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Electrical transport in diamond

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Sala Castagnoli, Istituto di Fisica, via P. Giuria 1

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Abstract

Diamond is as a fascinating semiconductor with exceptional physical properties such as a wide band gap, a high breakdown electric field, an outstanding thermal conductivity and high carrier mobilities. These exceptional properties make diamond an ideal semiconductor for high power and/or high frequency electronics which should surpass other materials like silicon, silicon carbide or gallium nitride. The substrate growth progresses are accelerating and the first power electronic devices have been demonstrated. Doping and electrical properties of diamond have been some major topics of the diamond community during these last fifteen years with often controversial debates. One of this controversial topic is the huge free carrier mobility (4500 cm2/Vs for electron and 3800 cm2/Vs for hole at room temperature) announced in 2002 [J. Isberg, et al. Science 297, 1670 (2002)]. Another important issue is the understanding and description of the carrier mobility dependence (electron and hole) versus temperature and versus doping level. Such electrical data are in increasing demand by the diamond based electronic device designers. In this presentation, it shown that for very low doped diamond, the maximum free carrier Hall mobility is close to 1000 $cm^2\ V^{-1}\ s^{-1}$ for electron and 2000 $cm^2\ V^{-1}\ s^{-1}$ for hole at room temperature under thermodynamical equilibrium. The elevated ionization energies (0.38 eV for boron acceptor and 0.57 eV for phosphorus donor) of dopants are at the origin of the limitation of the room temperature mobility of heavily doped samples due to neutral impurities scattering. The high mobility in the high temperature range is shown to be due to a high optical phonon energy (in comparison with Si and 4H-SiC). In order to overcome the problem of the high ionisation energy of dopant in diamond, which is at the origin of the high serial resistance in devices, an original structure is proposed based on boron delta-doping of diamond. The first simulations show that the boron dopants must be located in a 2 nm thin layer (or thinner) to get an enhancement of the mobility in the 2D gas in comparison with 3D material with the same doping level.

The Author

Julien Pernot obtained his Ph.D. in Physics of Condensed Matter at the University of Montpellier in 2001. His post-doctoral appointments include a position of Assistant Professor at “Groupe d’Etude des Semi-conducteurs” of the same University and a post-doctoral research position at the University of Nijmegen (Nederlands). In 2003 Julien Pernot obtained a position of Associated Professor at the Néel Institute and at the University of Grenoble.

His research activity is focused, among other topics, on the characterization of the electrical transport properties of wide-bandgap semiconductors, and in particular of artificial diamond.