1994 E-MRS Spring Meeting Highlights Topical Symposia

Under the auspices of the International Union of Materials Research Societies (IUMRS), the 1994 E-MRS Spring Meeting was held May 24–27, 1994 in the Council of Europe/European parliament building in Strasbourg, France. The agenda comprised a plenary session, an equipment exhibit, the First European Materials Research Society Workshop on Advanced Materials Education, a session on New Materials for the Conservation of Cultural Heritage, and six parallel symposia on such topics as photorefractive materials, polymer surfaces, high-temperature electronics, and porous silicon.

The following summaries are highlights of five of the 1994 E-MRS Spring Meeting symposia. For further information, contact: Paul Siffert, E-MRS Secretary, BP 20, 67037 Strasbourg, Cédex 2, France; phone: 33-88-28-65-43; fax: 33-88-28-62-93.

Photon-Assisted Processing of Surfaces and Thin Films (Symposium B)

Chairs: U.K.P. Biermann, Philips Research Labs, Eindhoven, The Netherlands; J. Dieleman, DSA Consultants, Waalre, The Netherlands; P. Hess, Ruprecht-Karls University, Heidelberg, Germany.

This symposium offered a rich diversity of subjects, providing a comprehensive survey of the field. Many papers dealt with the application of photon/laser-assisted processes to the deposition, modification, and etching of surfaces and thin films of a wide variety of materials, and with the characterization of the resulting films and structures. Several areas—laser ablation, in particular—were emphasized, with papers centering around the following topics:

- The use of advanced diagnostic techniques, especially modeling, to characterize the processes and understand the physics and chemistry involved.
- The advantages of photon-assisted processes over currently established techniques (for example, photon-assisted methods showing fast local treatment with high resolution and reduced substrate temperatures, allowing complicated structures to be obtained with unusual material combinations).
- Two striking trends in the laser ablation area—the use of laser beams with improved intensity homogeneity, and the predeposition surface treatment of surfaces—that are essential to improving our understanding of laser ablation and its application in high-quality manufacturing. Improved laser beam quality is also important for other photon-assisted processes.
- The application of optical techniques to the *in situ* control of growth, modification, and etching processes. Many papers dealt with this method for improving processing.
- Other applications, including: the fine-tuned production of multilayers with exciting physical properties, the fabrication of three-dimensional microobjects, rapid prototyping, laser-induced forward transfer for patterning, the production of permanently electrically conducting polymer wires, large-area uv-lamp-assisted deposition and annealing of oxides and dielectrics, laser recrystallization, and doping for the preparation of poly-Si and poly-Si-Ge thin films.

Photorefractive Materials: Growth and Doping, Optical and Electrical Characterizations, Charge Transfer Processes, and Space Charge Field Effects and Applications (Symposium C)

Chairs: G. Roosen, CNRS, Orsay, France; O. Schrimer, Osnabrück University, Osnabrück, Germany; F. Agullo-Lopez, Universidad Autonoma, Madrid, Spain; A. Kost, Hughes Research Laboratories, Malibu, California.

Discussion of photorefractive nonlinearities elucidated the intimate connection between the microscopic structural features of materials and their nonlinear properties and device performance, in this symposium comprising more than 120 abstracts. Contributions were classified into five main topics: (1) Insulating Materials: Growth and Characterization, (2) Bulk Materials for the Infrared, (3) Photorefractive Characterization, (4) Quantum Wells and New Materials, and (5) Applications of the Photorefractive Effect.

Session I focused on new structural and performance data for photorefractive oxides such as $LiNbO_3$, $KNbO_3$, SBN, $KTaO_3$, sillenites, and $BaTiO_3$. Particular emphasis was placed on new developments in the characterization of "blue" $BaTiO_3$ for infrared applications, and advanced microscopic characterization techniques (optical and ion beam, for example). In Session II, the accent was on the bulk semiconductors GaAs and CdTe, relating the microscopic properties of their active impurities to the observed photorefractive response.

Session III was devoted to different aspects of the photorefractive process, including spectroscopic characterization, short-pulse excitation, nonlinear scattering, fixing, and high light intensities. New possibilities for using the photorefractive effect with neutrons and synchrotron radiation were discussed, highlighting the challenging environment for such applications. The relevance of the photorefractive effect for spectroscopic analysis was also covered.

Session IV included promising results obtained with multiple quantum well (MQW) structures and the possibilities for application of such devices as spatial light modulators. The presentation covered other novel inorganic materials that show attractive photorefractive properties, such as the cubic magnetic terbium-gallium garnet, and interesting preliminary data on photorefractive polymers, a field that is expected to assume a high profile in future meetings. Session V dealt with holographic storage, and beam control and image detection.

Polymer Surfaces and Interfaces with Metals and Semiconductors (Symposium D)

Chairs: J.L. Bredas, Université de Mons, Mons, Belgium; W.R. Salaneck, Linköping University, Sweden; G. Wegner, Max-Planck-Institut, Mainz, Germany.

This two-and-a-half-day symposium focused mainly on surfaces and interfaces of conjugated polymers, covering both the basic materials science of conjugated polymers, as well as the developing technology of prototype devices based on these polymers. Of major interest was the new light-emitting diodes (LEDs). R.H. Friend of Cambridge University, in his Plenary Lecture at the meeting's opening session, discussed the pioneering work being done at Cambridge on conjugated polymer-based LEDs, including A. Holmes' custom design of processable polymer materials with electronic properties to increase device performance. The most recent devices, based on a certain CN-substituted poly(p-phenylenevinylene) (CN-PPV), have exhibited internal electroluminescence quantum efficiencies in excess of several percent. Lifetimes were claimed to be already reproducible in the range of 2,000 h, with breakdown and failure mechanisms apparently still not well understood.

The symposium began with overviews of the experimental and theoretical methods used in studying conjugated polymer surfaces and interfaces, followed by a

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description of new developments in conjugated polymer-based LEDs in the United States, covering both device issues and the basic physics of LED device structures. Presentations also covered nonlinear optics, metal-polymer interfaces, and STM/AFM of organic molecular systems.

A discussion featured the processing of ultrathin films of ordered polytetrafluoroethylene (PTFE) and a report on the molecular epitaxy of large conjugated molecules on such ordered PTFE substrates. The advanced materials processing session looked at future transform processing directly from synthesis to shapes. The final session included talks on the characteristics of LEDs, with an interesting CVD route to the preparation of poly(p-phenylenevinylene) films, and on polymeric optochips.

The main issues emerging from the symposium concerned the new polymer-based LEDs and the use of conjugated polymers in optoelectronic applications. Conjugated polymers are the basic materials of choice for future molecular-based electronic applications, based on recent developments in conjugated-polymer processing. Chemistry has dominated the development of conjugated polymers as unique quasi-one-dimensional physical systems, and continues to play a major role in device applications. From a physics point of view, the role of the interface between conjugated polymers and metallic or semiconducting contacts remains an important and controversial area of study—one in which participants showed little agreement.

In the optoelectronics area, AKZO Electron Products BV, The Netherlands, is involved in studies of nonlinear optical properties with optical switches, optochips, and future telecommunications application. Europe is maintaining a strong profile in the LED area, with extensive projects in both universities and industry. Funding programs are provided by the European Commission under ESPRIT and BRITE EURAM, and by such industrial participants as Philips in Eindhoven, Hoechst AG in Frankfurt, and Thompson-CSF in Paris. The intellectual property arising from original work on polymer electroluminescence at Cambridge has been transferred to a new company, Cambridge Display Technology; the activities involved in transferring these devices from the laboratory to the marketplace are accelerating rapidly. Although the graphic display market is an obvious target, the scope for applications is very wide; the first applications are more likely to be in areas requiring considerably less investment and development.

High-Temperature Electronics: Materials, Devices, and Applications (Symposium E)

Chairs: K. Fricke, T.H. Darmstadt, Germany; J.P. Colinge, UCL, Belgium; V. Krozer, T.H. Darmstadt, Germany; J.L. Robert, U. Montpellier II, France.

This symposium was directed at scientists working on materials and processing techniques for fabricating devices for use in high-temperature electronic applications. Such devices are vital components in the oil, lumber, avionics, automotive, and nuclear power industries, among others. The auto industry, in particular, needs devices capable of functioning reliably at temperatures in excess of 200°C, a criterion which excludes bulk silicon devices.

Three speakers gave presentations on high-temperature silicon-on-insulator (SOI) devices, providing details on device physics and circuit applications. SOI CMOS logic circuits, power devices, and sensors for high-temperature operation were demonstrated. SOI technology is relatively mature and can be operated at temperatures over 300°C.

A major contender for higher temperature operation (600°C)—semiconductor silicon carbide—was covered in the symposium. Considerable work is being done to improve the growth conditions of SiC, with the goal of improving the stoichiometry, crystal size, and crystal quality of the material, and reducing its price. The optical and electronic properties of SiC are being extensively characterized, and some high-temperature SiC devices (stabilitron, dinistor, and combined JFET-MESFET) were reported on.

Diamond, another semiconductor material which can be used at high temperatures, received attention in this symposium. Because of its excellent thermal conductivity, CVD diamond shows great promise as a heatsink material for electronic chips (silicon or other materials). Diamond can also be used as a semiconductor. Methods for growing diamond films are being extensively studied and developed, including ohmic-contact formation techniques. Also reported was the performance of diamond diodes and light-emitting diodes (blue and green emission, operating in the 20–460°C range).

An additional candidate for high-temperature applications—semiconductor III-V compounds (GaN, GaAs)—were described. A new complementary heterostructure FET was presented; this device reduces the gate leakage current that is the main drawback of III-V MESFET devices, so that operation at 500°C can be achieved.

Porous Silicon and Related Materials (Symposium F)

Chairs: R. Hérino, Université Joseph Fourier, Grenoble, France; W. Lang, Fraunhofer Institute for Solid State, München, Germany.

This four-day symposium described the state of the art of porous silicon, updating and building on the 1993 meeting symposium, Light Emission from Porous Silicon. Reports detailed the progress made in the preparation of porous films, and the investigation of alternative methods such as laser ablation or spark erosion of crystalline silicon, that have led to the production of materials with excellent emission efficiencies. Other reports showed the possibility of forming porous layers in other semiconductors such as germanium or silicon-germanium alloys.

Numerous contributions were devoted to the characterization of electrochemically etched porous silicon, which remains the most studied material. Porous films of very large porosities, of the order of 90%, can now be obtained without damage by using the supercritical drying technique. This technique, already known from the formation of highly porous aerogels, keeps the porous structure from being exposed to the capillary forces which appear during drying in air—forces which can partially destroy the microstructure of the material. Supercritically dried layers, moreover, show a photoluminescence of higher intensity than layers dried in air.

New experimental techniques, such as acoustic microscopy, low-temperature photoconductivity, magnetic resonance, and other optical experiments, have led to a better knowledge of the porous silicon structure and of its emitting properties. Infrared and Raman spectroscopies, and tunneling microscopy are being used increasingly in controlling the surface chemistry and the structure changes which may result from various post-treatments of the porous layers.

Several contributors focused on porous silicon's electrical and transport properties, which previously have not been widely studied because of the difficulty in obtaining reproducible electrical contacts on the porous layers. The results presented at the symposium pose new questions on the current transport mechanisms in relation to the material microstructure. Further work in the field is clearly needed to extend our knowledge of the porous structure.

Although there is no general agreement about the physical origin of porous silicon luminescence, an increasing number of researchers refer to the quantum confinement effect to analyze their results. Invited speaker M. Lannoo showed that calculations based on the quantum confinement concept can account for several aspects of the light emission, providing a coherent picture of porous silicon luminescence. Other presenters, however, said that the emission cannot be explained by confinement effects. Their view is based on new experiments on the photoluminescence of porous films under high pressure, in a range covering the semiconductor and metallic phases of silicon, that seem to show that the luminescence is not related to any of these phases.

Further work was presented on electroluminescence using liquid contacts. Although this luminescence cannot be used for fabricating devices, studying its characteristics can be useful for extending our knowledge of the charge exchange mechanisms that govern it. For example, the efficient and wavelength-tunable emission obtained with n-type porous layers can be explained by the selective injection of charge carriers into crystallites of different sizes, according to the applied polarization. Studies on solid-state electroluminescence concentrate on the possibility of improving the emission efficiency, which is still too small to allow porous silicon to compete with other light-emitting devices. Two approaches which seem promising were presented: (1) Improve the contact with the porous layer by filling the pores with a conductive material, which may be either a polymer or a metal, and (2) Achieve efficient injecting junctions by forming porous p-n junctions. Further improvements in emission efficiency are still required, however, before industrial applications can be considered. An invited talk by P. Steiner on micromachining applications of porous silicon indicated that this is a field in which porous silicon appears mature for industry. Steiner showed that porous silicon can be used to produce elaborate silicon microstructures, which can be used in microsensor fabrication.

The symposium confirmed that, in spite of important progress made since the first paper on the topic by L.T. Canham, there is still much to understand about porous silicon. The intense research activity devoted to this material seems likely to continue, driven by unanswered fundamental questions, as well as by the still promising electrooptical applications.

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