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## PREFACE

# Charge transport in nanoscale junctions

**Guest Editors**

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Understanding the fundamentals of nanoscale charge transfer is pivotal for designing future nano-electronic devices. Such devices could be based on individual or groups of molecular bridges, nanotubes, nanoparticles, biomolecules and other ‘active’ components, mimicking wire, diode and transistor functions. These have operated in various environments including vacuum, air and condensed matter, in two- or three-electrode configurations, at ultra-low and room temperatures.

Interest in charge transport in ultra-small device components has a long history and can be dated back to Aviram and Ratner’s letter in 1974 (*Chem. Phys. Lett.* **29** 277–83). So why is there a necessity for a special issue on this subject? The area has reached some degree of maturity, and even subtle geometric effects in the nanojunction and noise features can now be resolved and rationalized based on existing theoretical concepts. One purpose of this special issue is thus to showcase various aspects of nanoscale and single-molecule charge transport from experimental and theoretical perspectives. The main principles have ‘crystallized’ in our minds, but there is still a long way to go before true single-molecule electronics can be implemented. Major obstacles include the stability of electronic nanojunctions, reliable operation at room temperature, speed of operation and, last but not least, integration into large networks. A gradual transition from traditional silicon-based electronics to devices involving a single (or a few) molecule(s) therefore appears to be more viable from technologic and economic perspectives than a ‘quantum leap’.

As research in this area progresses, new applications emerge, e.g. with a view to characterizing interfacial charge transfer at the single-molecule level in general. For example, electrochemical experiments with individual enzyme molecules demonstrate that catalytic processes can be studied with nanometre resolution, offering a route towards optimizing biosensors at the molecular level. Nanoscale charge transport experiments in ionic liquids extend the field to high temperatures and to systems with intriguing interfacial potential distributions. Other directions may include dye-sensitized solar cells, new sensor applications and diagnostic tools for the study of surface-bound single molecules. Another motivation for this special issue is thus to highlight activities across different research communities with nanoscale charge transport as a common denominator.

This special issue gathers 27 articles by scientists from the United States, Germany, the UK, Denmark, Russia, France, Israel, Canada, Australia, Sweden, Switzerland, the Netherlands, Belgium and Singapore; it gives us a flavour of the current state-of-the-art of this diverse research area. While based on contributions from many renowned groups and institutions, it obviously cannot claim to represent all groups active in this very broad area. Moreover, a number of world-leading groups were unable to take part in this project within the allocated time limit. Nevertheless, we regard the current selection of papers to be representative enough for the reader to draw their own conclusions about the current status of the field. Each paper is original and has its own merit, as all papers in *Journal of Physics: Condensed Matter* special issues are subjected to the same scrutiny as regular contributions.

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The Guest Editors have deliberately not defined the specific subjects covered in this issue. These came out logically from the development of this area, for example:

- ‘Traditional’ solid state nanojunctions based on adsorbed layers, oxide films or nanowires sandwiched between two electrodes: effects of molecular structure (aromaticity, anchoring groups), symmetry, orientation, dynamics (noise patterns) and current-induced heating.
- Various ‘physical effects’: inelastic tunnelling and Coulomb blockade, polaron effects, switching modes, and negative differential resistance; the role of many particle excitations, new surface states in semiconductor electrodes, various mechanisms for single molecule rectification of the current, inelastic electron spectra and SERS spectroscopy.
- Three terminal architectures allowing (electrochemical) gating and transistor effects.
- Electrochemical nanojunctions and gating: intermolecular electron transfer in multi-redox metalloproteins, contact force modulation, characteristic current-noise patterns due to conformational fluctuations, resonance effects and electrocatalysis.
- Novel architectures: linear coupled quantum-dot-bridged junctions, electrochemical redox mediated transfer in two center systems leading to double maxima current–voltage plots and negative differential resistance, molecular-nanoparticle hybrid junctions and unexpected mesoscopic effects in polymeric wires.
- Device integration: techniques for creating stable metal/molecule/metal junctions using ‘nano-alligator clips’ and integration with ‘traditional’ silicon-based technology.

The Guest Editors would like to thank all of the authors and referees of this special issue for their meticulous work in making each paper a valuable contribution to this research area, the early-bird authors for their patience, and *Journal of Physics: Condensed Matter* editorial staff in Bristol for their continuous support.