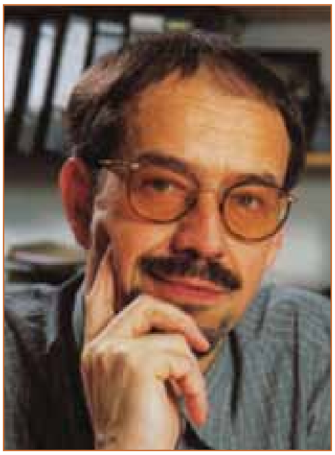
In Memoriam



Ulrich Gösele

1949-2009

It is with great regret and a sense of shock that we announce the completely unexpected and untimely death on November 8, 2009, at the age of 60, of **Ulrich Gösele**, Director of the Max Planck Institute of Microstructure Physics in Halle, Germany, and Scientific Member of the Max Planck Society. Ulrich Gösele was a lifelong member of ECS (he joined 1987), and in 1999 he received the ECS Electronics and Photonics Division Award. Over the last two decades he was well known for organizing several successful ECS symposia ranging from Semiconductor Wafer Bonding, to Silicon Materials Science and Technology, and to Porous Silicon.

Ulrich Gösele was born in Stuttgart, Germany in 1949. He started his career in science as a physics student at the universities of Stuttgart and Berlin and received his PhD at the University of Stuttgart, Germany (1975) for his theoretical thesis work performed at the Max-Planck-Institute of Metals Research in Stuttgart. After visiting researcher assignments at the atomic energy board in Pretoria, South Africa (1976-77), and subsequently at the IBM T. J. Watson Research Center in New York (1980-81), he became a research scientist at the Siemens Research Labs in Munich, Germany. In 1985, he moved to the U.S. and became a full professor of materials science at Duke University in North Carolina at the age 36. In 1991 he spent a year at the NTT LSI Laboratories in Japan, as a visiting scientist; and in 2003 he held a visiting professorship at Harvard University in Cambridge, Massachusetts, USA.

In 1993 Professor Gösele became one of the two founding Directors of the newly established Max-Planck-Institute of Microstructure Physics in Halle, Germany, while being at the same time an adjunct professor at the Martin-Luther-University of Halle-Wittenberg and at Duke University, in North Carolina, as well as Honorary Professor at the Chinese Academy of Sciences. Professor Gösele was a member of the German Academy of Sciences, Leopoldina, and the recipient of the Information Science Award in 2005. He was involved in numerous international expert bodies. He was a Fellow of the Institute of Physics, and from 2002-2005 he was on the board of directors of the Materials Research Society. He was notified by the German Government that he was to be bestowed with the "L'ordre national de mérite" (Bundesverdienstkreuz) Medal of Honor in 2010.

Professor Gösele's research interests have focused on different pioneering areas of semiconductor materials science: theory of point defects and diffusion processes in silicon and other semiconductors; defect formation during crystal growth or during device processing and implications on the electronic quality of the materials; quantum effects in porous silicon; the science and technology of semiconductor wafer bonding; self-limited fabrication of nanostructures; quantum dots; quantum wires and atomic layer deposition (ALD); and ferroelectric thin films, photonic crystals, and silicon photonics.

During his career Dr. Gösele published more than 610 articles in refereed journals, and a similar number of conference papers, which have been cited collectively more than 20,000 times, including over 2,500 times last year, leading to an *h*-factor of 67, which is impressively high in the field of solid state physics and semiconductor physics.

Gösele was a major leader in the development and utilization of directly bonded wafers (Silicon-on-Insulator or SOI) and to the ECS community; he is, of course, most famous for his work on the science and technology of semiconductor wafer bonding. He developed the first model for the hydrophobic wafer bonding mechanism; he invented the first bonding machine (micro-cleanroom) and developed the "Smarter-Cut" process by using boron and hydrogen ions co-implantation to reduce the critical dose of layer splitting in silicon. He also developed bonding-based processes for the heterointegration of semiconductors such as silicon carbide, germanium, gallium arsenide, and gallium nitride, and various techniques for twist bonding and compliant substrate formation. But above all, Dr. Gösele was well known and most famous for his two seminal books entitled, *Semiconductor Wafer Bonding: Science and Technology* by Q.Y. Tong and U. Gösele in The Electrochemical Society Monograph Series (Wiley-Interscience, 1998), and *Wafer Bonding: Applications and Technology* by M. Alexe and U. Gösele in Springer Series in Materials Science (Springer, 2004). These two monographs, together with the proceedings of the ECS wafer bonding symposia, established the standard reference today in this field. In 1991 Dr. Gösele launched the first of the successful ECS symposia on Semiconductor Wafer Bonding: Science, Technology, and Applications, which he organized for several years with Dr. Takao Abe from SEH Co. and others. The 11th ECS Wafer Bonding Symposium this year in Las Vegas in October 2010 will be dedicated to the memory of its founder, Professor Gösele.

Ulrich Gösele was among the early group of scientists globally, who investigated the nature of point and extended (line) defects and their mutual interaction during both crystal growth and subsequent device (MOSFET) fabrication. These studies were often utilized en route to fabricating DRAMs, the significantly important device utilized for integrated circuit (IC) memory applications. The role of such defects, often in conjunction with various concentrations of oxygen and carbon, resulted in the formation of variously configured "swirl" type patterns in the silicon wafers. The swirl formation during silicon single-crystal growth and subsequent modification and relation to diffusion mechanisms in silicon during MOSFET device fabrication was a major component in the observation of less than anticipated device performance, yield and reliability. Introduction of metallic impurities, both purposely during device fabrication and, often, due to contamination during the multitudinous device fabrication processes, presented significant issues for their comprehension and control. Indeed, where diffusion was modelled by Fick's Laws, the more complicated diffusion and segregation equation (DSE) yielded critical insight in the understanding of gettering mechanisms, during both silicon crystal growth and subsequent device fabrication in single-crystal silicon. Gösele was at the forefront, in conjunction with leadership silicon research personnel from Japan, Europe, and America, in facilitating the comprehension and clarification of these various phenomena.

Additionally, Gösele and Tan developed (around 1989) a model of the precipitation, dissolution, and re-precipitation of oxygen in single-crystal silicon wafers under a specific set of fab thermal process conditions. Indeed, as the IC industry

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expanded to include 300 mm wafers, a marvellous opportunity developed. That is, the initial 300 mm wafer shipments from the various silicon wafer producing companies were utilized to assess their wafer handling capabilities in the fab, such as at SEMATECH and other leading-edge IC manufacturers. Not surprisingly, each silicon wafer supplier exhibited a rather narrow, but different magnitude of oxygen concentration during these early days of assessing 300 mm wafers. According to one of the authors (HH), their experimentation (at SEMATECH) of these initial silicon wafers, with significantly different oxygen concentration in the as-delivered silicon wafers from the various suppliers, and the resulting differences in the oxygen concentration behaviour to a set of thermal process conditions, were in quite good conformance with the Tan/Gösele theory noted above. That is, the oxygen precipitation, dissolution of oxygen precipitates, and then the re-precipitation of oxygen was, indeed, experimentally replicated and found dependant on the initial oxygen concentration range. These were quite heady times in the rather complex behavior of both the experiments and their consistency with theoretical considerations.

Gösele was a significant presence and participant in many of the international conferences on Silicon Materials Science and Technology, also referred to as the Silicon Symposia. Gösele was a session organizer and, subsequently, symposium co-organizer and co-editor with Huff and Tsuya (Sumitomo Sitix Corporation) for the Eighth Silicon Symposium in 1998. This particular symposium may indeed have been the peak of the ten symposia (1969 through 2006) inasmuch as the symposium was also celebrating the 50th anniversary of the commercialization of the point-contact transistor. Of the ten iterations, the eighth symposium was the largest in terms of number of papers, pages, and global participants.

On a more personal note, one author (HH) had the thrill of the meetings with Gösele and colleagues in Germany akin to the meetings in the 1920s with leaders in Germany establishing the new quantum mechanics, in conjunction with key visitors from Europe, England, and America. And in the 1990s, with Gösele's leadership playing a key role in the formulation and interpretation of the dynamics associated with oxygen, carbon, metallic impurities, etc., in silicon, along with oxygen precipitation, dissolving, and the re-precipitation formulation. This author (HH) has retained these most happiest of thoughts of his participation with Gösele and colleagues ever since.

As a scientist, Ulrich Gösele made lasting contributions in many fields; he is perhaps best known for invoking quantum effects in the context of microporous Si. The first paper, entitled "Porous Si Formation—A Quantum Wire Effect," published in *Applied Physics Letters* in February 1991 was originally turned down by the referees, like several other ones with revolutionary ideas from Gösele, but was ultimately cited 1,146 times and triggered thousands of papers in the general area of porous semiconductors (together with an independent paper by L. Canham). From microporous Si evolved substantial work in the related area of meso- and macroporous semiconductors and alumina that was not only widely acclaimed but also formed the basis for Si-based photonic crystals and Si photonics, again with outstanding success. Moreover, porous materials, often with self-organized structures, were used as templates for a wide range of nano-structured functional materials. Ulrich Gösele was a regular keynote and invited speaker at the ECS "Pits and Pores" symposia. His intellectual and verbal sharpness will be sorely missed. The ECS fall meeting in Las Vegas from Oct. 10-15, 2010, will contain a "Pits and Pores" symposium dedicated to the memory of Ulrich Gösele.

Dr. Gösele is survived by a son, Michael Gösele; two daughters, Andrea Thomas and Bettina Gösele; and their mother Julia Gösele; all residing in the United States. He is also survived by a sister, Regine Grupp, who resides in Germany. ■

This memorial notice was contributed by Helmut Baumgart, Chaired Professor of Electrical Engineering, Old Dominion University, Norfolk, Virginia; Cindy Colinge, Tyndall National Institute, Cork, Ireland; Tadatomo Suga, University of Tokyo, Japan; Howard Huff, SEMATECH Senior Fellow, Emeritus, Austin, Texas; Bernd Kolbesen, University of Frankfurt, Germany; and Patrik Schmuki, University of Erlangen-Nuremberg, Germany.

In Memoriam

Clifford F. Hiatt (1932-2009), member since 1976, Electronics and Photonics Division.

James E. Hawkey (1936-2009), member since 1976, Electronics & Photonics Division

Robert L. Lambert (1915-2009), member since 1945, Electronics & Photonics Division

2. SED FUNDAMENTALS. Solid electrochemical deposition is a modified form of conventional chemical vapor deposition (CVD). Figure 1 compares SED with conventional CVD. Briefly, in an SED process, at least one reactant (A) is transported from the source side of a solid phase (E) to the sink side under well-controlled thermodynamic and kinetic conditions.Â None of these have equaled the performance of electrochemical vapor deposition. Thus, Î•YD has become a key technology for the aforementioned applications. 4. closed circuit sed -polarized electrochemical vapor deposition. Fundamentals of Electrochemical Deposition, Second Edition is a comprehensive introduction to one of today's most exciting and rapidly evolving fields of practical knowledge. The most authoritative introduction to the field so far, the book presents detailed coverage of the full range of electrochemical deposition processes and technologies, including: * Metal-solution interphase * Charge transfer across an interphase * Formation of an equilibrium electrode potential * Nucleation and growth of thin films * Kinetics and mechanisms of electrodeposition * Electroless deposition * In situ cha

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Center for Electrochemical Engineering Research, Ohio University. 9. Electrochemistry Fundamentals. Current Efficiency, and Current Distribution â€¢ Current efficiency = 100 * WAct/WTheo. Wact is the weight of metal deposited or dissolved WTheo is the corresponding weight to be expected from Faradayâ€™s.Â Electrochemistry Fundamentals. â€¢ How to determine the potential of deposition for two metals codeposition ? Key point- the onset of the reduction peaks in CV. (1) If the two reduction peaks of metals are not separated, both of metals can be reduced when operating potential is more negative than the onset potential. 5.1.2 Fundamentals of metal deposition. Faradayâ€™s laws provide the theoretical basis of electrodeposition (Antropov, 1977). The quantity of metal deposited (W) at the cathode surface can be expressed as the product of quantity of total coulombs passed (Qc) and the electrochemical equivalent of the metal (zc): [5.4]. Q.Â Potential changes during electrochemical deposition of lead metal were monitored with the help of platinum electrode P2 coupled with a calomel electrode C. Figure 13.23. Experimental setup to monitor potential changes during electrochemical deposition of metals in a batch reactor [52]. View chapter Purchase book. Substitution of solvents by safer products. @inproceedings{Paunovic2006FundamentalsOE, title={Fundamentals of Electrochemical Deposition: Paunovic/Fundamentals of Electrochemical Deposition, Second Edition}, author={Milan Paunovic and Mordechay Schlesinger}, year={2006} }. Milan Paunovic, Mordechay Schlesinger. View via Publisher. Save to Library. Create Alert. Cite. Share This Paper.