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Preface

Carbononics – integrating electronics, photonics and spintronics with graphene quantum dots

This special issue of *physica status solidi – Rapid Research Letters* is devoted to Carbononics, an emerging area of research enabled by graphene. Carbononics stands for electronics, photonics and spintronics realized in a single material, graphene. This is realized by engineering graphene in terms of lateral size, shape, edge, strain and number of layers. Why should we be interested in carbononics? While current semiconductor technology is extremely successful it has disadvantages in terms of growing power dissipation, use of rare elements in limited supply and classical principles of operation. The potential of quantum applications for carbon-based devices is some of the motivating factors in search for alternative technologies. In current information and communications technology (ICT), information processing is divided into three physically separate functions realized with three different classes of materials – information processing with silicon transistors, communication with photons using compound semiconductors, mainly InAs, InP and GaAs, and information storage predominantly with ferromagnetic metals and increasingly, with semiconductor-based flash memories. Such division leads to problems with interconnects and power dissipation. Increasing use of rare materials, such as indium, available in limited quantities, may render further development of ICT not sustainable. Graphene and, in particular, graphene quantum dots offer an alternative to today's information technologies. Graphene is a one atom thick two-dimensional crystal made of carbon atoms arranged on a hexagonal lattice. Early theory of graphene was formulated by Wallace at the National Research Council of Canada already in 1947. Subsequently, graphene related structures, graphite intercalated compounds, fullerenes and carbon nanotubes were investigated. After the isolation of a single graphene sheet in 2004, followed by the 2010 Nobel prize to Geim and Novoselov, a large research effort worldwide on graphene research exists today. The situation is similar to semiconductors in the late 1970s. Bulk semiconductors were understood but a new research area of artificially structured semiconductor materials, quantum wells, wires and dots, was just emerging. This new research area, enabled by engineering materials at the atomic level, led to many discoveries and applications, from quantum dot lasers to the discovery of the fractional quantum Hall effect and construction of quantum processors based on electron spin. Carbononics is about creating artificial materials with carbon atoms. Starting with 2D graphene, one can now attempt to engineer a new class of materials, such as graphene quantum dots, by controlling lateral size, shape, edge, sublattice symmetry, strain, number of layers and carrier density. Research on graphene quantum dots is at an early stage, from top-down etched quantum dots with millions of atoms to colloidal quantum dots with hundreds of atoms. This special issue covers the current status of research on graphene quantum dots, starting with their electronic properties [1–4], spintronics implemented through sublattice engineering [5–7] and optical properties of graphene nanodevices [8, 9]. Finally, related and complementary material involving the physics of massive Dirac electrons in transition metal dichalcogenides is covered [10]. The goal is to summarize what is currently known about electronic properties of graphene quantum dots, what is needed to make further progress, how one can realize different functionalities and stimulate research toward their integration. The ultimate goal would be the realization of a graphene based quantum circuit.

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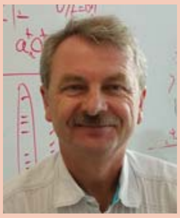

Pawel Hawrylak received M.Sc. from Wroclaw University of Technology, Poland, in 1979 and Ph.D. in condensed matter theory from the University of Kentucky, USA, in 1984. After postdoctoral stay at Brown University, Providence (RI), USA, he joined the National Research Council of Canada in Ottawa in 1987 where he led the Quantum Theory Group and coordinated the Quantum Information project. Currently, Pawel Hawrylak is a University Research Chair in Quantum Materials at the University of Ottawa. He is a Fellow of the Royal Society of Canada, American Physical Society, recipient of CAP Brockhouse Medal, Humboldt Research Prize and honorary doctorate from the University of Crete.

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