

## E-MRS Holds Summer School on Current Problems of Semiconductor Surfaces and Interfaces

Fermi once said, "If a solid volume is a God, its surface is the Devil." This is no longer true since so many scientists have tackled the structure of solid surfaces with a large number of sophisticated instruments. Last summer in Bavaria, 80 scientists from Europe and the United States reviewed present knowledge on semiconductor interfaces and surfaces and their impact on semiconductor devices at a five-day summer school.

A flavor of German tradition enveloped the summer school on "Current Problems of Semiconductor Surfaces and Interfaces" held June 30 to July 4, 1986 in Burghausen, West Germany. The first dinner was served in the vaulted room where, in 1373, the duke of Bavaria sold his land of Brandenburg (which later became Prussia) for 250,000 gulden. Attendees could also view many Bavarian lakes and churches.

The school was hosted by Wacker-Chemitronic, producer of almost 40% of the hyperpure silicon needed worldwide. Wacker-Chemitronic, the Council of Europe, and E-MRS were the principal funding organizations. The program, organized by H. Jacob and E. Sirtl (Wacker-Chemitronic and Heliotronic) and by M. Rodot and J. Derrien (CNRS), covered four main topics: fundamental aspects of semiconductor surfaces and interfaces, surface and interface technology and diagnostics, specific interfaces, and homoepitaxy of semiconductors.

Clean surfaces were described by G. Le Lay (CNRS, Marseille) and A. Kahn (Princeton University, New Jersey) for Si and III-Vs, respectively. The growth and structure of layers deposited on such surfaces, beginning with a small fraction of a monolayer, were discussed by J. Derrien (CNRS, Grenoble) and J.A. Venables (University of Sussex, Brighton). Several modern diagnostic techniques, together with examples of recent research results, were reviewed as follows: photoemission by W. Mönch (Duisburg University) and F.J. Himpsel (IBM); vibration spectroscopy by H. Ibach (Institute of Nuclear Research, Jülich); LEED by M. Henzler (Hannover University), SIMS by A.M. Huber (Thomson-CSF).

Special mention is due to scanning tunneling microscopy, a new technique presented by R.J. Behm (Munich University). It has a very high potential value, as recognized by most specialists, to characterize the topography and electronic and chemical states of surfaces with a resolution of a few angstroms.

### Schottky Barriers

Schottky barriers were one of the



**W. Freiesleben, president of Wacker-Chemitronic and Wacker-Siltronic Companies, welcomes attendees.**

meeting's highlights. It is difficult to believe that, half a century after their first description, we are not able to account for the observed barrier heights. While it is known that some "interface states" control this feature, the origin of these states is controversial. The choice is between MIGS (metal-induced gap states), which were pledged by F. Flores (Madrid University), and states due to defects inside the semiconductor. L. Brillson (Xerox) and A.B. McLean (Cardiff University) showed how microscopic interface modifications (including chemical reactions) may modify Schottky barrier heights in a way that pleads for defect states rather than MIGS. Since interface states do exist, they should be made measurable: that task was fulfilled by C. Barret (Orsay University) by transport measurements at variable temperatures and frequencies, adding further credibility to the model of defect states.

### Industry Practices and Needs

Many presentations started from the practice and needs of the microelectronics industry: wafer surface preparation (D. Huber, Wacker-Chemitronic, and J.B. Theeten, LEP); chemical vapor deposition (M. Druminski, Siemens, and M.W.M. Graef, Philips); molecular beam epitaxy of Si (E. Kasper, AEG, and F. Arnaud d'Avitaya, CNET Grenoble). For instance, MBE specialists established that steep doping of layers was made easier by applying an electric field or impinging an electronic beam onto the growing layer. MBE is often applied to III-V microstructures, whose electronic properties and applications were reviewed by H.R. Rupprecht (Fraunhofer Institute, Freiburg) and K. Ploog (Max Planck Institute, Stuttgart). The control and reliability of very thin (10 nm), high quality oxide layers were discussed by R.F. de Keersmaecker (IMEC, Leuven) and D.R. Wolters

(Philips), while the metal-polyimide bond was described by P. Ho (IBM).

Attendees also heard about other key technological problems, such as the gettering techniques capable of increasing crystal perfection (B.O. Kolbesen, Siemens), and metallic contacts, dealt with in three papers. F. Jahnel (Siemens) explained the difficulties frequently met in several types of metallization used in VLSI; for instance, the Ta-Si contacts could suffer consumption, cancer, pocks, measles, cellulitis obscura, and more. G. Bomchil's (CNET) paper centered on the formation of refractory silicides, and M.A. Nicolet's (California Institute of Technology) on diffusion barriers (e.g. TiN) which may become necessary in some cases. Finally, H.T.G. Hentzell (Linköping University), studying the influence of impurities on the recrystallization of amorphous Si, created a surprise by finding traces of an Al silicide as an intermediate step in this process.

Research is so active in this field that numerous opportunities for debate are being prepared. One of these will be the Second International Conference on the Formation of Semiconductor Interfaces, to be held in 1988 in Osaka (Japan) under the direction of A. Hiraki.

M. RODOT

## E-MRS Symposium Features Advanced Materials for Telecommunication

Symposium A at the E-MRS Spring Meeting held in Strasbourg, France during the week of June 16, 1986 featured eight sessions on "Advanced Materials for Telecommunication."

The symposium organizers were P.A. Glasow (Siemens AG Research Laboratories, West Germany); Y.I. Nissim and J.P. Noblanc (CNET, France); and J. Speight (British Telecom Research, Great Britain).

A recognition that progress in telecommunication is intimately tied to advances in electronic materials prompted this four-day symposium concerned with all aspects of materials for modern and future telecommunication. The complete materials aspect—from emitters through transmitters and receivers—was covered. The symposium included the wide range of bulk III-V materials growth, all aspects of semiconductor materials analysis, and correlations of bulk material-processing-device properties. The symposium covered the various kinds of semiconductor heterostructures and their characterization. Materials for optoelectronic integration were also addressed as were contacts, interconnects, insulation, and passivation.

The symposium's eight sessions featured 28 invited papers and 48 contributed papers

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on the following topics: bulk single crystal growth of device graded substrate materials; bulk material characterization; processing and device properties; growth and characterization of heterostructures; material for optical transmitters; materials for optoelectronic integration; and new materials and layered structures for contacts, interconnects, insulation and passivation.

The following papers were among those presented by 28 invited speakers:

"Advanced LEC GaAs Crystal Growth for Optoelectronic ICs" by T. Fukuda (Japan)

"Defect Characterization by Magnetic Resonance and Infrared Spectroscopy" by J. Schneider (West Germany)

"Electron Nuclear Double Resonance-Optically Detected Electron Nuclear Double Resonance" by J.M. Spaeth (West Germany)

"Transport Properties in Modulation Doped Heterostructures and Quantum Wells" by G. Weimann (West Germany)

"Epitaxial Growth of II-VI Semiconductors for Telecommunications" by R.D. Feldman (United States)

"Characterization of Heterostructures and Multilayer Stacks by Optical Methods: Kinetic and Spectroscopy Ellipsometry, Microphotoluminescence, X-Ray Reflectometry" by J.B. Theeten (France)

"Material and Technology Requirements for GaAs Optoelectronic Integration" by F. Brillouet (France)

"Approach to Improved Materials Structures for Contacts to Compound Semiconductor Devices" by L.F. Eastman (United States)

"Telecommunication Systems" by J. Jerphagnon (France)

Special emphasis was given to the topic "Correlation of Bulk Material - Processing - Device Properties," which was discussed in a special rump session. It was agreed that this important issue should be suggested as a topic for a future E-MRS symposium.

## E-MRS Symposium Covers Magnetic Thin Films

Symposium E at the E-MRS Spring Meeting held in Strasbourg, France during the week of June 16, 1986 had as its topic "Magnetic Thin Films." The symposium organizers, led by R. Krishnan (CNRS, France), included P.G. Grundy (Salford University, UK), H. Hoffmann (Universität Regensburg, West Germany), and J.C. Lodder (Twente University of Technology, Netherlands).

The two-day scientific program, attended by over 50 scientists from industry and national laboratories, included sessions on soft films, multilayers, and applications, and a panel discussion on monolayer and multilayer films. Each session began with an invited paper which set the pace for subsequent contributed papers.

Prof. Hoffmann's invited talk on soft magnetic film properties started with a brief survey of the work done in the 1960s. He dealt with ripples in permalloy and finally discussed the implications in amorphous soft films. The next invited paper by Wettling et al., a stimulating one on surface spin wave studies in magnetic multilayers, demonstrated the use of Brillouin light scattering to investigate the collective excitations in multilayers, a subject of intense interest today. The role of anisotropic stack was also theoretically investigated. Experimentors can now obtain such samples. The last invited talk, representing industry and given by Bernstein et al., was on perpendicular recording properties of amorphous Tb-Fe and Gd-Fe films. They described the correlation between the recording properties and the magnetization process which they studied using magneto-optical techniques.

The following is a brief topical account of contributed papers:

**Thin films.** Five papers dealt with the domain structure, exchange coupling between a magnetically hard and a soft film, and an ion beam mixing technique to produce amorphous films.

**Multilayers.** Eight papers considered various aspects such as structure of sandwich-type films, surface magnetism, investigations using FMR and NMR and spin-resolved photoemission studies. The work described both epitaxial layers and polycrystalline ones dealing with the effect of layer thickness on properties. They brought out the importance of *in situ* characterizations.

**Applications.** Eight papers considered topics ranging from amorphous metallic films to ferrimagnetic spinel and garnet-type films. Stability in amorphous rare earth-transition metal films was discussed. A new assisted-CVD technique to prepare spinel films for recording applications was described. Magneto-optical properties both in metallic multilayers and garnet films were presented. Ion implantation problems in YIG and barium ferrite were discussed. A final paper dealt with Bloch line containing bubble wall states.

The panel discussion on monolayers and multilayers was an interesting, exciting session. Several aspects were discussed, including: various techniques of preparation and their merits and demerits, a wide spectrum of characterization techniques for obtaining a better understanding of the interface, coupling, and so on.

The participants seemed satisfied with the program, but according to symposium organizer Krishnan, much more could be accomplished, given more time. There are many conferences on magnetism and magnetic materials, and many could question the need for the E-MRS June meeting. Says Krishnan, "Yes, there are many conferences each year in many parts of the world,

but they tend to be either too large or too expensive for many. The result is that often the same people attend, and therefore a real exchange of ideas between those active in the field is not really achieved. Under these circumstances, I believe that a medium-sized forum in Europe is indeed most welcome, even if it is an annual event. It is necessary that European researchers meet periodically to confront and compare their ideas in order to effectively plan their research."

## E-MRS Plans 1987 Meeting

E-MRS has begun to solicit papers for its 1987 meeting to be held in June 1987. Papers are being solicited for the symposia described below. The deadline for submitting abstracts is March 15, 1987. For more information, contact the symposium chairs listed at the end of each symposium description.

### Amorphous Hydrogenated Carbon Films

This three-day symposium will consist of contributed and invited papers on the preparation, structure, properties, and applications of hard amorphous hydrogenated carbon (a-C:H) films. This metastable carbonaceous material is finding increasing application as an optical, dielectric, tribological, or corrosion-resistant coating and as a material for wall conditioning in fusion devices. Joint plenary talks will be organized with the "Symposium on Surface Engineering." Papers are solicited in the following areas:

#### Preparation

Process characterization (plasma chemistry, surface reactions)

Bonding and structure

Properties (a-C:H bulk and film/substrate interface)

Post deposition modification (heat treatment, ion beams)

#### Applications

Related materials (a-C, a-C:F, C/group IV-alloys, CVD-diamond films)

#### Symposium Chairs:

P. Koidl

Fraunhofer-Institut für Angewandte Festkörperphysik  
Eckerstrasse 4  
D-7800 Freiburg  
Federal Republic of Germany  
(0761)2714280

P. Oelhafen

Institut für Physik  
Universität Basel  
Klingelbergstrasse 82  
CH-4056 Basel  
Switzerland  
(061)442040

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