Rare-earth Information Center NEWS

Ames Laboratory
Institute for Physical Research and Technology
Iowa State University / Ames, Iowa 50011-3020 / U.S.A.

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INDIA—1989

In mid-November the editor visited several research institutes and attended the International Symposium on Thermochemistry and Chemical Processing in India.

The scheduled one day visits to the Tata Institute of Fundamental Research and to the Bhabha Atomic Research Centre, unfortunately, had to be changed to a few hour visits because of fog in London that delayed my arrival in India by 24 hours. I spent the morning at Tata and the afternoon at Bhabha, but because these institutes are on opposite sides of Bombay, approximately two hours were lost in transit.

Tata Institute of Fundamental Research

At the Tata Institute of Fundamental Research I spent most of the time with Drs. S. K. Malik and S. K. Dhar and their co-workers discussing their fundamental research projects on magnetic materials, low temperature superconductors such as La_3In, high temperature superconductors (primarily the thallium ones), and heavy fermion phases (including $Ce_{1-x}Gd_xAl_3$, and ternary Yb alloys).

Bhabha Atomic Research Center

At Bhabha Atomic Research Center I visited with Dr. D. D. Sood and his colleagues. They are responsible for nuclear fuel development and its chemistry, quality control, fuel behavior and post irradiation examinations, chemistry of fuel reprocessing and waste management processes, and some basic research on actinide and relevant fission product elements. They are doing some interesting work on carbide fuels and chemical reprocessing, and are re-examining metallic fuels for breeder reactors, based on the successful work carried out in the USA experimental

(Continued in next column)

New Staffer

We are pleased to announce that Joel Calhoun has joined the RIC staff as a Program Assistant III. He will be replacing Jennings "Cap" Capellen, who will be retiring on June 30, 1990. Joel comes to us from Brownell-Talbot College Preparatory School in Omaha, Nebraska, where he taught chemistry and physics. He spent several years in the U.S. Navy before obtaining his B.A. and B.S. degrees at Chadron State College, Chadron, Nebraska. He is taking a cram course from Cap and the director on the rare earths and how the center operates, and we are looking for a smooth changing of the guard next summer. He lives in Jefferson, Iowa, and has about a 45-minute commute to Ames. Joel is looking forward to meeting and helping you in the future.

(Continued from previous column)

breeder reactor program on U-Pu-Zr alloys.

Regional Research Laboratory, Trivandrum

The next stop on my itinerary was the Regional Research Laboratory, Trivandrum (RRL-T), which is located near the southern tip of India. This laboratory is one of the six regional laboratories of the 39 national research laboratories operated by the Council of Scientific Industrial Research (CSIR) of the government of India. The primary goals of the regional laboratories are to do research, extension, and consult in fields related to the raw-materials and products important to the development of the state or region in which

(Continued on page 7)

EDITORIAL

Does your company or institute support RIC? If it does—great! If it does not, should it? Yes it should, if your organization produces, manufactures, or sells rare earths or rare earth containing materials, or if it has a substantial research effort involving the rare earths.

If the answer to the first question is "no" and your company falls into any of the above categories, we expect you to join in and share the load in supporting RIC.

The rare earth field is expanding at a rapid rate and we at RIC are having a difficult time providing reasonable and adequate services to the scientific, technological, industrial, and business communities. RIC also needs to grow to meet the increasing demands for our services. If we are to do this, the main increase in financial support will need to come from new benefactors of the Center. We are not asking a lot of money, the minimum level of support is U.S. $300.00 and most sponsors contribute more. It is easy to join; just send us a check, or if you prefer we can send you an invoice. Furthermore, if you prefer, your organization can be an anonymous benefactor (we have several). Most sponsors, however, wish to be acknowledged in the *RIC News* and our brochure.

If your organizational regulations do not allow contributions, an alternate means of support is a subscription to *RIC Insight* and RIC information answering services. Your status will be the same as a benefactor.

As a benefactor of the center you will receive the limited circulation, monthly newsletter, *RIC Insight*, which is concerned with new scientific, technological, and industrial advances and how these may impact the near term and long range com-

(Continued on page 3)

The Rare Earths

25 *and I* 25

Here is the first story we received in response to our request for readers to send us personal, rare earth related stories. We are hoping others, after reading this story, will send us their stories so we might possibly publish a booklet containing all those received.

This incident was sent by Dr. Fred G. Jones, president of F. G. Jones Associates, Limited. In his letter that accompanied the story he states, "Here is a note about a humorous incident related to rare earth magnets. I was a young engineer at the time, and only recently have come to truly recognize the significance of what Joe Becker said to me."

Joe Becker and I

by

Fred Jones

The late Joe Becker of General Electric R&D was one of the pioneers in developing cobalt-rare earth magnets [cf. K. Strnat, G. Hoffer, J. Olson, W. Ostertag, and J. J. Becker, *J. Appl. Phys.*, **38**, 1001, (1967)]. He was a prolific writer and frequently presented papers at technical conferences. His presentations were always clear, concise, and well done.

At the 1976 Joint MMM-Intermag Conference, in Pittsburgh, Joe gave a paper on "Reversal Mechanism in Copper-Modified Cobalt-Rare Earths." He began by pulling a sheaf of yellow pages from his inside coat pocket and placing them on the lectern. He gave the paper without ever referring to these pages. When I was introduced as the next speaker, I found that Joe had left his yellow pages on the lectern. When I finished my talk I gathered up his pages with my notes and returned to the audience.

When I glanced at the papers, I found they were all blank. I returned them to Joe at the end of the session and, of course, asked him why he used blank pages. His answer was, "But, people **expect** me to have notes. . . ."

19th RERC

The 19th Rare Earth Research Conference will be held in Lexington, Kentucky from Sunday through Friday, July 14-19, 1991. Dr. Lance E. DeLong from the University of Kentucky is the General Conference Chairman for the event. Dr. Herbert B. Silber of San Jose State University is the Program Chairman. Topics will include: general and analytical chemistry, spectroscopy, metallurgy, crystal growth, intermetallic compounds, phase studies and diagrams, solid state physics, x-ray diffraction, neutron scattering, magnetism, thermal and transport properties, surface and interface phenomena, rare earth oxide superconductors, rare earth technology, industrial processes, and applications. The conference program will feature organized symposia as well as poster sessions that will provide an overview of rare earth and actinide research and technology. The program will include both invited and contributed papers.

The 6th Frank H. Spedding award for excellence in research and leadership in rare earth science and technology will be presented at this meeting. Details on submitting nominees for this award will be published in the *RIC News* when they are available.

For information on the conference contact: Dale D. Ensor, 19th RERC Secretary, Chemistry Department, Tennessee Technological University, Box 5055, Cookeville, TN 38505, U.S.A.

5ICPMM

The RIC has received a revision in the dates and locale of the *Fifth International Conference on Physics of Magnetic Materials*. So as not to conflict with the International Conference on *f*-Elements (ICFE) the dates have been changed to October 9-12, 1990, and the locale has been changed from Szczyrk-Bila to Madralin, Poland. It also was announced that the leading subject of the meeting will be "Origin of Magnetocrystalline Anisotropy and Magnetostriction." This is in addition to some of the topics mentioned in the December 1, 1989 issue of the *RIC News*. Also, it was announced that attendance will be limited to 50 persons, including 10 invited speakers.

(Continued in next column)

CONFERENCE CALENDAR

International Conference on Magnetic Phase Transitions (MPT '90)
Osaka, Japan
April 13-16, 1990
RIC News, **XXIV**, [2] 2 (1989)

NATO-ASI, Supermagnets, Hard Magnetic Materials
Il Ciocco, Italy
June 10-23, 1990
RIC News, **XXIV**, [3] 2 (1989)

NATO-ASI, Science and Technology of Nanostructured Magnetic Materials
Heraklian, Crete, Greece
June 25-July 7, 1990
RIC News, **XXIV**, [4] 2 (1989)

6th International Conference on Valence Fluctuations (VI-ICVF)
Rio de Janeiro, Brazil
July 9-13, 1990
RIC News, **XXIV**, [4] 2 (1989)

1st International Conference on *f*-Elements (ICFE)
Leuven, Belgium
September 3-7, 1990
RIC News, **XXIII**, [4] 4 (1988) and **XXIV**, [2] 2 (1989)

5th International Conference on Physics of Magnetic Materials (5ICPMM)
Madralin, Poland
October 9-12, 1990
RIC News*, **XXIV, [4] 2 (1989) and *This Issue*

REE in Processes of Petrogenesis
Tashkent, USSR
September 1990
RIC News, **XXIV**, [2] 2 (1989)

11th International Workshop on Rare-Earth Magnets and Their Applications and 6th International Symposium on Magnetic Anisotropy and Coercivity in Rare Earth-Transition Metal Alloys
San Diego, California, U.S.A.
October 21-25, 1990
RIC News, **XXIV**, [4] 2 (1989)

Rare Metals '90
Kokura, Kitakyushu, Japan
November 14-16, 1990
RIC News, **XXIV**, [4] 2 (1989)

19th Rare Earth Research Conference (19th RERC)
Lexington, Kentucky, U.S.A.
July 14-19, 1991
This Issue

**News Story This Issue*

For more information contact Dr. M. W. Gutowski, 5ICPMM Secretary, Institute of Physics, ON-3.2, Polish Academy of Sciences, Al. Lotnikow 32/46, PL-02-668 Warsaw, Poland.

Halide Glasses V

Halide Glasses V, edited by M. Yamane and C. T. Moynihan, contains the proceedings of the 5th international conference on this subject, which was held May 29 to June 22, 1988, at the Fuji Institute in Japan. The 670-page proceedings were published in a single soft cover book as Volumes 32 and 33 of *Materials Science Forum* by Trans Tech Publications Limited in 1988. To order send, SFr 280.00 (~U.S.$170.00) to the publisher, Journal Department, P.O. Box 10, CH-4711 Aedermannsdorf, Switzerland. The proceedings of the 3rd and 4th conferences are also still available for the same price.

Ninety-nine papers are included in the proceedings. Significant new fundamental results are included in the areas of rare earth doped lasers; ionic transport; thermodynamics of fluorozirconate melts; structural characterization by spectroscopic, diffraction, and molecular dynamics techniques; and light scattering from extrinsic sources. Other papers deal with purification of starting materials, analysis of light absorbing metallic impurities, applications of fluoride glasses as optical fibers for remote sensing, applications as bulk glass and fiber infrared lasers, and physical and mechanical properties of the glasses.

Research Chemicals

Randall Ice has been appointed general manager of the Research Chemicals Division of Rhône-Poulenc, Incorporated located in Phoenix, Arizona. He replaces Jim Cunningham who retired earlier this year. Jim will continue to act as a consultant for Rhône-Poulenc. We wish Jim the best in his years of retirement.

GAMI/Wheeler

Gorham Advanced Materials Institute (GAMI) and Wheeler Associates have joined forces to investigate the various and diverse factors of magnet design, performance, cost, patent and licensing positions of major players, raw materials supply, etc. From this study, which began in December 1989 and is expected to take 10 months, they plan on making forecasts for the markets for various magnetic materials for the year 2000.

Yttrium Orthosilicate Phosphors

"Single-Crystal Rare-Earth-Doped Yttrium Orthosilicate Phosphors" summarizes the results of a study of a group of Czochralski grown rare-earth-doped Y_2SiO_5 single-crystal cathodoluminescent phosphors. Such dopants as Ce^{3+}, Tb^{3+}, Eu^{3+}, Sm^{3+}, Tm^{3+}, Gd^{3+}, and some of their combinations were investigated by J. Shmulovich, G. W. Berkstreser, C. D. Brandle, and A. Valentino [*J. Electrochem Soc.*, **135**, 3141-51 (1988)]. The experimental results are presented and discussed in sections devoted to UV, blue, green, and red phosphors. The single-crystal samples were approximately 2 cm in diameter and 0.15 cm thick. The blue phosphor, $Y_{1.945}Gd_{0.05}Ce_{0.005}SiO_5$ was found to be better by a factor of 12.7 than the best blue garnet based phosphor and the high-power efficiency reached 5.3 percent. The new $Y_{1.83}Gd_{0.01}Tb_{0.16}SiO_5$ is the brightest narrow-band emission phosphor in the green region to date, according to the authors. They also found that Gd^{3+} in Y_2SiO_5 is an efficient narrow band UV emitter with a high spectral brightness, which makes it attractive in photolithographic applications.

English Edition Chinese RE Journal

The Chinese Rare Earth Society (Zhongguo Xitu Xuehui) has announced that beginning with Volume 8, published in 1990, there will be a Chinese version and an English version of *Zhongguo Xitu Xuebao (Journal of the Chinese Rare Earth Society).* The English version will have four issues annually. In addition to articles, notes, and communications on original research, a bibliography of rare earth papers published in China will be included in each issue. Minireviews on topics of current interest and brief articles on rare earth research institutes, laboratories, factories, companies, and individuals also will be published occasionally.

To inquire about acquiring distribution or sales rights, or to subscribe, contact Mr. Daohai Jiao, Head of the Editorial Department, Zhongguo Xitu Xuebao, 2 Xinjiekouwai Dajie, Beijing 100088, People's Republic of China.

Oxidation Protection

In 1937, L. B. Pfeil (U.S. Patent 459,848) discovered that trace additions of oxygen active elements like Y, La, and Ce to alloys that form chromium or aluminum oxide scales upon exposure at high temperatures have a strong beneficial effect on the oxidation behavior of these materials. In his patent, Pfeil commented that the mechanism of this effect was not understood. After 50 years, substantial progress has been made to elucidate the mechanisms of this important effect. The book, *The Reactive Element Effect on High Temperature Oxidation—After Fifty Years,* is an effort to collect in one reference, most of the current understanding of the reactive element effect. According to the editor, W. E. King, this was not completely achieved so he included 10 other references in his foreword.

Eight invited reviews appear in the 362-page soft covered book published in 1989 as Volume 43 of *Materials Science Forum.* It costs SFr 125.00 (~U.S.$84.00) and may be ordered from Trans Tech Publications Limited, Journal Department, P.O. Box 10, CH-4711 Aedermannsdorf, Switzerland.

Six of the eight papers involve rare earths with the last paper discussing sulphidation resistance of the oxygen active elements. The other two papers are on anion transport and stress development and are applicable to alloys containing rare earths.

Editorial

(Continued from page 1)

mercial developments in the rare earth field. Furthermore, your organization will have free access to our literature data system, which has nearly 50,000 citations. Do not let your competitors enjoy an information resource advantage over you—join the RIC family of benefactors today.

If you are not sure if your company is a benefactor of RIC, please call, write, or FAX us (the address or numbers are found on page 7). The list of benefactors on page 8 of this issue is incomplete because it only lists the companies that joined or renewed their support during the past quarter.

K. A. Gschneidner, Jr.
Editor and Director

Dilute Mixed-Valent and Heavy-Fermion Systems

The interaction of magnetic moments with conduction electrons and the broader issue of magnetic moment formation in metals has been a topic of much interest during the last three decades. Of special interest of late are the so-called "anomalous" rare earth systems, which show a large pressure and temperature dependence of the lattice constant. Anomalous behavior has been found in numerous Ce-, Sm-, Eu-, Tm-, and Yb-based compounds and alloys. The anomalous behavior is driven by a second ionic configuration, which in the solid has an energy comparable to the trivalent one. The ionic configuration leading to a valence instability of the 4*f*-shell is the divalent one for Sm, Eu, Tm, and Yb and the tetravalent one in the case of Ce. In addition, these systems have a relatively large hybridization between the 4*f*-states and the conduction band states. The hybridization allows the 4*f*-electrons to delocalize to some extent, inducing fluctuations in the 4*f*-charge, as well as in the spin and orbital degrees of freedom. This mechanism is capable of preventing magnetic order and gives rise to mixed-valent and heavy-fermion behavior.

P. Schlottmann has reviewed these systems and some of the models used to analyze them in a paper entitled, "Some Exact Results for Dilute Mixed-Valent and Heavy-Fermion Systems" [*Physics Reports*, **181**, 1-119 (1989)]. The review is available for Dfl 90.00 (~U.S.$48.00), postage included, from Elsevier Science Publishers, B.V., Journals Department, P.O. Box 211, 1000 AE Amsterdam, The Netherlands.

The paper is divided into nine sections, two appendices, and references. The section titles are: Introduction; The degenerate Anderson model; Bethe Ansatz solution of the degenerate Anderson model; Exact properties at T = O of the degenerate Anderson model; Thermodynamic properties of the degenerate Anderson model; Comparison with experiment; The multichannel Kondo problem; Mixed-valent impurity with two magnetic configurations; and Concluding remarks. The two appendices

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MECHANISMS

Volume 11 of the Springer series in material science contains the proceedings of the second in a series of biennial NEC Symposia on Fundamental Approaches to New Material Phases sponsored by the NEC Corporation, Japan. The subject of the symposium, and title of the book, is *Mechanisms of High Temperature Superconductivity.* It was held October 24-27, 1988, in Hakone, Japan.

Forty-eight leading theorists and experimentalists invited from Japan, U.S.A., and Europe stayed together at the site during the four days and were immersed in attempts to clarify the mechanism of high temperature superconductivity. Their aim was to deepen our understanding of the microscopic mechanisms of superconductivity by discussing the latest experimental results on magnetic, optical, electrical, thermal, and mechanical properties of the Cu-O and Bi-O superconductors, as well as proposed theoretical models of the mechanisms.

The 341-page book, edited by H. Kamimura and A. Oshiyama, contains 33 papers plus a summary of the conference. It was published in 1989 and may be obtained for U.S. $49.50 from its publisher, Springer-Verlag, Tiergartenstrasse 17, D-6900 Heidelberg, West Germany or from Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010, U.S.A.

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deal with diagonalization of the transfer matrix (generalized Bethe Ansatz) and solution of the Wiener-Hopf intergal equations for the ground state of the degenerate Anderson model. There are 353 references cited in the bibliography section.

Results obtained by means of the generalized Bethe Ansatz are reviewed with special emphasis given to solution of the degenerate Anderson model, especially in the presence of mechanisms that lift the degeneracy of the *f*-level, e.g., crystalline fields, spin-orbit coupling, and magnetic fields. Most of the review is devoted to properties of Ce and Yb impurities in intermetallic compounds. Section 8 describes some of the properties of Tm in metals. In Tm systems the two accessible configurations, $4f^n$ and $4f^{n+1}$ are magnetic.

Rare Earthers

The RIC has recently learned of the deaths, without any other details, of two researchers in the field of rare earths. First we heard that Professor Zipora B. Goldschmidt of the Hebrew University of Jerusalem had died. We want to extend our condolences to her husband and colleague Professor Zvi H. Goldschmidt.

We also wish to extend our sympathies to the family of Professor Luis G. Tejuca of the Instituto de Catalisis y Petroleoquimica of Madrid, Spain, who died recently.

Thin Films and Crystals

A review by M. Gasgnier entitled "Rare Earth Compounds (Oxides, Sulfides, Silicides, Boron. . . .) as Thin Films and Thin Crystals" has been published in *Phys. Stat. Solidi (a),* **114**, 11-71 (1989). The review treats not only the physical and chemical properties but also deals with the applications of these thin films and crystals.

Section 2, "Rare earth oxides: crystallographic properties—particular applications," has subsections on the sesquioxides, dioxides and intermediate oxides, and applications. Section 3, "Dielectric properties of rare earth oxide thin films," deals with capacitors and transistors. Section 4, "ZrO_2-Y_2O_3 (and Sc_2O_3) ceramics," deals largely with thin films and crystals of the ZrO_2-Y_2O_3 system but also includes some material on Sc_2O_3-ZrO_2 system. Section 5, "EuO and EuS thin films," discusses EuO and EuO based thin films, EuS_y and $Eu_xM_{1-x}S_y$ (M = Sm, Gd, Si, Pb, W, Sr, and Sr-Si) systems, and applications of the EuO and EuS based systems. Section 6, "Rare earth sulfide, oxysulfide, antimonide, bismuthide, and thiovanadate thin films," has subsections on monosulfides, sesquisulfides, monoantimonides and monobismuthides, oxysulfides, thiovanadates, and applications. Section 7, "Rare earth thin films-Si systems," deals with rare earth films on silicon substrates and solar cells with rare earth metal and oxide films. Section 8, "Rare earth-boron thin films," discusses films of LaB_6, SmB_6, and YB_x (x = 2, 4, 6).

This is an extensively documented review with a bibliography containing 394 citations. The wide diversity

(Continued on page 8)

25 Highlights From Past RIC News 25

To celebrate our 25th year serving rare earthers around the world, we will be bringing you selected articles from past issues of the *RIC News*. This issue, the first in the series comes from our very first issue, Volume **1,** No. 1, March 1, 1966. It is an item on the origin of the logo of the Rare-earth Information Center.

The Symbol: Alchemists Discover Rare Earths

No doubt you alchemy buffs may be wondering, "Is the history of the discovery of the rare earths, as described in our texts, wrong? Did the alchemists know about these 'unusual soils' centuries before Lt. Arrhenius' discovery in 1787?" No, we at RIC must confess we did not make a new find in the history of the discovery of the rare earths.

The truth is, we took poetic license and combined the alchemist's symbol for earth, "terra," (an inverted equilateral triangle with a cross bar) with the Latin word for rare (*rarus*) to generate the symbol we have incorporated into our letterhead and brochure.

ZIRCONIA III

Advances in Ceramics, Volumes **24A** and **24B,** *Science and Technology of Zirconia III,* were edited by S. Somiya, N. Yamamoto, and H. Yanagida. Published in 1988, these two volumes contain papers presented at the Third International Conference on the Science and Technology of Zirconia held September 9-10, 1986, in Tokyo, Japan. These volumes include 122 papers with topics on phase stability, powder and nonconventional processing, properties, ZrO_2-containing materials, phase relations, sintering, microstructure, electrolytes, and zirconia deposits. This two-volume hardbound set contains 1,110 pages with 83 papers dealing with rare earths in zirconia. These books are available for U.S.$162.00 from the publishers, The American Ceramic Society, 757 Brooksedge Plaza Drive, Westerville, OH 43081-6136, U.S.A.

Field Splittings

"The anomalous crystal field splittings of $^2H_{11/2}(Nd^{3+}, 4f^3)$" is the title of a paper published by M. Faucher et al. in *J. Phys. France,* **50,** 219-43 (1989). The paper resulted from the fact that the experimental splitting of some particular electronic energy levels of trivalent rare earths deviates strongly from predicted values. It happens for the $^2H_{11/2}$ level of Nd^{3+} at 16,000 cm^{-1} above the ground state. The disagreement is so systematic and conspicuous, whatever the compound, that the authors state that it cannot be assigned to an imperfection of the fitting procedure but rather to a specific failure of crystal field theory.

The authors studied $Nd(C_2H_5SO_4)_3 \cdot 9H_2O$, $Nd(NO_3)_3 \cdot 6H_2O$, NdOCl, $NdAlO_3$, NdF_3, Nd_2O_2S, Nd_2O_3, and Nd doped $LaCl_3$, $LiYF_4$, Y_2O_3, and $Y_3Al_5O_{12}$. They compared the observed splitting to the calculated splitting of the $^2H_{11/2}$ level, and the splitting calculated with and without uncoupling the twin that displays the same S, L, and J values and is observed at 35,000 cm^{-1}. A plot of $\Delta E_o/\Delta E_c$ (the observed/calculated splitting) versus $\Delta E_i/\Delta E_{co}$ (uncoupled/coupled splitting) indicated a direct relationship. They also found that the ratio of $\Delta E_o/\Delta E_c$ increased as the relative crystal field strength increased. The discrepancy between the observed and calculated splitting levels of several other systems are pointed out by the authors. By using different empirical adjustments the authors are able to closely match the observed and calculated levels but, as they say, the adjustments are empirical and the need still exists for a theoretical explanation of why these discrepancies exist and for an expression to help calculate levels that more closely match the observed levels.

Roskill-TMS

The Minerals, Metals, and Materials Society (TMS) of Warrendale, Pennsylvania, has become an official agent for Roskill Information Services of England. TMS will stock some 70 market surveys of various metals, materials, and minerals. This includes Roskill's 7th edition on rare earths published in 1988 and their 2nd edition on scandium pub-

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SESQUISULFIDES and SESQUIOXIDES

A review entitled "Optical Properties and Electron Structure of Rare-Earth Sesquisulfides and Sesquioxides" has been published in *Fiz. Tekh. Poluprovodn.* **23,** 393-415 (1989) [*Sov. Phys. Semicond.,* **23,** 245-59 (1989)]. Written by V. P. Zhuze and A. I. Shelykh, the review presents a systematic account of the investigations of the last 10 to 15 years of the optical properties in the fundamental absorption region and the electron structure of sesquisulfides and sesquioxides of rare earth metals. These compounds are *n*-type wide-gap semiconductors with a low carrier mobility and a high refractive index. Some of these materials are of practical interest as host crystals for active media of lasers and as efficient electrooptic materials for modulation of light beams. In some of the materials the magnetooptic Faraday effect and the photoconductivity are high. They are, therefore, promising as materials for magnetooptic devices, multilayered optical coatings, beam splitters, and passive integrated circuits in microelectronics. The review closes with a bibliography of 110 references.

Muswellbrook

Norton Jackson has retired as executive director of Muswellbrook Energy and Minerals Limited of Melbourne, Australia. He has agreed to remain on the Board of Directors and make his knowledge and experience available.

T. A. Ward has been named managing director and resumes a relationship with Muswellbrook that began when Mr. Ward was with Mary Kathleen Uranium Limited.

We extend our best wishes to Norton in his retirement, and knowing him, he will not be lacking for things to do.

(Continued from previous column)

lished in 1985. For information write TMS, Book Order Department, 420 Commonwealth Drive, Warrendale, PA 15086, U.S.A. Roskill's agent in Japan is the O.T.O. Research Corporation, Takeuchi Building, 1-34-12 Takatanobaba, Shinjuku-ku, Tokyo 160, Japan.

Magneto-Optic Materials

Volume 150 of the Materials Research Society Symposium Proceedings contain papers presented at the symposium on Materials for Magneto-Optic Data Storage held as part of the 1989 spring meeting of the Materials Research Society (MRS) in San Diego, California, April 24-28, 1989. The hard cover book (ISBN:1-55899-023-2), containing 281 pages, can be ordered from Materials Research Society, 9800 McKnight Road, Suite 327, Pittsburgh, PA 15237, U.S.A. The cost to MRS members is U.S.$37.00, nonmembers pay $42.00 in the U.S.A. and U.S.$48.00 elsewhere. *Materials for Magneto-Optic Data Storage,* edited by C. J. Robinson, T. Suzuki, and C. M. Falco, was published in 1989.

The symposium was the first of its type in that it dealt specifically with material science aspects of this technology. Leading groups in this field from Japan, Europe, and the U.S.A., working in areas of material preparation and characterization and in areas of basic and applied research, presented papers on their areas of expertise. Most papers dealt with binary, ternary, and quaternary alloys of rare earths with various transition materials or with garnets that are doped with rare earths.

The commercial importance of this technology is growing rapidly, with rapid progress being made in basic research and in the application of this research to data recording media. This book is one more step in this advancement.

Rare Earth-Copper Phase Diagrams

The RIC has received some more copies of the August 1988 issue of the *Bulletin of Alloy Phase Diagrams.* It is devoted exclusively to rare earth-copper systems with sections devoted to all the rare earths except for lanthanum and yttrium. A six-page introduction on R-Cu systems does have some La-Cu and Y-Cu data and reference is made to earlier articles on these systems in the *Bulletin.*

The Rare-earth Information Center will send a free copy to any interested reader. Please send your request to the address on the next to the last page of your *RIC News.*

Rare-Earth Permanent Magnets

A review with the above headline appeared in *RIC News,* **XXIV,** [4], 7 (1989). It reviewed Volume 80 Number 1 of the *Journal of Magnetism and Magnetic Materials* (soft cover) in which papers presented at the 1988 European Materials Research Society's fall conference on rare earth magnets, were published. A hard cover version has been published by North-Holland and is available for Dfl. 135.00 (U.S.$66.00) from Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands or, in the U.S.A./Canada, from Elsevier Science Publishing Company, Incorporated, P.O. Box 882, Madison Square Station, New York, NY 10159, U.S.A.

Crystal Growth from Molten-Metal-Solution

J.P.A. Westerveld, et al. [*J. Less-Common Met.* **46,** 189-95 (1989)] synthesized several new ternary compounds by growing crystals of metallic compounds in a molten metal solution. They then established a quantum-stability diagram to predict whether a ternary compound would form or if only binary or quasi-ternary compounds would form.

The solution (C) metals they tried included In, Ga, Pb, and Sn. The C metal always constituted the major portion of the mixture (84-97 at.%) with less than 10 at.% each of metal A and metal B. Metal A included rare earths while Metal B was usually a transition metal. The mixture was sealed in a quartz ampoule, heated to at least 1325 K, held for at least two hours, then cooled 5° per hour to a point about 100° above the melting point of metal C. The molten solution was centrifuged off to leave what crystals had formed behind.

Coordinates were calculated using various atomic properties of the metals. They found that two properties, the ratio of melting temperatures (T) and the atomic radii (R) differences, pointed out which systems were most likely to form ternary compounds. In the systems used, $T_A > T_B > T_C$. They found that if $T_A/T_B + T_A/T_C + T_B/T_C$ is

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WIM 150 Mineral Sands

CRA Exploration, a subsidiary of CRA, began a major exploration in the Murray Basin in the early 1980s. Their most significant discovery was a deposit known as WIM 150 at Drung South, about 300 km northwest of Melbourne and 15 km southeast of Horsham.

In 1987, CRA established a subsidiary, Wimmera Industrial Minerals (WIM) Pty. Ltd., to develop the deposit. Exploration of the site shows a central core of about 50 km² (~20 mi²) that is 10-15 m thick with 4-5 m of clay overburden. The WIM 150 core has proven reserves of 580,000 mt of monazite and 170,000 mt of xenotime. Rutile, ilmenite, and zircon total some 25,600,000 mt.

Pilot plant studies had to solve two major problems before processing could be considered. The problems arose because of the particle size of the heavy mineral grains (50 microns) compared to normal deposits with mineral grains of 100 to 200 microns. The traditional methods used for separation, gravity and electrostatic, did not work; so a flotation process was worked out to initially separate the heavy minerals from the quartz sand gangue and then to separate the individual minerals. The other problem had to do with the fact that the rutile and other high-titanium minerals were below the size used in existing pigment plants. A method was developed to increase the particle size.

WIM has reached the conclusion that the deposit could be mined at low cost and on a large scale by dredge methods. They envision an operation of perhaps 20 million mt per annum with a primary concentrator floating in the dredge pond and a secondary separation plant located nearby. This would result in an eventual output of 12,000 tpa of rare earth minerals.

The next step is a larger scale pilot plant, followed by a marketing survey and customer testing of products. WIM hopes to make a decision to mine in 1991 and if so commercial production could start in 1993 some 10 years after the discovery of WIM 150.

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greater than 14 and if $|\Delta R_{AB}| + |\Delta R_{AC}| + |\Delta R_{BC}| > 1.8$ the formation of ternary compounds is likely.

Zirconia Oxygen Sensors

In the paper, "Spectroscopic and Electrical Studies of Yttria-Stabilized Zircona for Oxygen Sensors" [*Sensors and Actuators,* **17,** 555-68 (1989)] K. Schindler, et al. report on their studies as well as studies by other scientists. The paper has a bibliography with 42 entries.

Two kinds of samples were investigated: (100)-oriented single crystals of yttria-stabilized zirconia (YSZ) with 10 mol% yttria and polycrystalline YSZ pellets with 12 mol% yttria. X-ray (XPS), ion backscattering spectroscopy (ISS), and secondary ion mass spectrometry with fast atom bombardment by Ar atoms (FAB-SIMS) and with Ar^+ bombardment (SIMS) were used to determine surface elemental composition and surface impurities. Work functions and ionization potentials were determined by u.v. photoemission spectroscopy (UPS). The method yields detailed information about the density of states in the valence band of YSZ and about the position of the Fermi level relative to E_v as a function of temperature and oxygen partial pressure. Steady-state and current-voltage characteristics were obtained with Pt point-electrodes and Pt-paste counterelectrodes on YSZ single crystals at 1,000-1,250 K. The behavior of thin Pt layers on YSZ under various conditions was also studied using these techniques.

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India—1989

(Continued from page 1)

they are located. RRL-T, which is 10 years old, has two main divisions concerned with materials, glass and ceramics, and food and spices. My host was Dr. A. O. Damodaran, the director of RRL-T. The Materials, Glass and Ceramics Division focuses on clays, silica sands, ilmenite, and rare earths. The rare earth/ilmenite deposit in the state of Kerala is one of the world's largest and the government owned company Indian Rare Earths Ltd. converts monazite to several useful products for worldwide export in addition to internal consumption.

The rare earth research efforts at RRL-T involves the preparation of the rare earth metals by calciothermic and electrolytic processes, development of liquid/liquid solvent extraction processes, chemical analyses, metal matrix composites, rare earth aluminum alloy development, and high temperature superconductors.

International Symposium on Thermochemistry and Chemical Processing

The International Symposium on Thermochemistry and Chemical Processing (ISTCP) was held on November 20-22, 1989, at Indira Gandhi Centre for Atomic Research (IGCAR) in Kalpakkam, India, which is about 75 km (45 miles) south of Madras. The symposium was dedicated to Mr. C. V. Sundaram, who turned 60 in early November and was resigning as the director of IGCAR at the end of the month due to the mandatory retirement age of 60. Mr. Sundaram is one of the outstanding scientists in India and has made many distinguished contributions to the field of extractive nuclear metallurgy during his career, especially in the extractive metallurgy of Be, Ti, Zr, Hf, and Nb.

The conference consisted of 25 invited half hour oral presentations and 45 poster presentations (two sessions) over the three day period. Sixteen of the invited presentations were given by foreign speakers and nine by Indian scientists. The general topics covered: (1) thermochemistry of selected inorganic systems (3 papers), (2) thermochemistry in industrial alloys (6 papers), (3) thermochemistry in nu-

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clear technology (5 papers), (4) high technology materials (2 papers), (5) techniques and modelling (5 papers), and (6) extractive metallurgy (4 papers). The proceeding of the symposium is to be published in *Metals, Materials and Processes,* a new journal edited by Mr. C. V. Sundaram.

Indira Gandhi Centre for Atomic Research

The main mission of IGCAR is to build and test an experimental breeder reactor to ensure a continuous supply of fissionable material. Since India had a limited supply of U, but a large surplus of Th (as a by-product from the vast monazite deposits, which are being mined for the rare earths), they are using Th as the breeder material. While attending the symposium, I spent an afternoon visiting Dr. C. K. Mathews' physical chemistry group (Dr. Mathews was one of the conference organizers). Part of his group is responsible for testing the Na loop, which is used in the breeder reactor for cooling the nuclear fuel. A "cold" (in the nuclear sense) loop has been built and is in the final stages of becoming operational. They are also studying the chemical, thermodynamic, and physical properties of a large number of compounds that might end up in the Na loop as a result of leaching out the alloy agents in stainless steel (Cr, Mn, Ni etc.) and fission products, which would eventually end up in the Na due to small pinhole leaks in the stainless steel cladding of the UC-PuC fuel rods. Many of these compounds are ternary oxides such as $NaCrO_2$, Na_3NbO_4, and various Na-Fe-O compounds. As one might expect, this is a well equipped laboratory with many of the latest innovations.

Epilogue

It was a wonderful, interesting, and stimulating visit, in spite of spending about 18 hours in the London airport. The Indian scientists were extremely gracious hosts and were most helpful in making this a successful and memorable journey.

Denison Mines

John Britt has been named director of marketing for Denison Mines Limited of Toronto, Ontario, Canada. He assumed the duties of Noel O'Brien, vice president, marketing, who has retired. We hope Noel enjoys his retirement years.

Ion Exchange Handbooks

J. Korkisch has put together a series of six volumes of *Handbook of Ion Exchange Resins: Their Application to Inorganic Analytical Chemistry,* published in 1989 by CRC Press Incorporated. The six volumes contain approximately 2,000 pages.

This is a review of Volume **1,** which devotes 180 of 301 pages to the separation and analysis of rare earths in various materials, including rare earth mixtures. The first 111 pages are devoted to ion exchange resins, fundamental concepts, and special analytical techniques that pertain to all the practical application sections that comprise the rest of the handbook volumes. Over 500 references are listed for the two introductory sections.

The section on rare earths begins with a short history. It then describes the systems and samples that are the subjects of tables 2 through 118. Each table is a concise description of one or more applications of an ion exchange analytical procedure. Details such as column size, elution rates, eluent, resin, solution strengths, etc. are included in each table along with the reference(s) from which the procedure was extracted. The section has a bibliography with 601 entries.

Volume **1** can be acquired from the publishers at 2000 Corporate Boulevard N.W., Boca Raton, FL 33431, U.S.A. The cost for this volume is $135.00 in the U.S. and U.S.$175.00 elsewhere.

While the practical applications section of Volume **1** is devoted to rare earths, other volumes have some tables involving rare earths. This is especially true of Volume **2** devoted to actinides. References to some of these tables are given as footnotes in the tables of Volume **1.**

Thin Films and Crystals

(Continued from page 4)

of the various subjects included in this paper demonstrate first, that rare earth elements have important physical and chemical properties, and secondly that these are often sharply modified in the case of compounds and/or alloys. These materials are interesting for industrial and laboratory applications and their uses, especially in microelectronics, is increasing.

Contributors

The third quarter of fiscal year 1990 was quiet as is normal. We had 34 sponsors who sent in their pledge or money during this quarter. Two new members were welcomed to our family of benefactors and one old friend was welcomed back to the list of supporters. For the year, we have 112 sponsors, 18 more than last year, and 38 away from our goal of 150 for the year.

The 34 additions to our list of benefactors during the third quarter, with the number of years they have been sponsors in parentheses, are listed below.

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Rhône-Poulenc

John Forti is now business director of rare earths and gallium for the Fine Inorganic Chemical Division of Rhône-Poulenc, Incorporated, with offices in Princeton, New Jersey. He moves up to replace Jim Spooner who moved on to another job with the company.

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