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Editorial

Photonic Properties of Silicon-Based Materials

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Photonics is a key technology of this century. The fast development of optical communications is a consequence of the advantages of photonics with respect to electrical signaling. As a bright demonstration, Charles K. Kao was awarded by the 2009 Nobel Prize in physics for groundbreaking achievements concerning the transmission of light in fibers for optical communication. The combination of photonics and Si technology is a great challenge because of the potentiality of coupling electronics and optical functions on a single chip, which is a dream for optical computing. Si-based light emitting device with high efficiency is a missing part in the design of complete optoelectronic circuits based on Si technology.

Research on Si nanocrystals was strongly activated by the discovery of the bright emission from porous Si done by Leigh T. Canham in 1990. From that time, many experimental and theoretical studies have been performed to understand and design the photonic properties of Si nanocrystals. In 1999, an important opinion was enounced by Philippe Fauchet and coworkers in United States when they provided strong arguments for surface origin of the light emission from oxidized porous Si. In 2000, optical gain in Si nanocrystals embedded in silica matrix was reported by Lorenzo Pavesi and coworkers in Italy. Works of electrically-pumped light sources are of special interest because of their high value for practical applications. An interesting approach to efficiently produce photons from Si-based materials exploits the use of light-emitting dopants, such as Er, where Si nanocrystals play a major role in the ion excitation mechanism. Importantly, Er ions emit at 1.54 μm, which is a strategic wavelength for telecommunication because it corresponds to minimum losses of silica optical fibers.

Indeed, generation of light in Si is a challenging perspective in the field; however, the issue of a laser and other light-emitting devices does not limit the practical activity. The research is also focused on light modulators, optical waveguides and interconnectors, optical amplifiers, detectors, memory elements, photonic crystals, and so forth. A particularly important task of Si nanostructures is to generate electrical energy from solar light taking benefit of the monitoring of the optical bandgap through the crystallite size. This is one of the central concepts of the third generation of photovoltaic cells with the final objective of an all-Si tandem solar cell.

Control of the optical properties of Si-based materials is central in designing photonic components (light emitters, optical waveguides, optical memory, etc.). It is not possible to understand and develop the optical properties of nanoparticles without fundamental information on their microscopic structure. This explains a large number of theoretical works based on empirical and on *ab initio* approaches. The fast development of computers and software supports these theoretical studies.

Many fundamental and practical problems should be solved in order to develop this technology. In addition to open fundamental questions, even more complex and important is to move the known experimental results towards practical realization. The demonstrated devices and approaches are often too complex and/or have too low efficiency. However, the world market for Si photonics is expected to be huge and the challenge to combine optical and electrical functions on a chip is very strong; thus, we expect more research activity in the field of Si nanophotonics in the future.

This special issue describes a part of activities in the area of Si photonics, in most cases working essentially on nanoscale. The tutorial review written by the Guest Editors presents a number of examples of research in the area, from theoretical modelling and fundamental experiments to the most promising applications. The original papers consider various aspects of Si photonics both from theoretical and experimental points of view.

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