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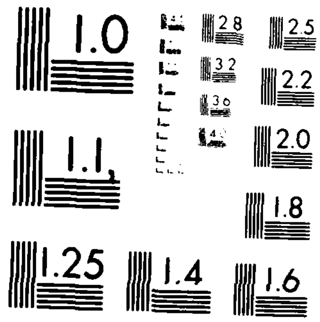
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ONR LONDON CONFERENCE REPORT

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OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

THE 29TH INTERNATIONAL FIELD EMISSION SYMPOSIUM

T.E. FEUCHTWANG
PENNSYLVANIA STATE UNIV.

28 APRIL 1983

UNITED STATES OF AMERICA

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The 29th Annual Field Emission Symposium was held at the Chalmers Technical Univ. in Göteborg, Sweden, from 9 through 13 August 1982. The topics exciting most interest were liquid metal ion sources and pulsed laser atom-probes. There were considerably fewer papers on electron emission than on ion emission. About half the papers were concerned with specific applications. This report lists all papers and briefly summarizes most.

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THE 29th INTERNATIONAL FIELD EMISSION SYMPOSIUM

Introduction

The 29th International Field Emission Symposium was held from 9 through 13 August 1982 at the Chalmers Univ. of Technology in Göteborg, Sweden. Sponsored by the Materials Science Center of the university, the meeting attracted some 70 participants, who presented 78 papers. A committee headed by Prof. H. Nordén (assisted by Dr. H.-O. Andrén) arranged an exceptionally well-organized and informative meeting.

The symposium consisted of 14 sessions and two workshops. The topics indicated the maturing of field emission, the shifting emphasis from the physics of the emission process to the study of specific devices, and the use of the process for applications such as probing of surfaces, corrosion, and alloys. Relatively large blocks of time were devoted to discussing two topics currently exciting great interest in the field: liquid metal ion sources (three sessions and one workshop), and the pulsed laser atom probe (one session and one workshop). An annotated list of the papers presented at the symposium is given below. Abstracts of all talks were available, and the proceedings, edited by Nordén and Andrén, will be published by Almquist and Wilksell International, Stockholm.

Liquid Metal Ion Sources (LMIS)

The interest in LMIS is not surprising, because they are high intensity sources of ion beams, which have a variety of uses, including ion beam lithography, ion probes, ion implantations, molecular beam epitaxy, coating and metal deposition, mass spectroscopy of organic molecules of biochemical interest, applications of ion beams needing highly charged ions, ion thrusters, and very high current ion sources.

Some papers were especially noteworthy. Of particular interest was the work by R. Levi-Setti et al. (Univ. of Chicago) on a Ga^+ 60-keV scanning ion microscope. The paper by Gaubi and Sudraud (Univ. de Paris XI), "In Situ [Transmission Electron Microscopy] TEM Observation of the Emission Region in Liquid Metal Sources," underscored the rather rudimentary state of the theoretical understanding of ion emission. In particular, the concepts of a Taylor cone or a more general equilibrium shape of the emission region are evidently inadequate representations of the asymmetric and fluctuating emitting protrusion. The point was also made on theoretical grounds by Cutler (Pennsylvania State Univ.), who discussed "Temperature and Space Charge Effects in Liquid Metal Ion Sources."

1. N.M. Miskovsky, P.H. Cutler, and T.E. Feuchtwang, Pennsylvania State Univ., University Park, PA 16802, "Temperature and Space Charge Effects in Liquid Metal Sources: Application to Beam Dispersion" (theory). The first theory discussing source geometries other than the Taylor cone. The modified peraxial ray equation is derived to account for space charge effects on the axial potential. A promising systematic approach to include successively more physical effects in the theoretical analysis of LMIS.

2. S.P. Thompson, "Some Comments on the Electrodynamics of Wetted Needle Anodes" (theory). Entry for E.W. Müller Memorial competition.

3. G.A. Evans, M.D. Macgregor, and R. Smith, Department of Mathematics, Loughborough Univ. of Technology, Leicestershire, LE11 3TU, UK, "A Computational Study of the Dynamics of LMIS." A progress report on the application of magneto hydrodynamics to the flow of liquid metal. The theory is not sufficiently advanced to be evaluated critically.

4. G.L.R. Mair, Department of Physics, Univ. of Aston, Birmingham, UK, "Space Charge Factors Affecting the Current Level in LMIS" (theory).

5. K. Gamo, Y. Ochiai, T. Matsui, and S. Namba, Faculty of Engineering Science, Osaka Univ., Toyonaka, Osaka, Japan, "Characteristics of Sn and Zn Liquid Metal Alloy Ion Sources."

6. J. van der Waal and P. Sudraud, Laboratoire de Physique des Solides, Université de Paris XI, 91405 Orsay, France, "Realization and Properties of a Uranium LMIS." Presumably to be used in isotope separation.

7. D.G. Welkie and R. Gerlach, Perkin-Elmer, Physical Electronics Division, 6509 Fly Cloud Drive, Eden Prairie, MN 55344, "Application of Field Emission to Microanalysis by [Secondary Ion Mass Spectroscopy] SIMS and [Auger Electron Spectroscopy] AES." No recent progress in realization of a practical device.

8. F.G. Rudenauer, W. Steiger, and H. Grasser, Austrian Research Center, Seibersdorf, Lenaugasse 10, A-1082, Vienna; P. Pollinger and H. Studnicka, Inst. f. Experimental Physik, Univ. of Vienna, Studelhofgasse 4, A-1090, Vienna, Austria, "Application of a LMIS in Microprobe Analysis." Capillary-type In LMIS incorporated in scanning ion microprobe.

9. A.R. Waugh, A.R. Bayly, and K. Anderson, VG Scientific Ltd., Imberhorne Lane, East Grinstead, Sussex RH19 1UB, UK, "An Application of LMIS to SIMS." A very impressive account of Ga LMIS incorporated in a commercial system (VG SIMSLAB).

10. R. Levi-Setti, K. Lam, and T.R. Fox, Department of Physics, Univ. of Chicago, Chicago, IL 60637, "Crystallographic Contrast With a 60 keV Ga$^+$ Scanning Microscope."

11. D.F. Barofsky, V. Giessmann, L.W. Swanson, and A.E. Bell, Oregon Graduate Center, 19600 N.W. Welker Rd., Beaverton, OR, "Use of a Liquid Metal Point Source for SIMS of Organic Compounds." A promising specialized technique for chemical analyses of organic compounds and biological tissue.

12. H. Gaubi and P. Sudraud, Laboratoire de Physique des Solides, Universite de Paris XI, 91405 Orsay, France. "New Results About In Situ TEM Observations of the Emission Region in LMIS."

13. C. Bartoli, H. Herhudt von Rohden, and S.P. Thompson, European Space Research and Technology Center, Keplerlaan, Noordwijk, the Netherlands, "LMIS for Space Propulsion." Realization of a low cost, simple, modular ion thruster--as part of the project for field emission electric propulsion (FEEP).

14. K.L. Aitken, D.K. Jefferies, and P.D. Prewett, UK Atomic Energy Authority, Culham Laboratory, Abington OX14 3DB, UK, "Multiple Emission Zones in LMIS Thrusters." Emitter in the form of a slit supporting linear array of emitting zones, as discussed in Bartoli's paper.

15. C. Mahony, L. Cowland, and P.D. Prewett, UK Atomic Energy Authority, Culham Laboratory, Abington OX14 3DB, UK, "LMIS for High Technology Applications: The FED Sprayer." Field emission deposition-sprayer produces microdroplets to be used to build up highly adherent dense coatings.

16. M.P. Thomas and B. Ralph, Department of Metallurgy and Materials Science, Univ. of Cambridge, UK, "A Primary Atom Probe [Field Ion Microscopy] FIM Study of the Sputtering of Ni_3Al by Ga Ions From a LMIS." Source could produce Ga^+, Ga^{++} at 4 to 10 keV. Operated at 4.5 keV for comparison with inert gas sputtering.

Pulsed Laser Atom Probes

The utility of the pulsed laser (as opposed to the pulsed voltage) in field emission microscopes operated as an atom-probe is self evident--and so is the flurry of papers discussing this latest improvement in the atom-probe FIM. Three of the five papers presented were authored by the Pennsylvania State Univ. group and its ex-students.

17. S.B. McLane, J.J. Kinkus, and T.T. Tsong, Dept. of Physics, Pennsylvania State Univ., University Park, PA 16802, "Construction of a High Resolution Pulsed Laser Atom-Probe FIM."

18. T.T. Tsong, T.J. Kinkus, and S.B. McLane, "Pulsed Laser Time of Flight Atom-Probe Field Ion Microscopy."

19. G.D.W. Smith, C.R.M. Grovenor, K.M. Delargy, T.J. Godrey, and A.P. McCabe, Department of Metallurgy and Science of Materials, Univ. of Oxford,

Parks Rd., Oxford OX1 3PH, UK, "Direct Comparison of Performance of Atom-Probe in Pulsed-Laser and Voltage-Pulsed Modes."

20. G.L. Kellogg, Sandia National Laboratories, Albuquerque, NM 87185, "The Pulsed Laser Atom-Probe Recent Applications." To insulating glasses and measurements of the charge state distributions of field evaporated ions.

21. W. Drachsel, Th. Jentsch, and J.H. Block, Fritz-Haber-Institut der Max-Planck Gesellschaft Faradayweg 4-6, 1000 Berlin 33, FRG, "High Energy Field Ions in Photon Induced Field Ionization of Metals." Careful study of the physics ot photon induced field ionization of metals.

FIM and FIM Mass Spectroscopy

Three sessions and 10 papers were devoted to essentially technical discussions ot these instruments. However, some of the papers in this category also discussed some interesting applications of the instruments.

22. T. Sakata and S.H. Block, Fritz-Haber-Institut der Max-Planck Gesellschaft Faradayweg 4-6, 1000 Berlin 33, FRG, "Field Ion Microscopy of Silicon With Different Imaging Gases." H_2, SiH_4, O_2, and N_2 were considered.

23. T. Arise, M. Nakamura, A. Suzuki, K. Otake, Y. Suzuki, H. Lu, R. Yamamato, K. Endo, and M. Doyama, Department of Metallurgy and Material Science, Faculty of Engineering, the Univ. of Tokyo, Bunkyo-ku, Toyko 113, Japan, "FIM of Transition Metal Trichalcogenides." $NbSe_3$ forms needle-shaped crystals, which pose a technical problem in FIM studies of this unusual material.

24. E. Krantz, W. Polanschutz, and G. Haiml, Institut für Festkörperphysik, Technical Univ. of Gratz, A-8010 Gratz, Austria, "The Influence of Dissolved Hydrogen in FIM of Niobium." Hydrogen is useful as imaging gas, but its absorption by the tip may seriously affect the experimental observations.

25. J. Lira-Olivarez, Dept. Ciencia Materiales, Univ. Simon Bolivar, Caracas, Venezuela, "Description of a Low Temperature, High Voltage Orientable Holder for FIM." Not new.

26. S. Wong and F.W. Rollgen, Institute of Physical Chemistry, Univ. of Bonn, Wegelerstr. 12, D-5300 Bonn, FRG, "Field Ion Emission From Single Organic Droplets Studied by Optical Microscopy and Mass Spectrometry." An interesting technique, though the underlying physics is even less understood than that of LMIS.

27. C.C. Curtis, K.C. Hsieh, A.M. Hudor, and E. Keppler, Department of Physics, Univ. of Arizona, Tucson, AZ 85721, "A Field Ion Mass Spectrometer for Space Applications."

28. A.J. Melmed, M. Martinka, and R. Klein, Surface Science Division, National Bureau of Standards (NBS), Washington, D.C., "A General Purpose Atom-Probe FIM." $\Delta m/m > 150$ at half height. Performance characteristics described.

29. J.A. Panitz and G.L Fowler, Sandia National Laboratory, Albuquerque, NM 87185, "Point Projection Imaging of Individual Ferritin Molecules on Metallic Substrates." The microscopy, in conjunction with a digital processing algorithm, produces images of a three-dimensional quality (depth) usually associated with scanning electron micrographs. A very promising technique for FIM studies of biological macromolecules.

30. J. Piller and H. Wendt, Institut für Metallphysik, Univ. of Göttingen and Sonderforschungsbereich (SFB) 126, FRG, "Autocorrelation Analysis of Atom-Probe Concentration Profiles." An important contribution to an improved quantification of atom-probe experiments.

31. K. Murakami, T. Adachi, O. Komoda, T. Kuroda, and S. Nakamura, The Institute of Scientific and Industrial Research, Osaka Univ., 16 Araki, Osaka 567, "Atom-Probe Analysis of LaB_6." A new atom-probe. LaB_6 is an interesting material in its own right, but here was just used as a test of the capabilities of the instrument. LaB_6 is distinguished by its low work

function and is a promising electron field emission source.

Electron Field Emission Microscopy (FEM) and Spectroscopy (FES)

Three sessions were devoted to FEM, FES, and field emission sources. H.F. Gray (Naval Research Laboratory) and C.A. Spindt (SRI International) presented excellent papers on field emitter arrays during the session on emission sources. The papers, presenting the state of the art in array technology, were distinguished by their clarity and organization. The potential advantages of field emission sources in sophisticated experimentation were underlined during a talk on electron beam holography in the microscopic study of magnetic fields.

32. M. Blaszczyszyn, R. Blaszczyszyn, and R. Meclewski, Institute of Experimental Physics, Univ. of Wroclaw, Poland, cooperating with T.E. Madey and A.J. Melmed, NBS, Washington D.C., "FEM Study of S-Ni Adsorption System."

33. Dao Viet Dung, Institut de Chemie, Université des Liège, Sart-Tilman B6, 4000-Liège, Belgium, "Field Emission Spectroscopy Study of Surface Reactions and Alloys." W-3% Re and W-26% Re were studied.

34. J.K. Wysocki, Institute of Experimental Physics, Univ. of Wroclaw, Cybulskiego 36, 50-205 Wroclaw, Poland, "Investigation of Apparatus Function in a FES."

35. D.B. Hibbert, Department of Chemistry, Bedford College, Univ. of London, Regent's Park, London NW1 4NS, UK, "Field Stimulated Exoelectron Emission." Field stimulated exoelectron emission from borosilicate glass and quartz was discussed. The paper was neither clear nor convincing.

36. T. Barsotti, J.M. Bermond, and M. Drechsler, Centre de Recherche sur les Mechanismes de la Croissance Cristalline-CNRS, Campus de Laminy, Case 913, 13288 Marseille Cedex 09, France, "A Study of the Equilibrium Shape of a Face Centered Cubic Metal Crystal." For a Ni field emitter tip of large radius, the authors reported an experimental determination of the equilibrium shape and the calculation of the corresponding anisotropic surface free energy by the inverse of Wulff's construction. The claimed accuracy of the measurement seemed too high. Hence, agreement with calculated surface free energy (paper 37) must be questioned.

37. M. Drechsler, "On the Anisotropy Surface (Free) Energy and Surface Structure of Hexagonal Metal Crystals." Continuation of the preceding talk. Theoretical and experimental estimates of the surface free energy of hexagonal metals were discussed. It was argued that hexagonal close-packed metals cannot have surface steps of height equal to one interplanar distance on hexagonal surfaces. This in contrast to face-centered cubic and base-centered cubic metals. The approach is probably too elementary to be of quantitative significance.

38. M. Gesley, P. Davis, and L.W. Swanson, Oregon Graduate Center, "Crystallographic Work Function Distribution on LaB_6." Careful study of surface orientation dependence of the work function using thermionic and field emission methods.

39. H.F. Gray, Naval Research Laboratory, Washington, D.C., "Silicon Field Emitter Array Technology" (invited talk). An outstanding contribution. For silicon, field emitter arrays (FEA) are fabricated using standard silicon processing technology. Emitter heights are about 1μ. Each tip is placed in the center of an aperture of 1μ diameter. Significant emission is obtained with less than 100 V. The varied uses of arrays were reviewed: e.g., cold low noise cathodes for microwave and millimeter wave tubes, cathode ray tubes, and scanning electron microscopes.

40. C.A. Spindt, C.E. Holland, and R.D. Stowell, SRI International, Menlo Park, CA, "Field Emission Cathode Array Development for High Current Density Applications." This was an excellent report on an outstanding technological achievement. Emitter arrays with $(1.2)\times10^6$ tips/cm^2 were fabricated, producing 100 A/cm^2.

41. J.M. Derochette, Université de Liège, Institut de Chemie, Sart-Tillman, 4000 Liège 1, Belgium, "Field Emission Thermal Desorption Spectroscopy. Dynamic Measurement of Work Function." (Winner of the E.W. Müller Memorial medal.) A useful technique clearly presented.

42. A. Tonomura, T. Matsuda, R. Suzuki, and H. Fujiwara, Central Research Laboratory, Hitachi Ltd., Kokubunji, Tokyo 185, Japan, "Application of Electron Holography to Microscopic Magnetic Field Measurements." Using a field emission tip as a coherent electron source, the authors were able to split the beam and produce electron holograms, which were reconstructed optically. One of the interesting applications of the technique is representation of the magnetic fields in terms of the contour lines in the interference electron micrographs. The technique thus allows the direct probing of fields inside ferromagnetic materials. Another application was the direct observation of the Bohm-Aharonov effect.

43. F. Okuyama, Department of Fine Measurements, Nagoya Institute of Technology, Gokiso-Cho, Showa-ku, Nagoya, Japan, "Growth of Cr Needle Crystals Induced by Electron FE." Cathodic needle growth due to metal particles coming from electron emission induced plasma in metal carbonyl vapor.

44. R.E. Thurstans, School of Physics, Leicester Polytechnic, Leicester LE1 9BH, UK, "Electron Emission From Electroformed Metal-Insulator Metal [MIM] Structure." The results have little significance.

General Theory

Only one session was reserved for a dicussion of theoretical aspects of field emission (electrons and ions). This is evidence not that the processes are completely understood, but that the problems are difficult and have not in general attracted the attention of theoreticians. Furthermore, some theoretical papers were grouped under specific topical sessions.

45. T.E. Feuchtwang and P.H. Cutler, Department of Physics, Pennsylvania State Univ., University Park, PA 16802, "Nonlinear Electron Transport in Junctions: Application to Metal-Metal Point Contact Spectroscopy." A novel discussion of field emission techniques in a point-contact configuration used as a probe of the electron-phonon interaction. Introduces the concept of a weak link between two normal metals to explain the applicability of the "golden rule" to the problem. Discusses the prospect for studying nonlinear electron transport in such weak links.

46. R.G. Forbes, Department of Physics, Univ. of Aston, Gosta Green, Birmingham, UK, "The Escape Mechanism in Low-Temperature Field Evaporation." Review of semiclassical discussion of the mechanism of field emission of ions. It appears that this approach has been pursued to its limit and that further insights will depend on the development of a more fundamental quantum treatment of the problem.

47. R.G. Forbes and K. Chibane, "The Derivation of Surface Atomic Information From Field Evaporation Data." Continuation of the preceding paper. A description of a method to derive the phenomenological parameters of the theory from experimental data on field evaporation.

48. M. Steslicka and M. Radny, Institute of Experimental Physics, Univ. of Wroclaw, Cybulskiego 36, 50-205 Wroclaw, Poland, "An Effect of Oxidation on Surface States for Si Part II." Paper was not presented because authors could not attend.

49. D.R. Kingham, Cavendish Laboratory, Madingley Rd., Cambridge CB3 OHE, UK, "Mechanism of Charge Transfer During Field Evaporation." (An entry for the E.W. Müller Memorial Medal competition.) An interesting first effort to apply a full quantum treatment to the problem of field evaporation. The problem was discussed in terms of the local density of electronic states on the ion undergoing field desorption. Work suggests that low temperature field evaporation occurs by a "change drainage" mechanism with a possible subsequent post ionization.

50. N.K. Kang, D. Tuggle, and L.W. Swanson, Oregon Graduate Center, 19600 N.W. Walker Rd., Beaverton, OR 97006, "A Numerical Analysis of the Effect of Space Charge on the Emission Properties of a Field Electron Source." Theoretical. The commonly used planar diode approximation was shown to be inadequate for the analysis of space charge effects in field emission. Field emission guns were very sensitive to small changes in emitter shape. This conclusion corroborates the results reported by Miskovsky, Cutler, and Feuchtwang on the importance of geometry in an analysis of the I-V characteristics of point-contact diodes.

Applications of FIM

The field ion microscope, operated as an atom probe, has unique capabilities for detailed quantitative studies of surface-related processes and structures on an atomic scale. When complemented by related techniques, such as scanning electron microscopy and low-energy electron diffraction, the FIM studies become even more rewarding. However, quantification of the observations still needs to be improved considerably, so that a detailed theory of the effects investigated can be developed.

Surface Studies

Because of pioneering work at Pennsylvania State Univ. and the Univ. of Illinois, the application of FIM in the study of individual atoms and atom clusters on well-defined substrates is widely known. Reports from researchers at both universities reflect the continuing shift toward quantitative rather than qualitative studies.

51. H.-W. Fink and G. Ehrlich, Coordinated Science Laboratory, Univ. of Illinois, Urbana, IL 61801, "Binding Energy of Individual Atoms to Epitaxial Surface Layers." (Not presented.)

52. S.C. Wang and T.T. Tsong, Department of Physics, Pennsylvania State Univ., University Park, PA 16802, "FIM Study of Atomic Processes on Metal Surfaces." Discussed (1) potential barrier height seen by a single adsorbed atom at the reflecting boundary of a facet, (2) field and temperature dependence of drifting velocity in directional walks of single adsorbed atom, its dipole moment and electric polarizability, (3) Monte Carlo simulation of atomic processes, including migration of diatomic clusters, displacement distributions of single and diatomic clusters, adsorption layer superstructure formation.

53. O. Nishikawa, M. Shibata, and T. Yoshimura, Department of Materials Science and Engineering, The Graduate School at Nagatsuta, Tokyo Institute of Technology, 4259 Nagatsuta, Midor-ku, Yokohama 227, Japan. "Atom-Probe Study of Physisorbed Hydrogen on Cu." The effects of hydrogen pressure and tip temperature were presented.

54. N. Ernst, G. Bozdech, S.H. Allam, and J.H. Block, Fritz-Haber-Institut der Max-Planck Gesellschaft, Faradayweg 4-6, 1000 Berlin 33, FRG, "Temperature Programmed Field Desorption of Hydrogen From W." The paper described a scanning technique allowing the measurement of the temperature dependence of the abundance of desorbed single ions.

55. O. Nishikawa, Y. Tsunashima, E. Nomura, M. Wada, S. Horie, M. Shibata, T. Yoshimura, and R. Vemori, "Atom-Probe Study of the Initial Stage of Silicide Formation." Initial stages of the silicide formation were investigated by deposition of Si on W and Ni tips. The tips were annealed and then mass analyzed with an atom-probe.

Oxidation and Corrosion

The work on oxidation and corrosion is in fact a particular subclass of surface studies. The absence of any theoretical framework is painfully obvious.

56. R.M. Cornell and G.K.L. Cranstoun, Inorganic Chemistry Laboratory, Univ. of Oxford, Oxford OX1 3QR, UK, "Imaging Atom-Probe Investigation of Oxide Films on Iron." A very competent qualitative study of a difficult problem. Oxide films formed on Fe under diverse conditions were compared.

57. A.R. McCabe and G.D.W. Smith, Department of Metallurgy and Science of

Materials, Univ. of Oxford, Parks Rd., Oxford OX1 3PH, UK, "FIM Desorption Probe Study of Oxidation of Pt-Rh Alloy." Pt-Rh alloys are industrial catalysts under strongly oxidizing conditions. Their efficiency depends on surface preparation, i.e., structure and composition. The study provided a Rh concentration profile as a function of temperature. A competent study.

58. W.A. Schmidt, J.H. Block, and K. Becker, Fritz-Haber-Institut der Max-Planck Gesellschaft Faradayweg 4-6, 1000 Berlin 33, FRG, "Etching of a Ni Single Crystal by the Reaction with CO to $Ni(CO)_4$, FIM Study." A study of the structural aspects of the formation of $Ni(CO)_4$ by the reaction of CO with solid Ni.

59. T. Terao, M. Kozakai, F. Iwatsu, Y. Suzuki, H. Morikawa, and Y. Yashiro, Department of Coordinated Science, Nagoya Institute of Technology, Gokoso-Cho, Showa-ku, Nagoya 466, Japan. "Corrosion of W With N-octyl Alcohol With an Applied D.C. Voltage."

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Of the nine papers dealing with steels, four were presented by S.S. Brenner's group at U.S. Steel, which has a long record of distinguished work in a difficult field. Most papers applied FIM-atom-probe instruments as microprobes of chemical and structural details. The analysis was often aided by applying TEM.

60. N. Nakamura, T. Arise, Y. Suzuki, R. Yamamoto, and M. Yoyama, Department of Metallurgy and Materials Science, Faculty of Engineering, The Univ. of Tokyo, Bunkyo-ku, Toyko 113, Japan. "A FIM Observation of Martensitic Transformation of Carbon Steels."

61. G.M. Worrall, T.D. Mottishaw, and G.D.W. Smith, Department of Metallurgy and Science of Materials, Univ. of Oxford, Parks Rd., Oxford OX1 3PH, UK, "A Study of the Effects of Cr and Mn on the Pearlite Transformation in Steels." Combined scanning transmission electron microscopy and FIM atom-probe study. The latter technique is required for quantification but is difficult to apply because a transformation must be obtained in the apex of the tip. The requisite specimen preparations were discussed.

62. T.D. Mottishaw and G.D.W. Smith, "FIM Atom-Probe of Microalloyed Pearlite Steels Containing V and Cr." Very competent technically; an entry in the E.W. Müller Memorial Medal competition.

63. S.S. Brenner, M.G. Burke, L.J. Cuddy, M.K. Miller, and J. Piller, U.S. Steel Corp. Research Laboratory, Monroeville, PA 15146, "Atom-Probe and Electron-Microscopy Analyses of Precipitates in High-Strength, Low-Alloy Steel."

64. J. Piller, M.K. Miller, and S.S. Brenner, "Nucleation and Coarsening Behaviour of TiC Precipitates in α-Fe and Effects of Sb Additions."

65. M.K. Miller, S.S. Brenner, and B.E. Wilde, "The Distribution of Pd in Pd-modified 4130 Steel."

66. M.K. Miller, S.S. Brenner, P. Camus, J. Piller, and W.A. Soffa, "Low Temperature Precipitation in Fe-Cr Binary Alloys."

67. D. Blavette, A. Bostel, J.M. Sarrau, and J. Gallot, ERA 258 CNRS Faculte des Sciences et des Techniques de Rouen, BP 67, 76130 Mont-St.-Aignan, France, "Atom-Probe Analysis of Matrix-Precipitate Interface in an $FeCr_{20}$-Ni_2Al_2 Alloy; Depth of Analysis Determination." Dealt with correction to composition profiles.

68. A. Henjered, L. Karlsson, H.-O. Andrén, and H. Nordén, Department of Physics, Chalmers Univ. of Technology, S-412 96 Göteborg, Sweden, "Grain Boundary Depletion and Enrichment in Austenitic Stainless Steels." A meticulously and competently executed research program was reported. Due to the large grain sizes, the width of the boundary zones with non-bulk composition was large compared with the depth of field evaporation--hence the need to combine electro-polishing, or ion etching, or both with FIM and TEM.

69. N. Igata, S. Sato, and T. Sawai, Department of Materials Science and Engineering, Tokyo Institute of Technology, Yokohama 227, Japan,

"Radiation Induced Segregation in Ni Alloys." Ni -3.79% Al, Ni -0.86% Si were irradiated in a 400-kV heavy ion accelerator. Surface enrichment of Si and depletion of Al were found.

70. N.S. Mishra and S. Ranganathan, Department of Metallurgy, Indian Institute of Science, Bangalore 5 60 012, India, "FIM Study of Short Range Order and Microdomains in Ni-W Alloys." Ni -15% W was studied; computer simulations of FIM from Ni, Ni_2W, Ni_3W, and Ni_4W were used to interpret data. Unanswered question: are clusters or microdomains responsible for the short range order of Ni_4W indicated by this work? Entry in E.W. Müller Memorial Medal competition.

Magnetic Materials and Metallic Glasses

71. W.A. Soffa, S.S. Brenner, P. Camus, and M.K. Miller, U.S. Steel Corp. Research Laboratory., Monroeville, PA 15146, "Atom-Probe Studies of Precipitation on Fe-CO-Cr Alloys." Atom probe used to follow kinetics and morphology of precipitation reactions in magnetic alloys: Fe-Cr-33Cr.

72. F.W. Zhu and H. Wendt, Institut für Metallphysik, Univ. of Göttingen and SFB 126, FRG, "FIM Atom-Probe Analysis of a FeCrCO Based Permanent Magnet." Researchers followed time development of the decomposition into microstructures, leading to optimum magnetization.

73. A. Menand, M. Bouet, C. Martin, and J. Gallot, ERA 258 CNRS Faculte des Sciences et des Techniques de Rouen, BP 76130 Mont-St.-Aignan, France, "Atom-Probe Study of FeB Amorphous Alloys."

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75. T. Abe, T Yoshimura, M. Shibata, K. Hirano, and O. Nishikawa, Department of Materials Science, Faculty of Engineering, Tohoku Univ., Sendai, 980 Japan, "Atom-Probe Study of G.P. Zones in Al Alloys." Al-Mg and Al-Cu alloys are considered. Concentration fluctuations with aging are interpreted as evidence for spinodal decomposition.

76. S. Fukase, M. Wada, and O. Nishikawa, Department of Materials Science and Engineering, Toyko Institute of Technology, 4529 Nagatsuta, Midori-ku, Yokohama 227, Japan, "Atom-Probe Study of the Interaction Between Solute Atoms." Application of auto- and cross-correlation functions to interpret data.

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