Rare-earth Information Center NEWS

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REO Strategic Minerals Inventory

Earth science and mineral resource agencies from several countries founded the International Strategic Minerals Inventory in a cooperative effort to gather information about major sources of strategic raw materials. The result of this effort is the publication *International Strategic Minerals Inventory Summary Report-Rare Earth Oxides* and is published as U.S. Geological Survey Circular 930-N. The report was prepared by the respective agencies of Australia, Canada, Germany, The Republic of South Africa, the United Kingdom, and the United States.

Part I, Overview, begins the report by giving a general review of rare earth oxides (REO), including a brief background of rare earths. Topics include applications, mineralogy and geology, major rare earth minerals, types and distribution of rare earth deposits, REO resources, production, supply and consumption, production and capital costs, mining and beneficiation, metallurgy and refining, and world trade in REO. Tables provide general information, such as typical rare earth distribution of the three major source minerals: bastnasite, monazite, and xenotime, as well as the chemical formula for 19 of the major rare earth minerals.

For the person who wants to know where the major commercial rare earth deposits are located around the world, several maps are included which identify the operating mine and deposit type, including total resources at each of the sites. Of particular interest is a map which locates the world's rare earth processing plants, and their owners. Other tables include information on annual global REO production by selected countries. Since most of the information was gathered by 1989, trends and forecasts are given for later years.

Part II, Selected Inventory Information for REO Deposits and Districts, contains information in tabular format from the International Strategic Minerals Inventory

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(ISMI). This interesting compilation identifies world wide REO site names, provides the location of each in latitude and longitude, identifies the deposit type, the host rock, geologic age, local environment, principal mineral assemblages, and average grade of mineral at each site.

The *International Strategic Minerals Inventory Summary Report-Rare Earth Oxides* is recommended for those rare earth companies in the business of importing and exporting materials world wide, or for anyone needing a "big picture" summary of the primary production of rare earths. The 68-page report was written by W.D. Jackson and G. Christiansen, and was published in 1993 by the U.S. Geological Survey. For a free copy, contact the U.S. Geological Survey, Map Distribution, Box 25286, MS306, Federal Center, Denver, CO 80225 USA. ▲

Rare Earth Research Group
N.S. Kurnakov Institute of General and Inorganic Chemistry

Pictured in the photo above, front row left to right, are Drs. G.V.Lisanova, L.Z. Gohman, B.F. Dzhurinskii, N.N. Chudinova, E.V. Murashova, E.G. Tcelebrovskaya, back row from left to right, Drs. N. Yu. Anisimova, V.A. Muratova, V.P. Orlovskii, G.A. Bandurkin, A.B. Pobedina, M.G. Komova, and G.M. Balagina.

The N.S. Kurnakov Institute of General and Inorganic Chemistry of Russian Academy of Sciences, Moscow, is well known for the work conducted there on High Temperature Superconductivity (HTSC). Also at the Institute is the Laboratory of the Rare Elements and Inorganic Polymers, at which most of the experiments on the chemistry and systematics of rare earths have been carried out. The current projects at the Laboratory include rare earth phosphates, halogenides, ferrocyanides and various complexes.

Dr. B.F. Dzhurinskii (at center of photo) leads a research group concerned with the systematics and properties of rare earth borates, molybdates, ferrocyanides, phosphates, diphosphates, cyclophosphates, and other compounds. The Laboratory has published several books on series *Khimia Redkih Elementov*, including *Chemistry of the Rare Earth Elements and Systems of the Group I-III Element Oxides*. The research under Dr. Dzhurinskii is focused in two directions: 1) systematics and properties of the lanthanides; and 2) lanthanide compounds with mixed oxide anions, such as $LnBO_2MoO_6$, $Ln_3BO_3WO_6$, Ln_3GePO_9, $(LnO)_7BO_3(PO_4)_2$, etc. (where Ln = lanthanides). ▲

Tailored Microstructures in Hard Magnets

The Office of Basic Science (BES), Office of Energy Research, U.S. Department of Energy, has initiated a program to encourage close collaboration between BES laboratories and industry in several areas of synthesis and processing. One of these areas is Tailored Microstructures in Hard Magnets.

Currently, the magnetics synthesis and processing group is seeking an effective way of obtaining industry input as to basic research programs in permanent magnets which will benefit the U.S. permanent magnet industry as a whole. An open meeting will be held Monday afternoon and evening, October 3, 1994 in Rosemont (Chicago) Illinois. The date and time of this meeting corresponds to the ASM TMS Materials Week '94 in Rosemont. The meeting is being planned by a committee consisting of Andreas R. Hütten (Lawrence Berkeley Laboratory), Samuel D. Bader (Argonne National Laboratory), R. William McCallum (Ames Laboratory), Robert F. Krause (Magnetics International Inc.), K. Narasimhan (HOEGANAES), and V. Panchanathan (MAGNEQUENCH).

For more information contact Bob D. Dunlap; Tel:708 252 4925; Fax:708 252 4798; E-mail:bddunlap@anl.gov. ▲

SCES '95

The International Conference on Strongly Correlated Electron Systems (SCES'95) will be held September 27-30, 1995 in Goa, India. SCES'95 is expected to bring together researchers who are working on the various aspects of correlated electron systems. The tentative list of topics that will be covered at the conference include: heavy electron phenomena, Kondo (lattice) effects, anomalous f and d electron systems, correlation in high T_c compounds, superconductivity in heavy electron systems, magnetic and superconducting properties of borocarbides, electron correlation and magnetic order, charge and spin fluctuations, etc.

For additional information and to receive the first circular, contact Prof. R. Vijayaraghavan, Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Bombay - 400 005, India; Tel:91 22 2152971; Fax:91 22 2152110; Telex:011 83009; E-mail:"RV@TIFRVAX.BITNET". ▲

Conference Calendar

*** A NEWS STORY THIS ISSUE**

September '94
Thirteenth International Workshop on Rare-Earth Magnets and Their Applications and Eighth International Symposium on Magnetic Anisotropy and Coercivity in Rare-Earth Transition Metal Alloys
Birmingham, England
September 11-15, 1994
RIC News, **XXVIII**, [4] 2 (1993)

October '94
Tailored Microstructures in Hard Magnets
Chicago, Illinois, USA
October 3, 1994
*This issue

12th Technology Short Course on Permanent Magnet Design
Detroit, Michigan, USA
October 24-6, 1994
*This issue

August '95
The Third International Conference on Rare Earths Development & Application
Baotou, Inner Mongolia, China
August 21-25, 1995
RIC News, **XXIX**, [1] 3 (1994)

September '95
European Magnetic Materials and Applications Conference (EMMA 95)
Wein, Austria
September 4-8, 1995
RIC News, **XXIX**, [1] 3 (1994)

International Conference on Strongly Correlated Electron Systems (SCES'95)
Goa, India
September 27-30, 1995
*This issue

Permanent Magnet Short Course

Princeton Electro-Technology, Inc. will hold its 12th Technology Short Course, with accompanying exhibition, on Permanent Magnet Design on October 24-6, 1994, in Detroit, Michigan USA. The course will be of interest to permanent magnet designers, engineers, and technical managers who are involved in rare earth permanent magnets. Topics include the latest developments in material properties and processes, magnet behavior under increasingly demanding environmental conditions, modern methods for magnetic circuit design and analysis, with a number of design studies from today's most important commercial applications, including motors, actuators and sensors. Special emphasis will be on neodymium-iron-boron and other advanced rare earth magnets. The course will be presented by four leading experts in the field of permanent magnet materials, design and applications: Dr. Fred G. Jones on magnet properties, production methods and costs; Dr. Peter Campbell on magnet stability, circuit design and field analysis; Reinhold Strnat on magnetization and testing, techniques and

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Course/*Continued from previous column* ➪

equipment; and Professor David Howe on applications and design studies. The three-day course will be based on *Permanent Magnet Materials and Their Application*, written by Dr. Peter Campbell.

For further information, contact: Princeton Electro-Technology, 7300 West Camino Real, Suite 131, Boca Raton, FL 33433; Tel:407 361 0773; Fax: 407 361 0877. ▲

Workshop and Symposium on Permanent Magnets

The Rare-earth Information Center still has a limited supply of the proceedings of both the *Twelfth International Workshop on Rare Earth Magnets and Their Applications*, and the *Seventh International Symposium on Magnetic Anisotropy and Coercivity in Rare Earth Transition Metal Alloys*.

The cost of the two-volume set is $150.00 US, or $75.00 US for either volume alone For ordering information check page 7 of the September 1, 1993 issue of the *RIC News*, or contact the Rare-earth Information Center, Institute for Physical Research and Technology, Iowa State University, Ames, IA 50011-3020, USA; Tel:515 294 2272; Fax:515 294 3709. ▲

Plasma-Sprayed Yttria Coatings

Because of their important thermal and mechanical properties, yttrium oxide coatings have been studied extensively in recent years. With a melting temperature of 2450°C, yttria coatings provide corrosion protection for equipment exposed to severe operating conditions by acting as a thermal and stress barrier in aeronautical and various industrial applications. One of the methods that is widely used to deposit these coatings onto component parts is by plasma spray.

V. Gourlaouen et al. in *Mat. Res. Bull.*, **28**, pp.415-25 (1993) report on metastable phases in yttrium oxide plasma spray deposits and their effect on coating properties. The thickness of these coatings can be varied from a few tenths of a millimeter to several millimeters, depending on the end use of the component to be covered. This method produces materials having undergone ultra rapid quenching of their melts and a high pressure impact on the substrate. Because of these deposition conditions, structural modifications of the yttria occurs, often resulting in structural types not found in traditional equilibrium diagrams.

The authors conducted experiments on various plasma spray techniques of Y_2O_3, using different parameters, and the resulting structural phases produced by each. The plasma spray method introduces solid yttria particles into a plasmagenic gas flow composed of Ar, N_2, H_2 and He. This gas flow is ionized by an electric arc generated between a copper anode and a tungsten cathode. The accelerated molten particles then collide with a relatively cold substrate at a speed of several hundred meters per second. The hot mixture then cools at a rate of about 10^6 °C/sec which forms a coating of several superimposed layers.

The authors tested several plasma spray techniques by altering the spray distance (distance between torch and substrate), particle impact pressure, deposition atmosphere (pressure and oxygen content), substrate temperature and plasma gas composition. Yttrium oxide deposits obtained by plasma spraying consisted of two phases: a predominate cubic *C* form, stable up to the melting point; and the monoclinic *B* form. In addition, it was found that the extremely high cooling rate may produce a metastable phase that can not be obtained under normal conditions.

The existence of metastable *B* phases in

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rare earth oxides obtained by plasma spraying may be due to the influence of the crystal/liquid interface energy on *B* and *C* nucleation kinetics. In fact, the monoclinic phase nucleation was found to be faster than the $B \rightarrow C$ transformation.

The authors conclude that the proportion of the metastable monoclinic *B* form to the stable cubic *C* phase of yttria depends mainly on the spray operation atmosphere and the torch/substrate distance. Annealing by thermal treatment (between 700 and 1450°C) causes this metastable *B* form to convert into a stable *C* form. It was found that the higher the annealing temperature, the faster the transformation. The $B \rightarrow C$ phase transformation is characterized by an 8.4% increase in volume and leads to significant weakening of the mechanical properties of the deposits. ▲

PBM 94 Proceedings

The Second International Conference on Polymer Bonded Magnets 94 was held in Chicago, Illinois, USA, April 12-13, 1994. The conference proceedings from that conference, *Polymer Bonded Magnets 94*, is now available. The proceedings includes a set of program materials containing a list of participants and eighteen presentations. These presentations cover such topics as: Hydrogenation, Decomposition, Desorption and Recombination (HDDR) anisotropic bonded NdFeB permanent magnets; new markets and product opportunities for rare earth permanent magnets; automotive applications; corrosion control for bonded NdFeB magnets; and calendering process improvements. The proceedings will be useful to those permanent magnet manufacturers involved with in-mold or post-magnetization techniques and provides insight on how to achieve compound homogeneity. For a breakdown of worldwide markets and trends in ferrite permanent magnet production and demand, including a direct comparison of ferrite bonded magnets and rare earth permanent magnets, a paper by Hiroshi Yokoyama provides an excellent summary. Recent permanent magnet technological advances in the U.S.A., Europe and Asia/Pacific are also reviewed.

The 225-page *Polymer Bonded Magnets 94* was published in 1994 and is available for $795.00 US by contacting Intertech Conferences, 411 U.S. Route One, Portland, ME 04105, USA; Tel:207 781 9800; Fax:207 781 2150. ▲

Super Sonar

The American Superconducting Corporation has successfully tested a low frequency underwater sonar transducer that uses high-temperature superconducting (HTS) coils and terbium-dysprosium (TbDy) magnetostrictive materials and has delivered it to the Navy. This represents a new application for superconductors and is the first time that an integrated system involving HTS coils, cooled by a mechanical cryocooler, and utilizing novel magnetic materials technology has been used.

The acoustic transducer was made of HTS coils fabricated by using BiSrCaCuO-2223 HTS wires and a single-stage, Sterling-cycle cryocooler to cool the coils and the Tb-Dy rod to 50-65 K. When energized by electrical current, the coils create an AC magnetic field of 0.1 T at 50 K which cause an oscillatory strain on the magnetostrictive rod. The magnetostriction is then passed through a cryostat to two head masses that transmit sound energy to the surrounding environment. The superconducting sonar device enables more sophisticated signal processing and the ability to identify objects by distinctive sonar echoes.

The navy currently uses sonar devices for detection of underwater objects such as submarines and mines that use piezoelectric ceramic materials. These materials expand and contract when stimulated by an electrical signal but operate at a higher frequency and a lower power than Tb-Dy magnetoelastic alloys, which limits their range. Since magnetoelastic alloys operate at a lower frequency and have a higher power output than ceramics, the sound energy generated is much less affected by attenuation and can thus travel further.

While magnetostriction is perhaps the most important single material property for high power sound transmission, other properties such as magnetomechanical coupling and elastic moduli are also important. One disadvantage of the Tb-Dy alloy is its ductility which limits its ability to do work. Further research is being conducted to solve this problem.

These superior sonar capabilities will be useful in shallow water locations such as the Arabian Gulf, and may be used for ocean mapping and mineral exploration as well. ▲

In 1912 X-ray spectra confirm that only 15 lanthanides are to be expected plus the two closely related metals Sc and Y.

Maria Goeppert-Mayer Award

Laura H. Greene, professor of physics at the University of Illinois, Urbana-Champaign, was chosen by the American Physical Society for the 1994 Maria Goeppert-Mayer Award. Professor Greene was selected for "her work on the physics of novel materials, in particular, studies of the effects of oxygen and atomic substitutions on the physical properties of bulk high-temperature superconductors; and for research on superconductivity effects and tunneling in artificially layered superconducting magnetic and heavy-fermion thin film structures."


Professor Laura H. Greene

Professor Greene also had the distinction of being selected as Fellow of the American Physical Society in 1993, and serves as General Councilor of the American Physical Society. She is an editor for "Superconductivity Review", and is a member of the editorial board of "Encyclopedia of Physics". She has served on several advisory committees, including NATO-ASI, "Superconducting Materials" 1989, and was symposium chair of the 1992 Fall Meeting of the Materials Research Society. In addition, she has been invited to give more than 100 talks and has been involved in over 100 publications. ▲

Hugh Douglas & Company

Hugh Douglas & Company, based in Burlington, Vermont, USA, has made an agreement with KyrghyzAltyn of Bishek, Kyrhgyzstan, to market ten high purity rare earth metals and oxides. The agreement, according to Mr. Hugh Douglas, enables the company to exclusively offer these materials from KyrghyzAltyn to the United States and Canada. The company seeks to establish long-term relationships with users of rare earths based on high quality, competitive pricing and reliable delivery.

For more information on the company's products and services, contact: Mr. Hugh Douglas, P.O. Box 1092, 80 Austin Drive 18, Burlington, VT 05402-1092; Tel: 802 860 1026; Fax: 802 860 7063. ▲

1994 Shiokawa Award

Professor H. Kanno, Head of the Chemistry Department of the National Defense Academy of Japan, was the recipient of the 1994 Shiokawa Award of the Rare Earth Society of Japan. This award is presented annually in recognition of scientific and/or engineering achievement in rare earth science and technology in Japan. Prof. Kanno was recognized for his Raman and DTA studies of aqueous rare earth electrolyte solutions at low temperatures, in which he clearly showed that the inner-sphere hydration number of rare earth ions changes from nine to eight in the middle of the series. In addition, he demonstrated that the hydration number changes show very anomalous behavior as to the salt concentration dependence. He has also conducted studies on rare earth glasses and rare earth-doped electroluminescent thin films.


Professor H. Kanno

Prof. Kanno was born in 1941 and earned his Doctor of Science degree from Tokyo University in 1968. RIC congratulates Professor Kanno for receiving this prestigious award. ▲

Vacodym 411

A new high temperature rare earth permanent magnet is being offered by Vacuumschmelze GmbH (VAC) of Hanau, Germany. The new magnet, known as VACODYM® 411, is produced from Nd-Fe-B alloy and is designed primarily for use in highly dynamic servomotors. The material has an extremely high coercivity of $H_{cJ} = 41$ kOe at room temperature and $H_{cJ} = 17$ kOe at 150°C. It can be used in temperatures up to 200°C in strong opposing magnetic fields. Performance graphs supplied by the manufacturer show a straight demagnetization curve with a gradient close to one.

For more information on this new material, contact Vacuumschmelze GmbH, Public Relations, P.O. Box 22 53, D-63412 Hanau, Germany; Tel: 49 6181 38-0; Fax: 49 6181 38-2860; Telex: 61818201=vac. ▲

Honorary Doctorate

Mrs. Renata Reisfeld, an inorganic chemist and expert in solid state lasers, glasses and solar energy at Hebrew University, Israel, was presented an honorary doctorate by the University of Lyon, France. Three hundred and sixty four of her papers have appeared in scientific journals concerning glasses, lasers, optics and sensors. She has written over 70 papers dealing with rare earths. They cover borate and fluoride glasses, rare earth-doped laser crystals, luminescent crystals and glasses, and applications of rare earths in solar energy.


Professor Renata Reisfeld

She is the author of the book *Lasers and Excited State of Rare Earths*, which she explained the incorporation of rare earth ions, such as erbium, into glasses. The book is entirely theoretical, but the technique is now the basis of a multi-billion-dollar industry, fiber optic amplifiers. Her work has also been applied to fluorescent lights, television cathode ray tubes, and personal computers.

Originally from Poland, Reisfeld studied at Hebrew University, eventually becoming the Enrique Berman Chair of Solar Energy in 1980. In 1976 she started a laser group at the University of Lyon, France. She has also collaborated with other laboratories world wide, including the Szold Institute and the Ministry of Science in Israel, the U.S. Air Force and Army, and the Volkswagen and Krupp Foundations, among others.

RIC congratulates Mrs. Reisfeld on her life-long accomplishments as well as her Doctor *Honoris Causa*. ▲

Advances in RE Research

Advances in Rare Earths Research, the proceedings of the Symposium on Rare Earth Materials Research, was a cooperative effort of the Indian National Science Academy and the USSR Academy of Sciences. The Symposium was held in Trivandrum, India, November 5-7, 1990.

The 1993 proceedings is a collection of 44 papers which cover coordination chemistry of rare earth compounds, geochemistry, solvent extraction, fluorescence studies of phos-

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Ce-Doped Electroluminescent Films

Recently, a post-annealing technique was used to make double-insulating SrS:Ce electroluminescent thin films {*Jpn. J. Appl. Phys.*, **32**, 1672-80 (1993)}. S. Okamoto, T. Kuki, and T. Suzuki report that this postannealing technique effectively lowers the substrate temperature during the deposition of SrS:Ce, and improves luminance and the blue color that is emitted.

Thin-film electroluminescent films (TFEL) that emit blue light have potential applications in medicine, and other fields for use in cathode ray tubes (CRT's) and other display equipment. Currently, the leading candidate for this color is ZnS:Tm TFEL, but it does not have sufficient luminance for practical applications so a new material, SrS:Ce, is being studied as a substitute. A new sulfur-cracking technique employed during electron beam deposition, followed by post-annealing, improves luminance, decreases the growth temperature of the SrS:Ce layer to less than 300°C, reducing sulfur-induced damage to the apparatus.

The authors report that the device is composed of two sections: an electroluminescent cell of a conventional double-insulating structure, and an insulator cell without an active layer. By using an electron beam, the SrS:Ce layer is deposited on top of indium-tin-oxide electrodes which sit on top of the glass substrate, then sandwiched by ZnS buffer layers and Ta_2O_5 insulators. The rear electrodes are made of aluminum.

The resulting electroluminescent spectra of the SrS:Ce device originate from the *5d-4f* transitions of Ce^{3+}. The emission colors are changed from green to blue-green by the SrS crystal field of the SrS:Ce layer. It was discovered that post-annealing the sample after preparation increased the blue component of the emission. Annealing not only improves the color emission of the TFEL device, but also the lightness. With further work, the blue-emission properties of TFEL devices may open up new applications for this material. ▲

Advances*/Continued from previous page* ⇨

phors, spectroscopy and other analytical techniques of rare earths, magnetism in rare earth alloys, high-T_c superconductors, RE oxides and intermetallic compounds, mathematical modeling, electrodeposition and catalysis. Others papers of interest include: the production of $SmCo_5$ alloy from Sm_2O_3 by calciothermy, the present state of rare

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earth metallurgy in India, and the study of materials containing RE sulfides.

The 327-page soft cover *Advances in Rare Earths Research* was edited by B.C. Pai, R.M. Pillai and A.D. Damodaran, and contains an author index. It is available for $100.00 US (including postage) by contacting The Library Officer, Regional Research Laboratory, Industrial Estate PO, Trivandrum 695 019, India; Tel:76774/73672; Fax:91 471 75186; E-mail:rrlt@sirnetm.ernet.in. ▲

Er-Doped Crystalline Si

The cheapest material available for use in optoelectronic technology is Si, but it does not emit light efficiently. Because of its indirect band gap, Si has an inefficient band-to-band luminescence under electrical excitation. Attempts to avoid this problem through band-gap engineering by adding either germanium or other isoelectronic impurities, or structural defects which cause radiative recombination, have not been successful. However, rare earth ions in the correct charge state exhibit luminescent intra-*4f* transitions, which are shielded from the surrounding medium by filled outer electron shells. The use of Er is interesting because these transitions occur near 1.5µm, which make it a good candidate in communication technologies. But, using Si for this application will only be feasible if enough Er can be doped into the crystal *c*-Si and made optically active.

A. Polman, J.S. Custer, E. Snoeks, and G.N. van den Hoven report that they have successfully incorporated high concentrations of Er in crystalline Si [*Appl. Phys. Lett.*, **62**, 507-9 (1993)] which was accomplished by solid phase epitaxy of Er-implanted amorphous Si (*a*-Si). The concentration is reported to be at least 2 orders of magnitude higher than has previously been achieved. The authors state that during thermal recrystallization of the amorphous layer, segregation and trapping of Er occurs at the moving crystal/amorphous interface. As long as the concentration of Er trapped in the crystal remains below a critical level, perfect epitaxial regrowth occurs. The concentration limit appears to be temperature dependent, decreasing from $1.2\pm0.2 \times 10^{20}/cm^3$ at 600°C to $6\pm2 \times 10^{19}/cm^3$ at 900°C.

The authors report that Er was incorporated into *a*-Si by either implanting Er directly into *c*-Si or into *a*-Si previously made amorphous by Si implantation ($3 \times 10^{15}/cm^2$ 350 keV Si followed by 1.3, 2.4, or $5.4 \times 10^{15}/cm^2$ 250 keV Er). All implants were performed with the samples heat sunk to a copper block cooled by liquid nitrogen.

The authors believe that if all of the Er incorporated into the *c*-Si could be optically activated, this would lead to the production of Si-based optical devices such as light emitting diodes and optical amplifiers. ▲

RE Doped Semiconductors

The properties of rare earth ions in solids have been studied in detail for decades, but until recently, this work was restricted to dominantly ionic hosts such as fluorides and oxides, and to a lesser extent to more covalently bonded hosts, such as tetrahedral II-IV semiconductors. *Rare Earth Doped Semiconductors*, a new book from the Materials Research Society (MRS), is one of the first attempts to compile selected research pertaining to rare earths incorporated into technologically important semiconductors. The book is based on a symposium which was held at the 1993 MRS meeting in San Francisco, California.

The book presents 57 papers in six parts entitled: Rare Earth Incorporation; Rare Earth Doped Silicon; Optical, Electrical and Structural Properties; Excitation Mechanisms; Novel Structures and Devices; and Theory and Models. The papers address the unique properties of rare earth doped Group III-V, Group IV, and Group II-VI semiconductors. The book also covers current trends in research and identifies the potential for current and future electronic and optoelectronic applications.

Twelve papers deal with the preparation of rare earth-doped semiconductors, including the procedures involved in ion implantation, crystal and film growth. Chapters on luminescence and photoluminescence of RE-doped silicon for use in optoelectronics and other applications provide insight into the many applications of these materials. Of particular interest is the section devoted to novel structures and devices. These papers present possibilities in the direction of market growth of rare earths in this field.

The 417-page *Rare Earth Doped Semiconductors* is Volume 301 in the MRS Symposium Series and is edited by G.S. Pomrenke, P.B. Klein, and D.W. Langer. The 1993 book is available in hardcover or microfiche to MRS members for $55.00 US, to non-MRS members in the USA for $65.00 US, and $70.00 US for all others. Contact the Publications Department, MRS, 9800 McKnight Road, Pittsburgh, PA 15237 USA; Tel:412 367 3012; Fax:412 367 4373. ▲

Multiclient Study

A seven-month multiclient study of the market and technical characteristics of the magnetic materials industry of China is now available. The study, *The Magnetic Materials Industry of China: Market Appraisal, Technical Assessment and New Business Opportunities, 1993-2000* was conducted to assess the growth and future markets of rare earth permanent magnets in the People's Republic of China. According to experts in the field, the magnetic materials industry of China is booming. Supported by the fastest growing economy in the world, the magnetic materials industry in China experienced a 14% growth rate in 1993. Dr. Olmstead, director of the study, pointed out that "In 1992, production of NdFeB reached 490 tonnes and production of hard ferrites totaled 52,000 tonnes. China's focus on technology development and manufacturing growth has made the country a leader in the global magnetic materials industry. If present rates of growth continue, China will be the largest producer of magnetic materials in the world by the end of the decade."

The Magnetic Materials Industry of China is comprised of thirteen chapters: Executive Summary; Overview of China Today; Neodymium-Iron Permanent Magnets; Samarium-Cobalt Magnetic Materials; The Rare Earth Industry in China; Alnico Permanent Magnets in China; The Development of Hard Ferrites in China; Bonded Ferrite Magnets in China; Development of Soft Ferrite in China; Amorphous Magnetic Materials in China; Magnetic Treatment of Fluids; Medical Magnetotherapy in China; and NdFeB Patents-Implications for China. The study details the activity underway in the magnetic materials industry of China. These include production, use, import/export, raw materials, new process developments and unique niche applications. Included in the report are 91 exhibits (tables and graphs), some of which include: economic indicators, industrial production, destination of exports, annual production, distribution of manufacturers, trend of NdFeB prices in China, and industrial reserves. The study also identifies permanent magnet factories operating in China and their production capacities.

This study is a "must have" for individuals, trading companies, and permanent magnet manufacturers worldwide who need an overall assessment of the permanent magnet industry. For additional information on

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Study/*Continued from previous column* ➩

the content of the 220-page study, a complete brochure is available by contacting Dr. Hugh D. Olmstead, Program Manager-Magnetic Materials, Intertech Corporation, 411 US Route One, Portland, ME 04105 USA; Tel: 207 781 9800; Fax: 207 781 2150. The cost to receive the study is $2,495.00 US. ▲

Handbook of Magnetic Materials

The *Handbook of Magnetic Materials*, Volume 7 is the latest in a series of publications that provide reviews on the latest information and the state of investigations of magnetic materials. This series can be used as a textbook for those wishing to be introduced to the field of magnetism without reviewing the vast amount of published literature, and as a reference book for scientists, engineers and researchers. Volume 7 was written by leading authorities working in this exciting field. Composed of six chapters: Magnetism in Ultrathin Metal Films, Energy Band Theory of Metallic Magnetism in the Elements, Density Functional Theory and the Ground State Magnetic Properties of Rare Earths and Actinides, Diluted Magnetic Semiconductors, Magnetic Properties of Binary Rare-earth 3*d*-transition-metal Intermetallic Compounds, and Neutron Scattering on Heavy Fermion and Valence Fluctuation 4*f*-systems, each chapter gives an extensive description in graphical and tabular form with emphasis placed on the discussion of the experimental material in the framework of physics, chemistry and materials science.

A major step forward in the understanding of metallic magnetism has been through electronic band structure calculation. Two chapters, one dealing with elements and the other with 4*f* and 5*f* systems, describe the physics behind these band calculations in a manner understandable to scientists having no experience in these calculations. Two later chapters deal with thin film technology, ultrathin transition metal films and novel magnetic phenomena when magnetic moments are incorporated in a semiconducting matrix. The final chapters describe the progress made in the field of heavy fermions and valence fluctuations including results obtained by neutron scattering. Perhaps the most interesting chapter of the Handbook, to rare earthers, is the chapter by J.J.M. Franse and R.J. Radwański entitled "Mag-

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Handbook/*Continued from previous column* ➩

netic Properties of Binary Rare-earth 3*d*-Transition-Metal Intermetallic Compounds" which reviews the progress made in this area. The chapter covers RT_2(T=Co Fe, Mn, Ni), RT_3 (T=Fe,Ni,Co), R_2T (T=Co,Ni), R_6T_{23} (T=Fe,Mn), RT (T=Co,Ni), RNi_5, R_2T_{17} (T=Fe,Co,Ni), and RT_{12} (T=Fe,Mn) compounds.

The 676-page *Handbook of Magnetic Materials*, Volume 7, was published in 1993 edited by K.H.J. Buschow, and is available in the U.S.A. and Canada by ordering through: Elsevier Science Publishing Co. Inc., P.O. Box 945, Madison Square Station New York, NY 10160-0757; elsewhere Elsevier Science Publishers, P.O. Box 211 1000 AE Amsterdam, The Netherlands, fo Dfl. 380.00 ($237.50 US). Subscribers pay only Dfl. 323.00 ($202.00 US). The book will be sent to individuals post-free if payment accompanies the order. ▲

Quality Assurance ISO-9000 Series

RIC acknowledges two more companies who have achieved the International Organization for Standard accreditation (ISO): Optical Surface Technologies, a division of London & Scandinavian Metallurgical Co. Limited, England, and Rhône-Poulenc Chimie, France. The ISO quality assurance certification identifies those companies who have successfully completed a rigorous series of inspections of their quality management systems.

Optical Surface Technologies (OST) manufactures cerium oxide based glass and plastic polishing materials received ISO-9002 in January, 1992 and ISO-9001 in April, 1994. This makes Optical Surface Technologies the first rare earth company that we know of that has achieved this level of excellence.

Rhône-Poulenc Chimie received ISO-9002 for the production, marketing and sales of rare earths for automotive catalysis and phosphors in May, 1994. The certification applies to three of Rhône-Poulenc's production locations: Courbevoie, La Rochelle, France, and Watford, UK.

RIC congratulates both companies on meeting these worldwide standards for quality. If your company has been certified as meeting an ISO-9000 standard, please inform us of this achievement for future listing in this column. ▲

Thomas S. Mackey (1930-1994)

Dr. Thomas S. Mackey, engineer, metallurgist, geologist, civic leader and lawyer, died last February, 1994 of a heart attack. Dr. Mackey was president and chairman of Neomet Corporation of West Pittsburgh, Pennsylvania. He most recently retired from the Gulf Coast Water Authority board of directors, Texas City, Texas, where he had served since 1971. Mackey had served as chair of the TMS-AIME, Lead/Zinc/Tin Symposium, and president of the American Tin Trade Association. He was a member of the National Association of Professional Engineers, a certified geologist from the American Institute of Professional Geologists, a member of the Texas Bar Association and a fellow of the American Institute of Chemistry.

Dr. Mackey received a bachelor of science degree with honors from Manhattan College, a masters of engineering with honors from Columbia University, a Ph.D. with honors from Rice University, a doctor of jurisprudence degree from South Texas College of Law and L.L.M. in international law from the University of Houston.

Dr. Mackey was known to rare earthers by his papers dealing with the applications of rare earths, as well as reports on the developments of, and status of the rare earth industry. As Texas City Mayor Chuck Doyle said, "His death leaves a void in the community that won't be filled." These words also echo the sentiment of the scientific community. ▲

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Y

1794

Yttria, the oxide form of elemental yttrium, was discovered in 1794 by Gadolin and was named for the small mining town of Ytterby, located near Stockholm, Sweden. The old quarry yielded unusual minerals, many of which were parent materials for other rare earths such as erbium, terbium and ytterbium. In 1843 Mosander showed that yttria could be resolved into the earths of three elements. The name yttria was reserved for the most basic one, the others erbia and terbia.

Yttrium occurs in all of the three major rare earth minerals; bastnasite, monazite and xenotime, with the highest percentage occurring in xenotime, an accessory mineral in granitic and alkaline igneous rocks. Yttrium is also mined from sedimentary deposits of monazite sand. Wohler obtained an impure sample of the metal in 1828 by reduction of the anhydrous chloride with potassium. Current commercial production is carried out by reduction of the fluoride with calcium metal, although it can be prepared by other techniques. Yttrium metal is silvery-metallic and is relatively stable in air, but in powder form will oxidize quickly to Y_2O_3 (Yttria).

Yttria is the most important commercial compound of yttrium, with major uses in structural ceramics as yttria-stabilized zirconia (YSZ), and in electronic ceramics for oxygen sensors. The compound also plays an important role as a phosphor host in cathode ray tubes (CRT). Yttria is also used to produce yttrium-iron-garnets (YIG), $Y_3Fe_5O_{12}$, which are effective microwave filters, transducers of acoustic energy, and when doped with Nd is one of the most effective lasers in use today. Small amounts of yttrium are used in aluminum and magnesium alloys to increase strength. Yttrium also reduces the grain size of chromium, molybdenum, zirconium and titanium alloys, and has a low cross section for nuclear capture. One of the isotopes of yttrium, Y^{90} exists in equilibrium with its parent Sr^{90}, a product of atomic fission. The only naturally occurring isotope is Y^{89}.

Yttrium has been considered as a nodulizer for producing nodular cast iron, which has improved ductility. Yttrium is also used in

Continued in next column ⇨

Yttria/*Continued from previous column* ⇨

laser systems and as a catalyst for ethylene polymerization. It is one of the important constituents of high temperature superconductors (YBaCuO), simulated gemstones (cubic zirconia and yttrium aluminum garnet), and solid oxide fuel cells. The oxide form is also an excellent high temperature refractory compound and is used as a coating for gas turbines and other applications where its unique properties find important uses. ▲

Cerium Guidebook

As the most abundant member of the rare earths, cerium has naturally become one of the most important 4*f* elements in our industrialized society. In fact, it would be difficult to carry on day-to-day activities without utilizing some form of this material. From automobiles, fluorescent lighting, plastics, and even television, cerium has found an important and useful niche and is playing an ever-increasing role in consumer goods.

Cerium: A Guide to its Role in Chemical Technology, written by B.T. Kilbourn of Molycorp, Inc., provides insight to the discovery, development, chemistry, and in particular, applications of this element. The guide is broken down into three main sections: Resources and Recovery; Chemistry; and Applications, with emphasis on the latter. Following a brief introduction, the first section deals with the abundance, mineral resources, and production of cerium. This includes identification of the major ores and world reserves of cerium-containing minerals, including their processing and production. The second section explains the electronic structure and oxidation states of compounds formed by the various valence states of cerium (Ce^{4+} and Ce^{3+}). The properties of cerium metal and mischmetal are also discussed, as well as analysis, environmental behavior, biochemistry and toxicology. The emphasis of the guidebook is on applications of cerium and cerium compounds in the fields of metallurgy, glass and ceramics, phosphors, luminescence, catalysts and chemicals, including combustion additives, paint driers, and uses in plastics.

Cerium: A Guide to its Role in Chemical Technology is an excellent review of this important industrial and consumer material. The 42-page guidebook was published in 1992 and is available (free) from Molycorp, Inc., a Unocal Company, 709 Westchester Avenue, White Plains, NY 10604 USA; Tel: 914 997 8880; Fax: 914 997 8898. ▲

Supporters 1995

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We start the new fiscal year with 50 organizations who have already come to the financial assistance of the RIC. This includes support from three new institutions and one new individual. The supporters who wish to be listed, grouped into their appropriate catagories and with the number of years they have supported the RIC in parentheses, are identified below.

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There are many costs associated with the publication of the *RIC News* which are covered by contributions from our financial supporters. Although production, publication, and printing account for a large portion of the total costs of publication, much of our yearly budget is dedicated to mailing each issue to nearly 13,000 of our readers worldwide.

For several years, five organizations have contributed to the success of the *RIC News* by providing mailing services in The People's Republic of China, Australia, India, Europe, and Japan. Because of the efforts of these companies, RIC saved over $34,400 in mailing costs in 1993 alone. The Rare-earth Information Center, along with our readers outside the U.S., wish to express our gratitude to these companies. ▲

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