Oxford Conference Highlights Developments in Microscopy of Semiconducting Materials

The most recent in a biennial series, the 8th Oxford Conference on Microscopy of Semiconducting Materials concentrated on the latest worldwide developments in electron microscopical and related analytical studies of semiconductors. The conference took place at the University of Oxford, United Kingdom, April 5–8, 1993, and attracted delegates from 20 countries.

Scientific sponsorship of the conference was provided by the Royal Microscopical Society, the Institute of Physics (U.K.), and the Materials Research Society. The meeting was chaired by Tony Cullis (Defence Research Agency, Malvern) and Anne Staton-Bevan (Imperial College, London). Areas from fundamental research to electronic device fabrication and assessment were addressed in a program of 175 papers, with invited experts introducing key topics.

Delegates at the 8th Oxford Conference on Microscopy of Semiconducting Materials attend a lecture on high-resolution electron microscopy.

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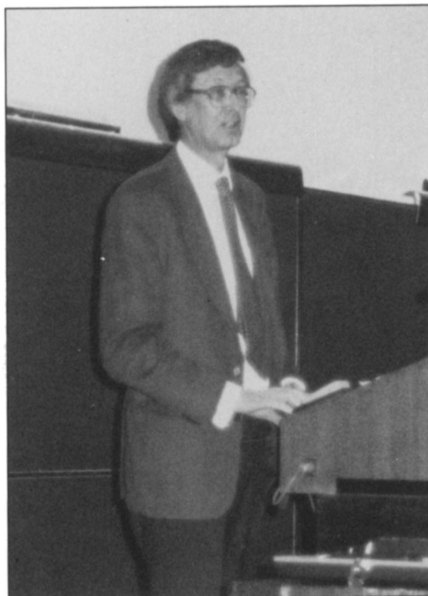
Following the opening address by Sir Peter Hirsch (University of Oxford), the first session highlighted high-resolution transmission electron microscopy. A. Ourmazd (AT&T, Holmdel, NJ) demonstrated how lattice images, recorded with imprecise knowledge of imaging conditions, can be processed using a multidimensional vectorial representation of unit cell contrast to give both topographical and compositional maps of buried interfaces with high accuracy. Examples of applications to the Si/SiO_2 interface and Si/GeSi/Si quantum wells were given. Other speakers extended and broadened the high-resolution analytical theme to cover the identification of nanometer-thick interfacial phases and the study of delta-doped layers.

A special session on the characteristics of dislocations in crystals was introduced by K. Sumino (Tohoku University) in a paper which surveyed the latest understanding of dislocation generation, motion, and pinning behavior in a wide range of semiconductors. The results of real-time dislocation studies using *in-situ* electron microscopy and x-ray topography were highlighted. The session continued with work ranging from studies of grain boundaries in Si and Ge to the investigation of plastically deformed InP.



C.J. Humphreys surveys the characteristics of advanced nanostructures.

A special feature of the conference was the in-depth examination of the structural effects of Si processing. J.M. Poate (AT&T, Murray Hill, NJ) described several areas in which the understanding of defect production is crucial to successful device fabrication. There was a special focus on the effects of wet-chemical cleaning on surface roughness at the atomic scale, including correlations with gate oxide integrity; atomic force microscopy (AFM) made essential contributions to the study of both hydrophobic and hydrophilic cleans. The oxidation-enhanced diffusion of boron also received detailed treatment, together with the associated diffusion of Si self-interstitials produced by oxidation and by ion implantation. Other important topics included light emission from Er-implanted Si, the characteristics of precipitates in bulk Si, the quantification of amorphization processes during ion implantation, the accurate measurement of oxide-

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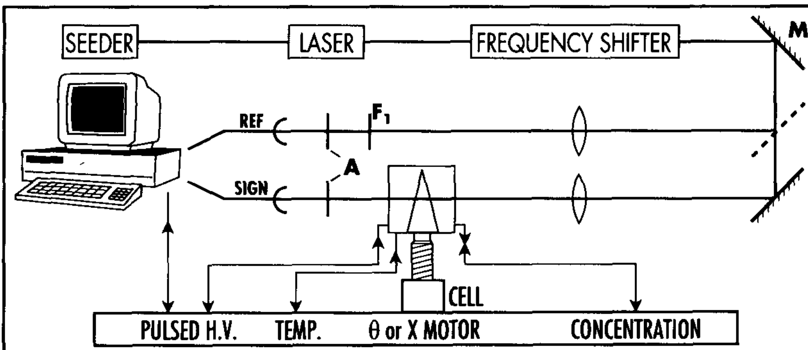

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nitride-oxide film thicknesses, and the determination of lattice strain in local isolation structures.

Novel amorphous Si crystallization processes mediated by silicides were described by J.L. Batstone (IBM, Yorktown Heights, NY), who presented impressive *in-situ* electron microscopy work which identified the importance of growth twinning for the underlying atomistic growth mechanism. While these studies concentrated on the characteristics of NiSi2, subsequent papers covered the characteristics of silicides of other elements, including those of Ti, Pt, and Fe. J. Brown (SEMATECH) gave an overview of the applications of many forms of microscopy in ULSI circuit manufacture. The use of cross-sectioning techniques to determine details of device architecture and to conduct failure mode analysis were described at length.

A second key feature of the conference was the extensive coverage of epitaxial layer growth in essentially all important semiconductor systems. Fundamental growth behaviors were described. F. Glas (CNET) focused on composition fluctuations and atomic clustering phenomena occurring in ternary and quaternary III-V compound alloy layers. These phenomena manifest themselves as coarse, quasi-periodic image contrast variations which have been observed in studies over a number of years. Distinct atomic ordering behavior in alloy layers was reviewed by A.G. Norman (IRC, Imperial College). This behavior can exhibit several different structural modifications and can markedly affect the electrical and optical properties of the layers. Ordering can be surface-induced, with a possible link to specific surface reconstruction during growth.

A wide-ranging discussion of strain relief in heteroepitaxial layer systems covered the characteristics of misfit dislocation introduction under many different circumstances. The complementary roles of x-ray diffraction and electron microscopy in assessing such systems were described by M.A.G. Halliwell (Philips Analytical) and important analytical approaches, including *in-situ* synchrotron x-ray topography, were addressed in other papers. In addition to discussing heteroepitaxial phenomena, N.A. Kiselev (Russian Academy of Sciences) considered the fabrication and properties of pointed single-crystal Si "nanotips" with atomic sharpness. The theme of nanostructures was extended by C.J. Humphreys (Cambridge University) to the fabrication of arrays of individual Si quantum dots in SiO_2 films by bombard-

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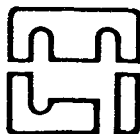

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Guests enjoy conference dinner in Keble College Hall: (left to right) J.M. Poate, J.L. Batstone, and N.A. Kiselev.

ment with finely focused high-intensity electron beams. The properties of more conventional epitaxial quantum-well and quantum-wire structures were described by many other authors.

A session was devoted to bulk compound semiconductors. C. Frigeri (MASPEC-CNR) described defect structures and impurity distribution inhomogeneities in LEC GaAs crystals. Gettering regions around grown-in dislocations were found to be mostly depleted of dopant atoms, and it was suggested that the deep donor EL2 is generated by these dislocations.

Scanning probe microscopy was employed in quite a number of investigations. J.B. Pethica (Oxford University) demonstrated how the scanning tunneling microscope (STM) can yield electronic-state images which allow atomic resolution of the work function on Si surfaces. Related work studied the adsorption of trimethylgallium on surfaces, while the AFM was exploited to examine a range of epitaxial growth phenomena together with integrated circuit microstructure. The application of advanced scanning electron microscopy (SEM) methods was much in evidence. D. Bimberg (Technical University of Berlin) described in detail how cathodoluminescence imaging can show the morphology of AlGaAs/GaAs heterointerfaces, with their associated step structure. Impressive work on the determination of carrier properties in GaAs quantum wires was also shown. Many investigators employed the electron-beam-induced current mode to measure the microscopic electrical characteristics of crystallographic defects. In addition, A.J. Wilkinson (Oxford University) demonstrated the use of a high-brightness SEM to image defects in bulk, unthinned samples by exploiting electron channeling contrast. The characteristics of misfit dislocations in SiGe/Si layers were examined and Burgers vectors directly determined from channeling contrast images obtained under controlled diffraction conditions.

The proceedings volume, about 800 pages, is to be published in 1993. In the United States and Canada it will be available from: Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237; phone (412) 367-3003; fax (412) 367-4373. Elsewhere, order from: IOP Publishing Ltd., Techno House, Redcliffe Way, Bristol BS1 6NX, U.K.; phone (44) 272-297481.

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