European Colloquium on Interfaces Held in Petten

The European Colloquium on "Designing Interfaces for Technological Applications: Ceramic-Ceramic, Ceramic-Metal Joining" was held April 20-21, 1988 in Petten, the Netherlands. It was sponsored and organized by the Joint Research Center (JRC), Petten Establishment within the framework of the Commission of the European Communities' role to support European industrial development.

The meeting's objective was to assess the potential of an interfacial science approach to improve the technology of joining ceramic materials. Joining is recognized as a critical factor in determining the acceptability of the new generation of engineering ceramics as components in industrial service.

JRC Petten, the host site of the colloquium, has an established tradition in high temperature materials research. The center, which has conducted extensive research in high temperature mechanical and corrosion properties of advanced ceramics, now has an ambitious research program on tailoring interfaces for ceramic joining and composites.

The colloquium was attended by 120 participants from research centers, universities and industrial laboratories. It covered three main subject areas, with topics in each area reviewed by invited eminent specialists as follows:

Joining Technology—technical requirements for designing interfaces for thermomechanical applications (D. Parker, T&N Technology Ltd., UK) and for electronic applications (K. Guy, GEC Research Ltd., UK); joining methods for structural ceramics (M. Nicholas, UKAEA-Harwell, UK); testing and mechanical properties of joints (G. Elssner, Max-Planck Institute, W. Germany), and fracture of joints (G. de With, Phillips Research Labs, Netherlands).

Interfacial Science—thermodynamics of ceramic/metal interfaces (J. Klomp, TNO University, Netherlands); structure of interfaces (M. Ruhle, University of California, Santa Barbara, USA); wetting and adhesion (N. Eustathopoulos, LTPCM-CNRS, France); and theoretical aspects of bonding (K. Stoneham, UKAEA-Harwell, UK).

Current Research and Outlook—review of R&D program in Europe (K. Ostijn, Belgian Welding Institute, Belgium), the United States (R. Loehman, Sandia National Labs, USA), and Japan (T. Suga, University of Tokyo, Japan); materials to be joined in 10 years from now (M. Lewis, University, Warwick, UK).

The colloquium was followed by a half-day workshop chaired by Prof. Fischmeister (Max-Planck Institute, W. Germany) in which the invited speakers and a number of selected experts participated. Its aim was to identify research needs, decide whether the bridging concept between interfacial science and joining technology is valid, and recommend research trends and follow-up actions. The workshop proved to be a valuable contribution to the colloquium and produced much constructive discussion. The workshop findings will be published in the colloquium proceedings.

For information about the colloquium proceedings contact: Materials Information Center, CEC, JRC Petten, Postbus 2, NL-1755 ZG Petten, Netherlands.

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Second European Workshop Demonstrates Strong Interest in MOVPE

The second European Workshop on Metalorganic Vapor Phase Epitaxy demonstrated the strong interest in MOVPE that has been established in Europe since the beginning of the 1980s. Organized by the British Association for Crystal Growth, the workshop has also established a pattern for annual workshops on this topic. The first workshop was held in Aachen, W. Germany in 1987. The third workshop is scheduled for June 4-7, 1989 at Montpellier and is being organized by Prof. G. Bougnot.

The second workshop was held June 19-22, 1988 at the University of St. Andrews, an ancient university town on the east coast of Scotland. It was organized in conjunction with a NATO-sponsored workshop on Mechanisms of Reactions of Organometallic Compounds with Surfaces. This provided an opportunity for joint sessions on reaction mechanisms and modeling, held the last day of the European workshop and at the start of the NATO workshop.

The format of the poster sessions presented the 207 workshop participants with a novel opportunity for discussion. All contributed papers (79) were presented as posters, but with the addition of post-viewing discussion sessions to highlight the more controversial points raised in the posters. Healthy controversy was evident throughout.

The morning sessions comprised invited talks on key issues in MOVPE. I.D. Henning (British Telecom) highlighted the challenge of new optoelectronic devices and, in particular, the need to integrate detectors and emitters with electronic functions. This requires the growth of heterostructures such as GaAs/InP and selective area epitaxy. The InP-based alloys are used for the emitters and detectors, while GaAs is used for FETs. It was proposed that GaAs FETs were less sensitive than detectors or emitters to dislocations, so it would be preferable to grow the lattice-mismatched GaAs onto InP rather than vice versa. The GaInAsP optoelectronic heterostructures could then all be lattice matched to the InP substrate.

A different view was taken by M. Razeghi (Thomson-CSF), who reported on recent advances in III-V epitaxy on Si. GaAs has a 4% lattice mismatch and InP an 8% mismatch with Si, which can give rise to high dislocation densities in the epitaxial layer. Propagation of dislocations can be reduced using a lattice-matched superlattice with device structures grown onto the superlattice. A further problem with heteroepitaxy on Si is the mismatch in thermal expansion coefficients. This is less in the case of InP, and recent results were reported where InP buffer layers were grown directly onto Si with 1.15 μm diodes or 1.3 μm lasers as the device structures.

A related poster session on non-lattice-matched structures highlighted the importance of reducing dislocation density and of the problems of thermal expansion mismatch. Several papers were concerned with GaAs heteroepitaxy on Si. Ackaert et al. (University of Gent) demonstrated a novel solution to the thermal mismatch problem by using selective epitaxy of GaAs in etched windows in an SiO_2 coating. Choice of the size and shape of the windows could avoid wafer bending and cracking in the GaAs.

Uniformity of alloy compositions and electrical properties is a topic that is increasing in importance with the commercialization of MOVPE. A. Mircea et al. (CNET) described a "T"-shaped horizontal reactor design which used a gas "curtain" to avoid reactive gases collecting around the rotating substrate. Uniformity results over a 2-inch wafer were 1% in growth rate, 100 ppm change in GaInAsP composition, and 5% in doping concentration.

Indeed, requirements for material quality and uniformity place ever increasing demands on materials characterization. B. Hamilton (UMIST) described some techniques and problems associated with characterizing MOVPE layers. The poster session on characterization featured a range of contributions covering x-ray diffraction, photoluminescence, electrical, chemical analysis, and electron microscopy.

The poster session on doping generated discussions on the problems of n-type doing III-V compounds at high carrier concentrations. X. Tang et al. (University of Nijmegen) showed that for donor concentrations above 3 x $10^{18}cm^{-3}$ in GaAs, the compensation ratio approached 1 and higher SiH_4 flows resulted in precipitates. M. Vilela et al. (Laboratoire Physique du Solide et Energie Solaire) used Pb from tetraethyl lead to dope GaAlAs up to concentrations of approximately $10^{19}cm^{-3}$.

Two different groups reported on a new effect of hydrogen incorporation in InP: S. Cole et al. (British Telecom) and B.R. Butler et al. (STC Technology). The electrically active level of zinc-doped InP depends on how it is cooled from the growth temperature. With an ambient of AsH_3, the activity is less than with PH_3 which, in turn, is less than for an H_2 ambient. Both groups agree on the mechanism of monoatomic hydrogen on the surface diffusing into a cooling layer. Concentrations of hydrogen up to approximately $10^{18}cm^{-3}$ were detected by SIMS and appear to compensate or neutralize the Zn acceptor.

Doping in II-VI compounds is at a much earlier stage of development but, if successful, could lead to rapid implementation of MOVPE for these materials. P. Capper et al. (Philips Research Laboratories) reported on successful p-type doping of CdHgTe using As from AsH_3 up to concentrations of $3 \times 10^{17}cm^{-3}$. Good agreement was obtained between SIMS and Hall data, indicating a high activity factor.

Speaking on $Cd_{0.7}Hg_{0.3}Te$ grown onto GaAs for optical fiber communications L.M. Smith et al. (GEC Hirst Research Center) challenged the domain of III-V quarternary alloys for 1.3 - 1.55 μm photodiodes. The low series resistance, 40Ω and approximately 10 nA reverse bias leakage currents were comparable with GaInAsP detectors. This result is all the more remarkable because the substrate/layer lattice mismatch is 14%.

A critical comparison between MOVPE and MOMBE was made by M. Weyers and P. Balk (Technical University, Aachen), who posed the question - are they really different? The differences are more a question of degree, despite the differences in growth chambers and transport mechanisms. V/III ratios, surface kinetics, and carbon incorporation were compared with the two methods.

The challenges for new device applications were highlighted in two contrasting papers, one on visible emitters by J.P. Andre (LEP) and the other from J.L. Beeby (University of Leicester) on new device concepts. New devices could exploit some of the physics of low dimensional structures, particularly in high electric fields. A very high degree of control would be required in the growth process, and old conflicts were stirred by comparisons with MBE.

A poster session on precursors demonstrated that MOVPE is no longer in the era of "just accept what's available" but represents a new challenge to design metalorganics for a required purpose.

Extensive studies of surface reactions of organometallic As compounds by T.R. Ormstead et al. (University of Minnesota) were used to propose reaction paths which help explain carbon incorporation problems. Arsine substitutes are an important topic because of the need to improve safety. Two other papers were devoted to this pursuit, one by M. Lopez Coronado et al. (Ciudad Universitaria, Madrid) using diethylarsine, and the other by R. Druilhe (CNRS) in collaboration with authors from Liban, Belvedere, and Valbonne, using trimethyl-and triethylarsine. Notably, much of the discussion session was occupied with aspects of safety. A novel solution to the old problem of monitoring alkyl pressures was proposed by Butler and Stagg (STC Technology), who used an ultrasonic technique to monitor trimethylindium.

The joint NATO/EW-MOVPE session on reaction mechanisms included talks on the D_2 labeling technique by G.B. Stringfellow (University of Utah), modeling of the chemical boundary layer by M.H.J.M. de Croon and L.J. Giling (University of Nijmegen), atomic layer epitaxy by P.D. Dapkus et al. (University of Southern California), and photo-induced organometallic processes by J. High (British Telecom). The posters on this topic mostly concerned reactor designs, modeling flows, and determining flow patterns. One notable poster that drew a large crowd was by J. van Suchtelen et al. (University of Nijmegen). Their poster on the pulse reactor was backed up with a video of the reactor in operation. Mass flow controllers were eliminated by switching in fixed volumes of precursors in the vapor at low pressures. The sequence of switching was elegant and certainly wins the prize for the most original approach.

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