TT 14: Focus Session: Physics of Quantum Rings (organized by HL)

Innovative recent findings in both experimental and theoretical physics of quantum rings and ring-like atom systems based on the most advanced state-of-the-art fabrication and characterization techniques as well as theoretical methods will be discussed. The experimental efforts allow for obtaining new classes of semiconductor quantum rings and quantum-ring-based metamaterials. An adequate characterization of quantum rings is realized using scanning tunneling microscopy methods. Dedicated theoretical models allow for interpretation of the novel topology-driven physical properties of quantum rings.

Organizer: Axel Lorke, Universität Duisburg-Essen.

Time: Monday 9:30–11:30 Location: POT 151

Topical Talk TT 14.1 Mon 9:30 POT 151

Impact of topology on physical properties of quantum rings — •Vladimir M. Fomin — Institute for Integrative Nanosciences, IFW-Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Advanced micro- and nanostructure fabrication techniques can be exploited to generate non-trivially shaped objects possessing man-designed topological features, such as doubly-connectedness (quantum rings) and one-sidedness (Möbius strips) [1]. Even though self-assembled semiconductor quantum rings ('quantum volcanos') are singly-connected and anisotropic, they exhibit the Aharonov-Bohm effect on the persistent current because the electron wave functions are exponentially decaying towards the center and are topologically identical to those in doubly-connected quantum rings. Theoretically predicted Aharonov-Bohm effect in 'quantum volcanos' was experimentally detected by torsion magnetometry. Symbiosis of a geometric potential and an inhomogeneous twist renders an observation of the topology effect on the electron ground-state energy in microscale Möbius strips into the realm of experimental verification. A 'delocalization-to-localization' transition for the electron ground state is unveiled in inhomogeneous Möbius strips [2]. This transition can be quantified through the Aharonov-Bohm effect on the persistent current. Recent findings suggest perspectives of topological control over electronic, spin, optical, magnetic and transport properties of micro- and nanostructures.

[1] V. M. Fomin (Ed.), Physics of Quantum Rings, Springer, Berlin–Heidelberg, 2014, 487 p. [2] V. M. Fomin, S. Kiravittaya, O. G. Schmidt, Phys. Rev. B 86, 195421 (2012).

Topical Talk TT 14.2 Mon 10:00 POT 151

Fabrication of ordered quantum rings — •Zhiming Wang — School of Microelectronics and Solid-State Electronics, University of Electronic Science and Technology of China, Chengdu, 610054 , P. R. China

Quantum rings possess unique properties and have attracted extensive theoretical and experimental attention. Up to now, various effects have been devoted to fabrication of quantum rings via both top-down techniques and self-assembly. Epitaxy has been demonstrated as an effective method to fabricate self-assembled quantum rings. Despite the well-controlled morphology of self-assembled quantum rings produced by using both Stranski-Krastanov growth and droplet epitaxy, the lateral ordering of quantum rings remains challenging[1]. In this presentation, both vertically and laterally aligned quantum rings are described. The fabrication of laterally aligned quantum rings is based on the transformation of ordered quantum dots using the self-organized anisotropic strain engineering technique. The vertically aligned quantum rings are fabricated by multi-step droplet epitaxy. The growth mechanisms of both vertically aligned and laterally ordered quantum rings are discussed. Fabrication of ordered quantum rings is of high priority for practical applications, in particular, as photovoltaic devices and photodetectors.

References
[1] J. Wu and Z. Wang, in: V. M. Fomin (Ed.), Physics of Quantum Rings, Springer, Berlin-Heidelberg, 2014, pp. 143-159.

Coffee break (15 min.)

Topical Talk TT 14.3 Mon 10:45 POT 151

Self-organized formation and XSTM characterization of GaSb/GaAs quantum rings — •Andrea Lenz — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

In the GaSb/GaAs material system, quantum rings (QRs) can occur already after the material deposition on GaAs(001), sometimes even without capping. Upon capping almost all quantum dots are transformed into QRs [1].

This presentation gives an overview of the structural parameters and the formation process of the GaSb/GaAs QRs using cross-sectional scanning tunneling microscopy (XSTM). Furthermore, information on the electronic structure of the QRs is shown, which is gained using scanning tunneling spectroscopy mode (XSTS). XSTS reveals the type-II alignment for GaSb/GaAs QRs [2], which makes them very promising for charge storage devices and in photovoltaics. Furthermore, the GaSb/GaAs system exhibits a strong Aharonov-Bohm effect since the central opening of the QRs is much more pronounced as compared with other material systems, like e.g. the InGaAs/GaP system, for which QRs have been observed quite recently [3].

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[1] A. Lenz and H. Eisele, in: V. M. Fomin (Ed.), Physics of Quantum Rings, Springer, Berlin-Heidelberg, 2014, pp. 123-142. [2] R. Timm et al., Nano Lett. 10, 3972 (2010). [3] C. Prohl et al., Appl. Phys. Lett. 102, 123102 (2013).

TT 14.4 Mon 11:15 POT 151

Current-induced spin dynamics in ring-like atom clusters on surfaces — •Benjamin Baxevanis, Christoph Hübner, Lars-Hendrik Frahm, and Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Germany

Recently, much attention has been devoted to artificially assembled magnetic structures made of iron atoms on non-magnetic substrates using a scanning tunneling microscope [1,2,3]. Some of these structures show unique dynamics and switching of magnetism under the influence of a spin-polarized current and the interaction with the substrate [2,3]. We theoretically consider the spin dynamics in a ring-like cluster of Fe atoms on a substrate tunnel-coupled to a magnetic tip. Employing a master equation approach, the effects of the spin-polarized current, anisotropy field and symmetry of the ring-like cluster [4] on the spin dynamics are studied.

[1] A. A. Khajetoorians, J. Wiebe et al., Nature Physics 8, 497 (2012)
[2] S. Loth, S. Baumann, C. P. Lutz et al., Science 335, 196 (2012)
[3] A. A. Khajetoorians, B. Baxevanis et al., Science 339, 55 (2013)
[4] B. Baxevanis and D. Pfannkuche, in: V. M. Fomin (Ed.), Physics of Quantum Rings, Springer, Berlin-Heidelberg, 2014, pp. 381-408.