Department and Solid State Institute
Technion-Israel Institute of Technology, Haifa 32000, Israel

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P- and n-type semiconducting diamonds can now be obtained by CVD growth and by ion implantation methods. The study of the electrical properties of such diamonds is of importance both for the understanding of the physics related to the conduction and for their implementation in actual devices. The major electrical properties of interest are: the conductivity type, the carrier concentration and carrier mobility, the activation energy associated with the dopant or defect level responsible for the conduction, the dopant and compensating defect concentrations and the doping efficiency. These can be evaluated by a variety of methods including conductivity (resistivity), Hall and Seebeck effects, CV, photoconductivity and photo-Hall measurements. These methods allow, when performed as a function of temperature, extraction of the main parameters describing the electrical characteristics of a doped or damaged diamond layer. In this paper, we first describe the main conduction mechanisms identified in diamond and the experimental methods used to assess them. Then we review the different processes used to form ohmic contacts to undoped, p- and n-type diamonds and present recent results of the electrical properties of natural and CVD grown, undoped, p- or n-type doped and damaged diamond layers. While p-type homoepitaxial diamond layers can be grown by CVD methods with characteristics that exceed even those of natural B-doped diamonds, n-type diamond obtained by P-doping during CVD growth exhibits rather poor electrical properties (high activation energy and low mobility) that limit its use in electronic applications. Ion-implantation doping with P has not yielded convincing results. The current status of the application of other dopants (such as sulfur) and doping methods (such as ion-implantation) as well as novel co-doping and dopant-impurity complex formation to achieve n-type diamond are discussed.

Corresponding author: kalish@ssrc.technion.ac.il