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ORNL/FTR--3422

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**ORNL**  
**FOREIGN TRIP REPORT**

ORNL/FTR-3422

DATE: October 23, 1989

SUBJECT: Report of Foreign Travel of C. J. McHargue, Senior Research Staff Member, Metals and Ceramics Division

TO: Alvin W. Trivelpiece

FROM: C. J. McHargue

PURPOSE: To attend the 2nd International Seminar on Surface Engineering by High Energy Beams in Lisbon, Portugal, and to deliver a paper entitled "Structure-Mechanical Property Relationships in Ion-Implanted Ceramics"; to visit the National Laboratory of Engineering and Industrial Technology (LNETI) at Sacavem, Portugal, for discussions on ion implantation studies; and to continue collaborative research with A. Perez, G. Marest, and N. Moncoffre at the University Claude Bernard-Lyon 1 (France).

SITES VISITED:	1989		
	9/25-27	2nd International Seminar on Surface Engineering by High Energy Beams, Lisbon, Portugal	A. P. Loureiro
	9/27	University of Lisbon, Portugal	J. C. Soares
	9/28	National Laboratory of Engineering and Industrial Technology, Sacavem, Portugal	M. F. de Silva
	10/2-5	University Claude Bernard, Villeurbanne, France	A. Perez G. Marest N. Moncoffre

ABSTRACT: A paper entitled "Structure-Mechanical Property Relationships in Ion-Implanted Ceramics" was presented at the 2nd International Seminar on Surface Engineering by High Energy Beams in Lisbon, Portugal. This seminar was sponsored by the International Federation of Heat Treatment and Surface Engineering and included discussions on surface modifications using laser, electron, and ion beams.

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The visit to the University of Lisbon and LNETI-Sacavem included discussions regarding collaborative research in which Prof. J. C. Soares and Dr. M. F. da Silva would conduct perturbed angular correlation (PAC) studies on ion-implanted samples supplied by the traveler.

The collaboration between researchers at ORNL and the University Claude Bernard-Lyon 1 (France) continues. Data were analyzed during this visit, plans for further experiments were developed, and a paper was drafted for publication.

## COMPREHENSIVE TRIP REPORT

2nd International Seminar on Surface Engineering  
with High Energy Beams - September 25-27, 1989

This meeting was held at the Lumiar site of the National Laboratory of Engineering and Industrial Technology (LNETI), Lisbon, Portugal, during September 25-27, 1989. The International Federation for Heat Treatment and Surface Engineering (IFHT) has attempted to broaden its scope to include newer technologies as shown by the recent addition of "and Surface Engineering" to its name. As a part of this expansion, the Federation organizes specialized seminars between the general international congresses. In spite of strong support given to IFHT by ASM International and the fact that its current president is Prof. George Krauss of Colorado School of Mines, there were only three attendees and one paper from the United States (that given by this traveler). Another U.S. paper was withdrawn at the last minute due to the illness of the author.

The seminar was attended by 102 registrants (plus a large number of students from Portuguese universities) from 21 countries. The largest number was from France (28) as was the largest number of papers (13). A large group of Japanese (22) attended but presented no papers. The two U.S.S.R. papers were not presented and the two Russians simply did not appear at the meeting after the opening morning session. Only one of the 13 scheduled papers from the People's Republic of China was presented and there was one attendee from there.

Several papers withdrawn at the last minute are contained in the proceedings which were distributed at the meeting. The organizers were able to fill out the program with several very good papers from Portuguese authors, some of which had been previously presented at another surface modification meeting in Switzerland in early September 1989.

The major portion of the program dealt with surface alloying using laser or electron beams. Several papers described attempts to model the heat flow in the molten and heat-affected zones and will be of interest to the Metals and Ceramics Division Welding Group who are involved in similar activities. A group from Ecole des Mines de Nancy, France, presented a model that includes the changes in physical properties with temperature, composition, and phase changes during heating and cooling - a very ambitious undertaking. (A workshop on mathematical simulation of laser treatment was held on the two days immediately following the seminar. A copy of the program for the workshop has been sent to the Welding Group.)

Several of the papers involved the collaborative efforts of authors from different countries, from different universities in the same country, or university-industrial cooperation. A significant fraction was the result of the European Economic Community to bring about international cooperation among member countries (EURAM, BRITE, etc.).

One of these programs has the goal of the production of amorphous ceramic coatings on mild steel for high temperature corrosion protection as a replacement for highly alloyed steels or Inconel. Techniques being used are laser surface alloying (French, Italian, and United Kingdom groups), electron beam surface alloying (a University of Liverpool, University of Birmingham, Harwell, and Rolls Royce collaboration), and laser-assisted chemical vapor deposition (Spanish group).

The European industrial community (as the Japanese) sent several engineers to assess the status of the studies, and there was much discussion with regard to industrial transfer or technology insertion issues. There was one U.S. industrial participant.

Attendance was useful for this traveler as it gave a chance to assess the role of ion implantation relative to other surface modification technologies. The effort to develop ion implantation as an industrial tool in Europe appears to be very small compared to the emphasis upon laser and electron beam techniques.

Visit to University of Lisbon and  
LNETI, Sacavem, September 27-28, 1989

At the end of the seminar on Wednesday afternoon, the traveler visited the laboratory of Prof. J. C. Soares, University of Lisbon, since he was to be away on Thursday. The purpose of the University is teaching and any research by the faculty is conducted on contracts funded by various agencies (both in Portugal and throughout Europe). A laboratory facility, the Technical Institute has been built at a central location in Lisbon, and faculty members from several universities maintain laboratory space there. Many of the studies involve collaboration, e.g., much of Soares' research is conducted with Dr. M. F. da Silva of LNETI.

Prof. Soares uses PAC (perturbed angular correlation) studies in connection with Rutherford backscattering (RBS)-ion channeling (conducted in da Silva's laboratory) to determine site location of impurity atoms (implanted or as grown) in silicon and  $\text{LiNbO}_3$ . The PAC measurements are useful adjuncts to the RBS-channeling measurements and have proved to be much more sensitive to changes in the location (or local symmetry) of these atoms during the early stages of annealing of implantation-induced damage.

Most of the equipment in these laboratories is either old or is made by the students. Nevertheless, excellent research is being conducted and the students appear to be given an excellent education.

Prof. Soares and Dr. da Silva are interested in expanding their collaboration. They are interested in conducting PAC studies on other materials. The base of information developed at ORNL on the amorphization and regrowth of ion-implanted  $\text{Al}_2\text{O}_3$  provides an opportunity for obtaining new results in a short time, and we will pursue this opportunity. It is especially interesting that PAC may give information on the very early stages of annealing in the amorphous state. There are relatively few probes that give such information.

On Thursday, September 28, the traveler visited the laboratory facilities of Dr. da Silva at the Institute of Nuclear Science and Engineering, LNETI-Sacavem. This laboratory was established in the 1960s as the site for the Portuguese research reactor and accelerator facility. Dr. da Silva has a 2-MeV accelerator (ca. 1975) which is used for proton-induced x-ray emission (PIXE), nuclear analysis (p, $\gamma$ ), and RBS/channeling. A fourth beam line is being built for ion beam mixing studies (using argon). The group also has constructed an ion-implanter (40 keV nitrogen) which will be used to prepare samples for corrosion studies by the Department of Metallurgy of the University of Porto (Portugal).

Measurements by RBS were being made by a Spanish visitor on multilayer Ge-Al samples subjected to laser mixing. Although the outer surface always remains pure Ge, there appears to be total mixing of the subsurface layers with an amorphous Ge-Al alloy being produced. The multilayers (each a few 10 nm thick) are prepared by evaporation in Madrid where electron microscopy is also carried out.

#### University Claude Bernard-Lyon 1, October 2-5, 1989

The main purpose of this portion of the visit was the continuation of collaborative studies with groups in the Department de Physique des Materiaux and the Institut de Physique Nucleaire and to serve on the jury for the doctoral thesis of Miss Laurence Romana. Visits were made to other groups in the University and at the adjacent engineering university.

In Villeurbanne, three universities, an engineering school, and a technical institute are situated adjacent to each other and there is much interaction among the facilities and staff. Because of the large number of visiting scholars, the city of Lyon has built an apartment complex to provide short-term rental housing for them.

Department de Physique des Materiaux. This department is composed of 80 people: 40 researchers (30 from the University, 10 of whom are professors and 10 full-time from CNRS), 26 student researchers, and 14 support personnel (technicians, etc.). My hosts were A. Perez and P. Thevenard with whom I have a long-standing collaboration. Much of the research in this department parallels the studies on ion beam modification of ceramics at ORNL, and it is desirable to coordinate the choice of materials systems and experimental conditions.

A major new thrust, which Perez is heading, involves deposition of coatings by beams composed of large clusters of atoms or molecules. There will be provisions for both "gentle" deposition (i.e., 1-5 eV) and high energy accelerated beams. The department has received a first year's (of three years) funding of \$500,000 (U.S. dollars) to initiate the project. In view of the recent report that researchers at Brookhaven National Laboratory have produced D-D fusion by bombarding a TiD target with clusters of D<sub>2</sub>O and the potential of new phenomena induced in very high density cascades, we should follow this work closely.

Prof. Perez discussed a French institute on metallic multilayers held in September 1989. G. Creuzet of Thomson (Orsay) has produced tailored high-temperature superconductors by molecular beam epitaxy deposition of atomically sharp, single atomic layers in the Y-Ba-Cu-O system. He is altering the number of copper oxide layers between the other layers to determine if the superconducting properties can be tailored. He is also preparing multilayer samples of alternating high-temperature superconducting and low-temperature superconducting materials.

Prof. Perez and I finished the draft of a manuscript to be given at the 1989 Materials Research Society meeting. I examined Romana's thesis in detail and served on the jury for her presentation and examination on Thursday, October 5. She has accepted an ORAU postdoctoral position with the Metals and Ceramics Division. Her thesis research directly relates to studies already in progress at ORNL.

I discussed the testing of adhesion of films to insulator substrates and the changes caused by ion bombardment with E. Abonneau and obtained samples from him for testing at ORNL. I delivered a seminar entitled "Ion Beam Mixing of Metals and Ceramics - Material Considerations" on Wednesday, October 4.

Institut de Physique Nucleaire. I visited two groups in IPN. The first group uses nuclear techniques in material science studies, and the Mössbauer studies of G. Marest is a part of our continuing collaboration. Dr. N. Moncoffre and her students are repeating many of the ORNL experiments but using polycrystalline  $Al_2O_3$ . We discussed the similarities and the differences (due to the presence of grain boundaries) in our results. I received some specimens from them in order to conduct mechanical property tests at ORNL to further define the effects of the grain boundaries.

I also visited with Dr. J. M. Mackowski who has been studying the deposition, structure, and properties of hard carbon (or diamond-like) films for several years. Much of his work is supported by the French space and defense agencies and is quite similar to studies in the Metals and Ceramics Division. His substrates are usually germanium and he is interested in multilayer devices. I received several facts that will help our program.

### Summary

Attendance at the conference allowed us to evaluate the relative merits of several surface modification techniques and to learn of European activities in this area.

The visits to the laboratories in Portugal revealed opportunities for us to obtain additional measurements of interest to ORNL programs by new collaborations.

The collaborations with the groups at UCB continue to produce important results that are leading to a better understanding of the structure of implanted ceramics. A new facility for ion cluster deposition or implantation is being constructed. The director of that effort is receptive to having an ORNL visitor once the facility is completed.

7/8

APPENDIX A

Itinerary

1989

- September 23-24 Travel from Farragut, TN, to Lisbon, Portugal
- September 25-27 Lisbon, Portugal, 2nd International Seminar on Surface Engineering by High Energy Beams
- September 27 Prof. J. C. Soares, University of Lisbon, discussion of potential collaboration
- September 28 Dr. M. F. da Silva, National Laboratory of Engineering and Industrial Technology, Sacavem, Portugal, discussion of potential collaboration
- September 29 Travel to Lyon, France
- September 30-  
October 1 Weekend
- October 2-5 Drs. A. Perez, G. Marest, N. Moncoffre, University Claude Bernard-Lyon 1, Villeurbanne, France, collaborative research on ion-implanted ceramics
- October 6 Travel from Lyon, France, to Farragut, TN

## APPENDIX B

Literature Obtained

1. Proceedings 2nd International Seminar, Surface Engineering with High Energy Beams, published by Center of Mechanics and Materials of the Technical University of Lisbon, Lisbon, Portugal, 1989.
2. R. C. da Silva, M. F. da Silva, A. A. Melo, J. C. Soares, E. Leitao, and M. Barbosa, "Diffusion and Corrosion Behavior of Tungsten-Implanted Aluminum and the  $Al_{12}W$  Phase," to be published in Nuclear Instruments and Methods in Physics Research B.
3. L. Rebouta, J. C. Soares, M. F. da Silva, J. A. Sanz-Garcia, E. Dieguez, and F. Agullo-Lopez, "Lattice Site Location of Europium in  $LiNbO_3$  by Rutherford Backscattering-Channeling Experiments," A. Phys. Lett. 55 (1989) 120-121.
4. E. Alves, M. F. da Silva, A. A. Melo, J. C. Soares, U. Feuser, and R. Vianden, "Regrowth of Indium-Implanted (100), (110), and (111) Silicon Crystals Studied with RBS and PAC Techniques," to be published in Materials Science and Engineering B.
5. L. Rebouta, J. C. Soares, M. F. da Silva, J. A. Sanz-Garcia, E. Dieguez, and F. Agullo-Lopez, "Combined RBS/Channeling and PAC Studies of Hafnium-Doped  $LiNbO_3$ ," to be published Nuclear Instruments and Methods in Physics Research B.
6. L. Rebouta, J. C. Soares, M. F. da Silva, J. A. Sanz-Garcia, E. Dieguez, and F. Agullo-Lopez, "Determination of Lattice Sites for Eu, Hf, and Nd in  $LiNbO_3$  by RBS/Channeling Experiments," to be published in Nuclear Instruments and Methods in Physics Research B.
7. C. Donnet, H. Jaffrezic, G. Marest, N. Moncoffre, and J. Tousset, "Iron Implanted Sintered Alumina Studied by RBS, CEMS, and SEM Techniques," to be published in Proceedings 1st European Conference on Accelerators in Applied Research and Technology, Frankfurt, FRG, September 1989.
8. H. Binczycka, G. Marest, N. Moncoffre, and J. Stanek, "Local States of Iron in Iron Implanted Hematite,  $Fe_2O_3$ ," to be published in Proceedings International Conference on the Application of the Mössbauer Effect, Budapest, September 1989.
9. N. Moncoffre, C. Donnet, G. Marest, and J. Tousset, "Characterization of Polycrystalline  $\alpha-Al_2O_3$  Implanted with Zirconium, Copper, or Iron," to be published in Proceedings of EPM, Dresden, DDR, September 1989.

10. G. Marest, C. Donnet, and J. A. Sawicki, "Microstructure of Iron Implanted Zirconia," to be published in Proceedings International Conference on the Application of the Mössbauer Effect, Budapest, September 1989.
11. A. Perez, J. Delafond, J. M. Pelletier, and B. Vannes, "Surface and Interface Treatments of Multilayers Using Ion or Laser Beams," to be published in Metallic Multilayers Trans. Tech., Lusanne, Switzerland.