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Advances in Silicon-Nanoelectronics, Nanostructures and High-Efficiency Si-Photovoltaics

This Special Issue of physica status solidi (a) covers presentations of Symposium D, 2019 Spring-EMRS Meeting in Nice, France.

Silicon in various bulk forms remains a fascinating material allowing for solar cell efficiency records by ultimate passivation of the bulk, surfaces, and contacts. In parallel, Si nanostructures emerge as capable building blocks in diverse fields ranging from nano-electronics and photonics to sensing. This symposium aimed to share the latest research in these fields and to create new interdisciplinary ideas.

Silicon is an omnipresent semiconductor material that can be implemented in multifarious applications and that represents the foundation of modern electronics and energy harvesting. Silicon-based microelectronics, which is nowadays better described as nanoelectronics, will reach the sub-10nm technology nodes in the near future. At these dimensions, nano-size effects comprising for instance quantum confinement, statistical issues of doping, surface states, etc., come into play and deteriorate the performance and reliability or even cause complete failure of the transistors. Several of these nano-size effects were already investigated on deliberately fabricated Si nanostructures and the findings obtained there, might be essential to circumvent the problems that occur when FETs reach single-nanometer dimensions. Furthermore, unconventional and novel approaches of Si nanostructures are of interest as they could provide alternative workarounds that help preventing further delays in implementing future technology nodes with the goal to provide more performance at reduced power consumption.

In addition to transistors for electronics, Si nanostructures such as nanowires and nanoparticles open a whole new vista for various interdisciplinary applications in the fields of sensors, quantum-devices, manipulators, actors, optoelectronics, biomarkers, etc. Due to their high surface-to-volume ratios Si nanostructures are dominated by their surface, which requires new physics and chemistry to understand their properties. This knowledge is yet to be completed and transferred to modern transistor technology.

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In the field of energy harvesting, Si photovoltaics has seen a boost in efficiency by replacing diffused p/n-homojunctions with heterojunctions that act as carrier-selective and highly passivated (recombination-free) contacts. This concept allows for a range of novel materials to be investigated as contacts but requires the precise understanding on their interface properties with Si. Despite reports about impressive conversion efficiencies, at least on lab-scale solar cells, the ideal hetero-contacts combining the right electronic and optical properties and being compatible with industrial mass-production, are yet not found. Further interdisciplinary research must find or develop materials that combine suitable Si-surface passivation with carrier-selective tunneling, long-term stability plus reliable and cost-efficient fabrication.

There are in total 11 articles in this Special Issue. One of them is the Feature Article by Greben, Khoroshyy, and Valenta about spectral dependencies of the stretched exponential decay of the photoluminescence and the quantum yield in nanocrystalline Si.[1] Two more papers also deal with Si nanocrystals, one with the enhancement of the photoluminescence by a metal membrane,[2] the other one with the general crystallization behavior.[3] Four contributions focus on photovoltaic applications: An improved wet-chemical processing of Si for heterojunction solar cells,[4] a deeper understanding of contact resistivity measurements via the TLM-method,[5] and the fabrication of nanostructures for enhanced light absorption by cryogenic dry etching[6] and by using self-assembled nanosphere-lithography masks.[7] Raman and infrared spectroscopy of Si nanowires with high free carrier densities are studied in ref. [8]. The integration of silicon with III-V semiconductors via ALD-grown nucleation layers is investigated in ref. [9], while ref. [10] is about quantum cutting, and ref. [11] about a nuclear frequency standard based on ^{229}Th implanted SiO_2.

We thank all participants of our symposium, in particular the invited speakers, the scientific committee members, and the authors of the Special Issue papers. In addition, we appreciate the support of our symposium sponsors Raith GmbH and xlith GmbH.

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Guest Editors

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