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ORNL

FOREIGN TRIP REPORT

ORNL/FTR-3376

DATE: September 13, 1989

SUBJECT: Report of Foreign Research Assignment of S. P. Withrow, Research Staff Member, Ion-Solid Interactions Group, Solid State Division

TO: Alvin W. Trivelpiece

FROM: S. P. Withrow

PURPOSE: To participate in research on ion implantation and annealing effects of deuterium into SiC at the Max-Planck-Institut für Plasmaphysik (IPP) as part of a scientific exchange between ORNL and IPP.

SITES VISITED:

3/1–8/27/89	Max-Planck-Institut für Plasmaphysik	Garching bei München, FRG	V. Dose J. F. Roth R. Siegele
4/3–6/89	Low Energy Ion Beam-5 Conference	Guildford, Surrey, UK	J. Golden I. H. Wilson
5/28–6/2/89	European Materials Research Society Conference; PHASE Laboratory, CNRS	Strasbourg, France	E. Fogarassy A. Golanski F. Priolo
6/5–8/89	Kernforschungsanlage	Jülich, FRG	C. Buchal B. Stritzker

ABSTRACT: The traveler was on foreign research assignment at the Max-Planck-Institut für Plasmaphysik at Garching bei München, FRG, from March through August 1989. He participated in research in the area of ion implantation of deuterium into SiC and subsequent annealing effects. The traveler attended and presented papers on work done in the Solid State Division at ORNL at two conferences: the Low Energy Ion Beam-5 Conference held at Guildford, UK, and the European Materials Research Society Conference at Strasbourg, France. Seminars were also presented during a laboratory visit to Kernforschungsanlage, Jülich, FRG, and at IPP.

I. INTRODUCTION

The traveler was on foreign research assignment at the Max-Planck-Institut für Plasmaphysik (IPP) at Garching bei München, FRG, from March 1 to August 27, 1989. The purpose of the assignment was to utilize the facilities available at IPP for hydrogen implantation and detection in order to study the interaction of deuterium with single-crystal SiC, a material of interest for fusion reactor applications and for high-temperature, high-power semiconductor devices. The assignment fell under the General Exchange Agreement between IPP and ORNL under which J. F. Roth from IPP has worked in the Solid State Division (SSD) at ORNL on three separate occasions since 1982.

While on foreign assignment, two conferences in Europe were attended: the Low Energy Ion Beam-5 Conference held April 3–6 at the University of Surrey, Guildford, Surrey, UK, and the European Materials Research Society (E-MRS) Conference held May 29–June 2 in Strasbourg, France. In addition, a laboratory visit was made to the PHASE (Physics and Applications of Semiconductors) Group, Centre de Researches Nucleaires (Nuclear Research Center), in Strasbourg, France, and to the Institut für Schicht- und Ionentechnik (Institute for Thin films and Ion Techniques) at the Kernforschungsanlage, Jülich, FRG.

This report describes the research carried out at IPP as well as personal impressions obtained during the assignment. Highlights of the conferences and laboratory visits are summarized in separate sections.

II. ASSIGNMENT AT THE MAX-PLANCK-INSTITUT FÜR PLASMA-PHYSIK, GARCHING BEI MÜNCHEN, FRG

A. Research at IPP

Research during this assignment was carried out using facilities in the accelerator laboratory of the Surface Physics Division at IPP in Garching bei München, FRG. The work was done in collaboration with J. F. Roth, a senior staff member, and with R. Siegele, a graduate student doing his thesis work at IPP. The traveler utilized the facilities available for hydrogen

implantation and detection to study the interaction of deuterium with single-crystal SiC. SiC is a candidate material for the first wall of magnetic confinement fusion reactors since it is a refractory material with good thermal shock resistance and has a low atomic number (Z) which minimizes radiation losses if particles enter the plasma. Relatively little is known about the trapping and retention behavior of H in SiC although this behavior may be critical for the operation of a fusion device. SiC is also of considerable interest as a candidate high-temperature, high-power superconductor material, and the traveler has been involved over the past several years in research on growing, doping, and characterizing single-crystal SiC for device applications. In this regard, understanding the interaction of H with SiC is necessary since some of the techniques presently employed to grow SiC involve hydrogen-containing compounds.

Single-crystal β-SiC samples prepared at North Carolina State University were implanted with D_2^+ ions at 24 keV (ion range of 1500 Å). Following implantation, damage in the lattice and total retained implant dose, as well as the lattice location of the D, were determined in situ using ion beam techniques. Samples were annealed in situ to 800°C using resistive heating of the mounting block and annealed to 1050°C in a separate vacuum chamber.

Radiation-induced damage is readily introduced into single-crystal SiC at room temperature, with doses of $>5 \times 10^{16}$ D/cm^2 (at the 12 keV/nucleon energies of these experiments) required to amorphize the lattice at the ion range depth. The measured displacement of Si lattice atoms is linear with dose up to near the amorphous dose. Additional implantation eventually creates an amorphous surface layer. Retention of D is 100% to a dose of $\sim 2 \times 10^{17}$ D/cm^2, and saturation occurs for a fluence close to 1×10^{19} D/cm^2, or above 0.5 D per substrate atom. For implantation at 500°C, three times the D dose is required to amorphize the substrate at the depth of the ion range, and the saturation dose is approximately half that at room temperature.

Most of the damage induced by implantation up to fluences approaching amorphization can be annealed at 800°C. However, no D is lost, and the D depth distribution does not change at this temperature. Annealing at 1050°C results in the loss of half of the implanted D. Scanning electron micrographs of samples heated above 800°C show evidence of micron-sized

bubble formation, and in some cases the "cap" on the bubbles has broken through the substrate surface, releasing D. Strain in the near-surface region from these bubbles was also observed in ion channeling spectra following high-temperature annealing.

Angular scans were obtained from three low index axes to determine the extent of D ordering with respect to the substrate lattice. No evidence of substitutional D under any of the implantation and annealing conditions studied was found.

A seminar entitled "Ion Beam Annealing of Implanted Si" was given at IPP. In addition, the facilities and the current research directions at the Surface Modification and Characterization (SMAC) Collaborative Research Center at ORNL were shown in a poster as well as discussed in a talk. A second poster, showing research results obtained at ORNL on ion beam deposition (IBD) of β-SiC layers onto α-SiC, was also displayed and discussed with IPP staff members during the assignment.

B. Comments on the Surface Physics Division at IPP

Research during this assignment was conducted in the Surface Physics Division at IPP. The division has nearly 70 members, of which at present 18 are permanent research staff, roughly the same number are graduate students, more than 20 persons provide technical support, and the remainder are postdocs and guests. This ratio of research staff to other division members is markedly different than found in the SSD at ORNL. Many of the technical personnel are directly assigned to individual permanent staff members or projects. Perhaps as a result of this, they appear to be considerably more involved and take considerable interest in the results of the research effort. The working relationship between the research staff and the technical staff is in most cases excellent. The high number of graduate students, most of whom are highly motivated (their paid tenure at IPP cannot exceed three years), assures a constant influx of new faces and ideas, similar to the situation in graduate departments at U.S. universities.

Research in the division is divided into three somewhat different areas: plasma wall interactions, plasma technology, and surface physics.

The plasma wall interactions group includes about half of the permanent research staff and is involved in basic research on the interaction of ions with materials of potential application to fusion reactors. In addition, this group provides technical support for the ASDEX and ASDEX UPGRADE programs at IPP and for other European plasma physics efforts. The plasma wall interactions group maintains an accelerator laboratory, which includes facilities for implantation of hydrogen species and other light elements and for materials analysis using ion beam techniques, including Rutherford backscattering (RBS), nuclear reaction analysis, and elastic recoil detection. In general, the data acquisition, data analysis, and computer systems in this laboratory are not as extensive or sophisticated as the corresponding facilities at ORNL. However, many of the capabilities for implantation and analysis of H species at IPP are not available at ORNL, and the traveler primarily utilized these facilities while on assignment.

At present, basic research interests in the plasma wall interactions group include studying the dynamic interaction of H plasmas with C, H loading of materials at elevated temperatures, and theoretical ion-solid computer simulations. The group also develops plasma diagnostics on the ASDEX tokamak. In a "crash program" in response to the cold fusion excitement (which occurred while the traveler was on assignment), the D-D neutron cross section was measured at incident energies down to 1 keV by implanting D into Ti. No anomalous behavior of the cross section was observed.

The plasma technology effort, which was started about one year ago, is directed toward producing thin-film coatings with applications for fusion devices using plasma deposition. The group is small and includes a research staff member, several graduate students and postdocs, and a technician. Four separate deposition systems are in various stages of development and use. Three of them utilize electron cyclotron resonance (ECR) plasmas and the fourth an rf plasma. One of the systems is designed primarily for studying the ECR film deposition process and hence is closely related to the ECR plasma effort currently under way in the SSD. This device has some very nice diagnostics, including a laser reflectivity thickness monitor, Langmuir probe for measuring plasma temperatures, and Thompson scattering for measuring plasma parameters. It operates with up to several

hundred watts input power and at an ambient pressure on the order of 10^{-2} Torr. Initial experiments include depositing carbon films from a methane plasma. In the future it is expected this apparatus will be used to study the deposition of BC films. The other three deposition systems are being developed for special tokamak applications, including film deposition onto the inside surfaces of a stainless steel waveguide used for heating the JET tokamak, deposition of insulating layers on the backside of a bolometer used for measuring radiation in plasmas, and deposition onto the irregularly shaped ion cyclotron heating antenna.

The surface physics group is involved in basic research using the inverse photoemission technique to measure electronic properties of materials. This program is organized very much like a university graduate program, with much of the equipment development and research carried out by graduate students under the supervision of the division director, V. Dose, and two permanent staff members. Dose, who has a strong background and interest in surface physics, is presently negotiating a joint surface physics appointment between IPP and the University of Bayreuth. Partly because of the demands this new call will make on his time, the division is presently undergoing a reorganization in which three permanent staff members are being promoted to be leaders of the research groups. It will take some time to evaluate how this new organization works in practice and what impact it might have on future collaborative research with the SSD.

III. LOW ENERGY ION BEAMS-5 CONFERENCE, UNIVERSITY OF SURREY, GUILDFORD, SURREY, UK

The Low Energy Ion Beam-5 (LEIB-5) Conference was the fifth in a series of meetings held every other year in the UK and organized by the Atomic Collisions in Solids Group of the (UK) Institute of Physics. LEIB-5 was co-sponsored by the Materials Research Society. Proceedings of the conference will be published in a special issue of the journal *Vacuum*.

LEIB-5 was chaired by I. Wilson of the University of Surrey. Approximately 100 scientists attended the meeting, of which about ten percent were from the U.S. Eight invited and 63 contributed papers were presented in

seven oral sessions and one poster session/equipment show. The invited papers were review papers in the style of Gordon Conference presentations, and the size of the conference allowed for a very informal atmosphere, which promoted excellent interaction among conference attendees both during and outside the technical sessions.

The LEIB conferences are designed for presentation of research on the development and application of low-energy ion beams for surface modification and materials analysis. Twenty percent of the talks at LEIB-5 were on ion sources and another 20 percent on ion optics. Several computer codes were discussed that simulate ion-solid interactions, including some that ran on PC's and one that ran on a PC and calculated ranges in single crystals. There seemed to be interest in these new codes, in part because of their convenience and cost to run.

Some interesting data were shown by A. Al-Bayati from Salford University using medium-energy ion scattering (depth resolution quoted at 6 Å!) to look at substrate damage that occurs during IBD onto a Si substrate. No enhanced scattering yield was seen deeper than 35 Å. This is in contrast to the deep damage seen in IBD samples at ORNL. The Salford ion optics are designed to minimize neutral particles hitting the target, which may explain the damage seen at ORNL. Unfortunately, and surprisingly, no results from the Salford group on IBD were presented. In discussions with conference attendees from Salford, the impression left was that their system has vacuum problems, and in addition, a strong emphasis is placed on their equipment design with less interest in applications.

An excellent paper was presented by I. Wilson showing scanning tunneling microscope pictures of craters left by individual ion impacts in a Si surface. While the sputter yield under the conditions of the experiments was not high, considerable rearrangement of atoms in the neighborhood of the impact occurred. Calculations were given correlating the size of the crater with the energy density deposition occurring during impact. Interest was shown by co-authors of this research in initiating a collaboration with the SMAC facility.

There has been interest in upgrading the IBD facilities in the Ion-Solid Interactions (ISI) group at ORNL. The traveler was surprised to learn that a firm in the UK, VSW Scientific Instruments, Ltd., (in close association with

Salford University) is planning to market an instrument for IBD. The instrument is being designed in part as an add-on feature for molecular beam epitaxy (MBE) systems to provide beams that cannot be easily obtained by evaporation techniques. The current density is expected to be comparable to that obtainable using MBE. The first VSW Scientific IBD instrument is planned for delivery in the UK in 1990, and at least one has been ordered by a university in the U.S. The cost for the entire VSW Scientific IBD system, which includes a vacuum chamber and many diagnostics, will be greater than $1,000,000. Individual components will probably be sold separately, but their marketing has not been determined. Further information on the instrument will be sent to the traveler when available. Because of the prominent position the ORNL group enjoys in the field of IBD, the representatives from VSW Scientific were very interested in feedback from ORNL personnel on this new product.

Program suggestions and impressions of the LEIB meeting from an organizational viewpoint were sent to staff members at ORNL who will host a similar topical conference in 1990.

IV. EUROPEAN MATERIALS RESEARCH SOCIETY CONFERENCE AND VISIT TO CNRS, STRASBOURG, FRANCE

The traveler attended the 1989 European Materials Research Society Conference held in Strasbourg, France, May 29–June 2. There were 603 participants listed in the conference directory, approximately 1/6th of which were from the U.S. The conference was held at the Council of Europe Building, which has modern meeting facilities, but the distance between the five parallel symposium locations and some technical problems with audio systems had a negative impact. Two talks at the opening plenary session dealt with funding of materials research programs in Europe. These programs require involvement of researchers from different countries and, in some cases, industrial collaboration, underscoring interest in collaborative research which mirrors a similar direction for some research funding found at ORNL. The traveler presented a talk in the Beam Processing and Laser Chemistry Symposium entitled "Ion Beam Annealing of Ga-Implanted Si."

An excellent paper on ion beam annealing (IBA) was presented by F. Priolo. New results show that IBA is possible in Si with oxygen present either implanted or as an oxide. In contrast, thermal annealing of Si-O systems is difficult. This result was touted as of particular interest due to possible device applications. During the conference, the traveler had the opportunity to exchange information with Priolo on recent results from research on IBA of Si with high-dose Ga and As implants. These discussions will be of great benefit in planning future research in this area at ORNL. Another interesting presentation, given by A. Golanski, was an overview of the field of ion beam synthesis of buried compound layers, an area of research interest at ORNL. The paper presented a good review of what has been learned and what prospects are envisioned, and the presentation stimulated one of the liveliest discussions in the symposium with a lot of comments and questions concerning possible applications. A. Golanski is presently a visitor to the SSD at ORNL for a year. Contact with him during the E-MRS Conference helped him organize this visit.

One afternoon the traveler arranged for a visit to the PHASE (Physics and Applications of Semiconductors) group laboratory at the Center for Nuclear Research in Strasbourg. Primary research facilities at the institute include YAG and excimer lasers, accelerators for implantation and ion beam analysis, secondary ion mass spectroscopy, and deep level transient spectroscopy. Current research interests involve deposition of high-T_c superconductor films using laser ablation, deposition of amorphous Si films, and scanning laser annealing studies. An apparatus for photo-enhanced chemical vapor deposition of amorphous Si is being built. This system will use an internal lamp system to avoid having to shine UV light thru a chamber window. Facilities for resonant ionization spectroscopy (one atom detection) are also under development.

V. VISIT TO KERNFORSCHUNGSANLAGE, JÜLICH, FRG

The traveler's visit to Kernforschungsanlage (KFA), Jülich, was hosted by C. Buchal and B. Stritzker in the Ion Technique (IT) Division of the Institute for Thin Film and Ion Techniques. This division consists of more than

20 persons involved in research in six areas: (1) ion beam analysis, including RBS, nuclear reaction analysis, and elastic recoil detection; (2) ion implantation and solid state epitaxy in ceramic materials; (3) medium-energy ion scattering; (4) silicides; (5) sputtering and ion beam mixing; and (6) high-temperature superconductors. These areas closely overlap research interest in the ISI group in the SSD at ORNL, and there has been close collaboration between the two groups for a number of years. The traveler's visit included a tour of the experimental facilities and discussions with KFA staff on current research interests. In addition, one day was spent using the RBS facilities in the IT accelerator laboratory to analyze a sample which the traveler provided. A seminar entitled "Ion Beam Deposition of β-SiC onto α-SiC" was given, followed by a discussion of the facilities and the current research directions at the SMAC facility at ORNL.

The experimental facilities at KFA for ion-solid interaction research are extensive and well-maintained. The accelerator laboratory has facilities for implantation and ion beam analysis comparable to the Extrion and Tandem accelerators in the SSD at ORNL. In addition, a medium-energy ion scattering system has been purchased recently and was being installed during the traveler's visit. In addition to the accelerator laboratory, the group maintains both a mechanical lab with a hardness tester and two different adhesion testers, as well as a sample preparation and characterization laboratory with a rapid thermal annealer, vacuum furnace, dectak for surface profiling, a four-point sheet resistance probe, and several lasers.

Discussions were held with both permanent staff members and graduate students on current research interests. S. Mantl is studying Si-Ge superlattices grown by MBE with research efforts aimed at tailoring the band gap by altering the buffer layer between the noncommensurate Si and Ge lattices. This work represents an industrial collaboration with the AEG Ulm Corporation. Mantl is also involved in studies of high-energy implantation to form buried silicides, including $CoSi_2$. C. Buchal is continuing work begun while a visitor to ORNL on the formation of waveguides in $LiNbO_3$. In addition, he is involved in producing thin-film, high-temperature superconductors using laser ablation. Considerable effort has been put into determining the necessary substrate temperature and oxygen ambient pressure to form good superconductors on $SrTiO_3$ substrates. Present interest is

directed toward finding a suitable buffer layer so that superconductors can be deposited onto Si substrates.

Several laboratories were also visited in the Institute for Solid State Physics. Of particular interest was a discussion held with G. Cox, who is part of a group that has built a scanning tunneling microscope. The instrument is being used to study defects in the surfaces of semiconductors, with particular interest in GaAs. The system incorporates a sample load lock chamber and a sample characterization chamber in addition to its microscope capabilities. The unique design of the sample mount allows minute translations of the sample so that the microscope can image different areas of the surface. Data from virgin GaAs have been used to study the best method for cleaving the samples. Changing the polarity of the tip allows for the imaging preferentially of either Ga or As atoms, and individual atomic vacancies as well as adsorbed atoms from the ambient at edge sites have been observed. In the future emphasis will be placed on imaging dislocations.

Another benefit of the visit to KFA was to learn about the data acquisition system for ion scattering that has recently begun operation in the IT division accelerator laboratory. In concept, the KFA system and one under development in the SMAC facility are very similar. "Hands-on" experience with the data acquisition system at KFA, for which there is no documentation, was obtained by analyzing a sample provided by the traveler. Details of the system were communicated to staff members at ORNL following this visit.

VI. CONCLUSIONS

This assignment provided the traveler an opportunity to utilize facilities maintained at IPP for implanting D to study the interaction of D with SiC. The results of the research undertaken will be of interest both to the fusion community and also to scientists working on semiconductor applications of SiC. The research initiated during the assignment will be continued as part of the thesis of R. Siegele, a graduate student at IPP, and further collaboration between IPP and the SSD at ORNL in this work is anticipated. The contribution that graduate students make to the IPP research effort was

evident and suggests we could benefit by examining ways to increase graduate participation in our research efforts. Information gained by using the analysis techniques available at IPP for the detection of H species and computer codes obtained for data reduction will be applicable to research in the ISI group at ORNL. Capabilities for D implantation are not available in the ISI group at ORNL, and similarly, there are materials modification techniques at ORNL useful to the research program at IPP. Hence, continued collaboration between the two institutes will be of benefit to both. As a result of this assignment the traveler will be involved in providing samples for an erosion experiment to be performed in the JET tokamak at Culham, UK, by IPP staff members.

Attendance at the LEIB-5 and the E-MRS conferences gave European exposure research results obtained in the ISI group at ORNL and allowed the traveler to have informal contact with scientists with research interests closely paralleling his and other group members. There was considerable interest among many scientists contacted in the IBA work presented by the traveler. The LEIB-5 Conference included several areas of low-energy ion beam research of considerable interest to ORNL, including ion beam optics and development of IBD and plasma deposition. It is recommended that ORNL be represented at future conferences in this series. Information obtained on the IBD system being marketed by VSW Scientific in the UK will be of use in plans for future development of that research effort at ORNL.

There is a strong overlap in research interests in the ISI group at ORNL and the IT group at KFA Jülich. Visiting this institute, in addition to promoting continued collaboration between the two institutes, gave the traveler an opportunity to view the excellent and extensive facilities for ion beam processing of materials at KFA and to exchange ideas on current and planned research. Of particular benefit from this visit will be the "hands-on" use of the ion backscattering data acquisition system recently developed at KFA. A similar system came on-line at ORNL during the time of this assignment, and ideas for future development of the ORNL system were obtained.

APPENDICES

A. ITINERARY

B. LITERATURE ACQUIRED DURING FOREIGN TRAVEL

APPENDIX A

ITINERARY

DATES	LOCATION	INDIVIDUALS CONTACTED	SUBJECT OF DISCUSSION
2/28/89	Travel en route from Oak Ridge, TN, to Munich, FRG, via plane		
3/1–8/27/89	Max-Planck-Institut für Plasmaphysik, Garching bei München, FRG	V. Dose J. F. Roth R. Siegele	Perform research on implantation and annealing of D into single-crystal SiC
4/3–6/89	Low Energy Ion Beam-5 Conference, University of Surrey, Guildford, UK	J. Golden I. H. Wilson	Present paper on IBD of β-SiC overlayer on of α-SiC. Discuss IBD results. Discuss new IBD equipment with representatives of VSW Scientific, Ltd.
5/28–6/2/89	European Materials Research Society Conference and PHASE Laboratory, CNRS, Strasbourg, France	E. Fogarassy A. Golanski F. Priolo	Present paper on IBA of Ga implanted into Si. Tour PHASE group laboratory at CNRS.
6/3/89	Travel to Jülich, FRG, via private car		

APPENDIX A (cont'd)

ITINERARY

DATES	LOCATION	INDIVIDUALS CONTACTED	SUBJECT OF DISCUSSION
6/4/89	Weekend		
6/5–8/89	Kernforschungsanlage, Jülich, FRG	C. Buchal B. Stritzker	Ion beam solid interactions, including data acquisition hardware and software. Tour of Institut für Schicht- und Ionentechnik. Present seminar on IBD.
6/9/89	Travel to Garching bei München, FRG, via private car		
8/28/89	Travel from Munich, FRG, to Oak Ridge, TN, via plane		

APPENDIX B

LITERATURE ACQUIRED DURING FOREIGN TRAVEL

1. *Program,* Conference, "Low Energy Ion Beams-5," University of Surrey, Guildford, UK, April 3–6, 1989.

2. *Preprint,* "Low-Temperature Formation of Silicon Nitride and Oxide Films by the Simultaneous Use of a Microwave Ion Source and an ICB Source," J. Ishikawa, G. Takaoka, and K. Matsugatani (submitted to *Vacuum*).

3. *Preprint,* "Radiation Damage in Si and GaAs Due to Low-Energy Ion Bombardment," A. Al-Bayati, K. Orrman-Rossiter, R. Baht, and D. G. Armour (submitted to *Vacuum*).

4. *Reprint,* "Effects of Isolated Atomic Collision Cascades on SiO_2/Si Interfaces Studied by Scanning Tunneling Microscopy," I. H. Wilson, N. J. Zheng, U. Knipping, and I. S. T. Tsong, *Phys. Rev. B* **38**, 8444 (1988).

5. *Reprint,* "Atomically Resolved Scanning Tunneling Microscopy Images of Dislocations," N. J. Zheng, I. H. Wilson, U. Knipping, D. M. Burt, D. H. Krinsley, and I. S. T. Tsong, *Phys. Rev. B* **38**, 12780 (1988).

6. *Reprint,* "Scanning Tunneling Microscopy of an Ion-Bombarded PbS(001) Surface," I. H. Wilson, N. J. Zheng, U. Knipping, and I. S. T. Tsong, *Appl. Phys. Lett.* **53**, 2039 (1988).

7. *Preprint,* "Computer Simulation of Ion Implantation Range Profiles in Single-Crystal Materials," R. S. Kalsi and R. P. Webb (submitted to *Vacuum*).

8. *Preprint,* "Observation of Swelling and Sputtering of a Silicon Target Under Argon Ion Irradiation Using Double Marker Technique," Z. Jafri, C. Jeynes, R. P. Webb, and I. H. Wilson (submitted to *Vacuum*).

9. *Reprint,* "A Simple Representation for the Angular Dependence of Scattered and Recoil Particle Energies," W. Eckstein and R. Bastasz, *Nucl. Instrum. and Methods Phys. Res. Sect. B* **29**, 603 (1988).

10. *Reprint,* "Synthesis of Buried Layers of β-SiC in Single-Crystal Silicon," Karen J. Reeson, Peter L. F. Hemment, John Stoemenos, John R. Davis, and George K. Celler, *Mat. Res. Soc. Symp. Proc.* **107**, 473 (1988).

11. *Preprint*, "Fabrication of Buried Layers of β-SiC using Ion Beam Synthesis," K. J. Reeson, P. L. F. Hemment, U. Stoemenos, J. R. Davis, and G. K. Celler, *Inst. Phys. Conf. Series* (in press).

12. *Reprint*, "The Use of Ion Beams in Thin Film Deposition," D. G. Armour, P. Bailey, and G. Sharples, *Vaccum* **36**, 769 (1986).

13. *Product Specification*, "Low-Energy Ion Beam Depositon System," VSW Scientific Instruments, Ltd.

14. *Product Specification*, "UHV Scanning Tunneling Microscope," "General Product Guide," and "Spectaleed, Reverse View LEED/Auger," Omicron Vakuumphysik GmbH.

15. *Preprint*, "Low-Energy He+ Scattering from Deuterium Adsorbed on Pd(110)," R. Bastasz, T. E. Felter, and W. P. Ellis.

16. *Reprint*, "A Simple Representation for the Angular Dependence of Scattered and Recoil Particle Energies," W. Eckstein and R. Bastasz, *Nucl. Instrum. and Methods Phys. Res. Sect. B* **29**, 603 (1988).

17. *Preprint*, "On the Mechanism of Sputtering of SiO_2 by Ar at Ion Energies Near the Sputtering Threshold," S. S. Todorov and Ivan Chakarov, (submitted to *Vacuum*).

18. *Preprint*, "Lattice Location of Deuterium Implanted in TiC," S. Nagata, S. Yamaguchi, H. Naramoto, and Y. Kazumata, presented at the 13th ICACS Conference, Aarhus, Denmark, August 1989.

19. *Program*, Conference, "European Materials Research Society," Strasbourg, France, May 28–June 2, 1989.

20. *Preprint*, "Ion Beam Synthesis of Buried Compound Layers: Accomplishments and Perspectives," Andrzej Golanski.

21. *Preprint*, "Plasma Deposition of Thin Hydrogenated Carbon Films in an Experimental ECR Device," W. Jacob, D. Boutard, V. Dose, A Koch, W. Möller, W. Renz, and R. Wilhelm.

22. Preprint, "Metallic Tube Coating by Means of Moving Coil ECR," A. Koch, W. Renz, D. Boutard, V. Dose, W. Jacob, W. Möller, J. Perchermeier, and R. Wilhelm.

23. *Computer Software,* "DERES and Related Subroutines," W. Möller, IPP Garching, FRG. VAX and PC-compatible programs for computing spectra depth resolution for Rutherford backscattering, nuclear reaction, or elastic recoil detection experiments.

24. *Computer Software,* "LORI and Related Subroutines," W. Möller, IPP Garching, FRG. VAX and PC-compatible programs for computing depth distributions (not using the surface energy approximation) for Rutherford backscattering spectrometry, nuclear reaction analysis, or elastic recoil detection experiments.

25. *Computer Software,* "LAYERN and Related Subroutines," W. Möller, IPP Garching, FRG. VAX and PC-compatible programs for computing impurity concentrations from Rutherford backscattering and nuclear reaction analysis data.

26. *Equipment information,* High Voltage Engineering Europa B.V., RBS Precision Goniometer, and Universal sample manipulator for use in ultrahigh vacuum.

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