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EDITORIAL

Superconductivity in ultrathin films and nanoscale systems

Guest Editors

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The recent technological developments in the synthesis and characterization of high-quality nanostructures and developments in the theoretical techniques needed to model these materials, have motivated this focus section of *Superconductor Science and Technology*. Another motivation is the compelling evidence that all new superconducting materials, such as iron pnictides and chalcogenides, diborides (doped MgB_2) and fullerides (alkali-doped C60 compounds), are heterostrucures at the atomic limit, such as the cuprates made of stacks of nanoscale superconducting layers intercalated by different atomic layers with nanoscale periodicity. Recently a great amount of interest has been shown in the role of lattice nano-architecture in controlling the fine details of Fermi surface topology.

The experimental and theoretical study of superconductivity in the nanoscale started in the early 1960s, shortly after the discovery of the BCS theory. Thereafter there has been rapid progress both in experiments and the theoretical understanding of nanoscale superconductors. Experimentally, thin films, granular films, nanowires, nanotubes and single nanoparticles have all been explored. New quantum effects appear in the nanoscale related to multi-component condensates. Advances in the understanding of shape resonances or Fano resonances close to 2.5 Lifshitz transitions near a band edge in nanowires, 2D films and superlattices [1, 2] of these nanosized modules, provide the possibility of manipulating new quantum electronic states. Parity effects and shell effects in single, isolated nanoparticles have been reported by several groups. Theoretically, newer techniques based on solving Richardson's equation (an exact theory incorporating finite size effects to the BCS theory) numerically by path integral methods or solving the entire Bogoliubov–de Gennes equation in these limits have been attempted, which has improved our understanding of the mechanism of superconductivity in these confined systems. In addition, the role of thermodynamic fluctuations on superconducting properties has been extensively studied in the context of nanoparticles and nanowires both experimentally and theoretically. In the past decade, a lot of work has been initiated in the area of interface superconductivity where different techniques have been demonstrated to tune T_c.

Although the progress in this field has deepened our understanding of nanoscale superconductors, there are several open and key questions which need to be addressed. Some of these are: (1) can superconductivity be enhanced and T_c increased in nanostructures with respect to the bulk limit and if so, how can it be controlled? (2) What are the theoretical and experimental limits for the enhancement and control of superconductivity? (3) Can the phenomena identified in conventional nanostructures shed light on phenomena in high T_c superconductors and vice versa? (4) How will the new fundamental physics of superconductivity at the nanoscale promote advances in nanotechnology applications and vice versa? The papers in this focus section reflect the advances made in this field, in particular in nanowires and nanofilms, but also attempt to answer some of the key open questions outlined above.

The theoretical papers explore unconventional quantum phenomena such as the role of confinement in the dynamics of single Cooper pairs in isolated grains [1] and Fano resonances in superconducting gaps in multi-condensate superconductors near a 2.5 Lifshitz transition [2]. Here a new emerging class of quantum phenomena of fundamental physics appear at the Bose–BCS crossover in multi-condensate superconductors [2]. Nanosize effects can now be manipulated by controlling defects in layered oxides [3]. A new approach is provided by controlling the self-organization of oxygen interstitials in layered copper oxides that show an intrinsic nanoscale phase separation [4]. In this case a non-trivial distribution of superconducting nanograins appears to enhance the critical temperature [4]. This is a hot topic as in the past year many works have clarified the nanoscale phase separation in electron-doped chalcogenides, showing the key role of a complex texture of nanograins and opening new avenues for the fundamental understanding of quantum phenomena in networks of superconducting nanograins. The advances in nanotechnology allow the exploration of the possible existence of superconductivity in single carbon nanotubes [5]. The technological applications presented by Gomez [6] and Lehtinen [7] show the fundamental physics of superconductivity at the nanoscale to promote new advances in quantum devices.

We hope that this combination will make these focus papers in *Superconductor Science and Technology* interesting and promote cross-fertilization among the different sub-branches of the field which all share the same goal of addressing the key questions on nanoscale superconductors.

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