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Microcrystalline and Nanocrystalline Semiconductors—1998

Editors: Leigh T. Canham, Michael J. Sailor, Kazunobu Tanaka and Chuang-Chuang Tsai
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Microcrystalline and Nanocrystalline Semiconductors—1998

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PREFACE

This book contains the papers presented at Symposium F, “Microcrystalline and Nanocrystalline Semiconductors,” at the 1998 MRS Fall Meeting in Boston, Massachusetts. It was the fifth MRS symposium held on this topic since 1989, and this proceedings contains 87 of the 166 papers presented. In addition to the now traditional themes of synthesis, structure, and optoelectronic properties of nano- and microcrystalline semiconductors, properties leading to new optical and biological applications were also reported.

In the area of synthesis, techniques have emerged for the production of nanoparticles with narrow size distributions and more well-behaved electronic properties. Wet chemical techniques to build core-shell structures (a nanoparticle of one semiconductor coated with a thin layer of a material having a larger bandgap) have yielded more chemically robust materials with higher photoemission quantum yields. Solution and gas phase methods to synthesize Si and Ge nanocrystallites have also been perfected. Chemical techniques have also been brought to bear on the modification of semiconductor interfaces, and many contributions described chemical reactions to functionalize or stabilize nanocrystalline materials. The interest in producing stable materials with narrow size distributions stems from the desire to design longer-lived electroluminescent devices and to impart specific functionality to the material for sensor, micromachine, or photonic applications.

Earlier symposia have focused on electroluminescent devices made of nanocrystalline and porous silicon. High-efficiency electroluminescent devices that operate at visible wavelengths are desired for display applications. Steady progress has been made in this area, and a porous Si device with an electroluminescence efficiency above 1.1% was reported in the symposium. Although the efficiencies are improving, long-term stability of these devices is still a problem. Communications applications require devices that emit at wavelengths in the near infrared, and a room-temperature device incorporating an emitting Er species in a nanocrystalline Si matrix was reported. Along with these more familiar optoelectronics themes, several new properties and applications of nanocrystalline materials were represented in the symposium.

One emerging theme involves the fabrication of passive optical elements made from nanostructured semiconductors. Multilayer structures can be used to artificially narrow the broad emission band from Si nanocrystallites or other emissive species to very narrow linewidths, providing a convenient means of fabricating devices with tunable optical properties. It has been found that multilayered structures, such as Bragg reflectors, can be easily synthesized by pulsed electrochemical corrosion of silicon. The porous silicon layers produced display a periodic porosity which provides the required optical characteristics. Such structures are currently of interest for applications in optical filtering and switching, and for silicon-based lasers.

Application of nanocrystalline materials to biology and medicine is another emerging theme that was explored in this symposium. Properly prepared luminescent quantum particles were reported to have characteristics for biological tagging and counting experiments superior to conventional fluorescent molecules. Highly sensitive biological sensors based on a chemically modified porous Si etalon structure were also reported. Finally, in-vivo studies of bulk and porous Si showed that their soft tissue biocompatibility is comparable to Ti, a well-established biomaterial.

Many contributions on microcrystalline semiconductors were concerned with the development of efficient solar cells. The recent fabrication of efficient (>10%) solar cells from microcrystalline TiO₂ films (the Graetzel cell) were discussed in several presentations, and crucial elements of

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microstructure and surface chemistry were explored. Although the initial TiO₂ cells were liquid junction devices, progress towards the development of an efficient, all solid-state device was presented. New syntheses and studies of ternary phase semiconductors of interest for solar cell applications were also presented. Symposium A at this Meeting focused entirely on polycrystalline Si, and so the representation of this field in our symposium was lower than in previous years.

A significant number of contributions reported observations of new properties of microcrystalline and nanocrystalline semiconductors. The coming of age of high-sensitivity near-field and far-field spectroscopic microscopy as an analytical tool has yielded some fascinating results on nanoparticles. Intermittent emission (blinking) phenomena from nanocrystallites seems to be a general trend; such observations were reported on group IV and II-VI materials. The intermittency is thought to be related to carrier trapping events at the nanoparticle interfaces. Unusual nonlinear optical properties and magnetic effects were reported for several systems. One of the more surprising observations was that nanocrystalline porous Si layers can emit a strong ultrasonic signal under an applied bias. The effects of size on the structural properties (lattice dimensions as well as microstructure) of nanocrystalline materials were also covered.

There was an unusually large number of authors associated with Symposium F who won MRS awards at this Meeting. The MRS best poster award for the Tuesday night poster session held at the Marriott Hotel went to Herman A. Lopez for his paper titled "Integration of Multilayers in Er-Doped Porous Silicon Structures for Optoelectronic Devices." The MRS best poster award for the Wednesday night poster session held at the Marriott Hotel also went to a Symposium F participant, Alkiviathes Meldrum, for his paper titled "Microstructure and Size Distribution of Compound Semiconductor Nanocrystals Synthesized by Ion Implantation." Bryan D. Huey was a Graduate Student Gold Award winner for his talk "Electronic Properties of Individual Grain Boundaries in ZnO and SrTiO₃ Bicrystals and Polycrystals." There were two Graduate Student Silver Award winners from Symposium F: Moonsub Shim for his presentation "Dielectric Dispersion Studies of Semiconductor Nanocrystal Colloids: Evidence for a Ground State Dipole Moment," and Eva M. Wong, who made two contributions to Symposium F, the poster "Photoluminescence of Zinc Oxide Quantum Particle Thin Films," and the talk "The Growth Kinetics of Nanocrystalline Zinc Oxide Particles From Colloidal Suspensions."

In conclusion, the organizers would like to thank the authors, speakers, and session chairs of Symposium F, the MRS staff for their excellent back-up facilities available during the Meeting, and the symposium aides who provided tireless assistance to the organizers and session chairs. Our special thanks go to Ms. Christie A. Canaria for her help in preparing and indexing this volume. Finally, the organizers wish to thank the sponsors listed below for financial assistance:

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