

Rare-earth Information Center NEWS

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

Volume XXVII

June 1, 1992

No. 2

R₂Fe₁₄B Materials Review

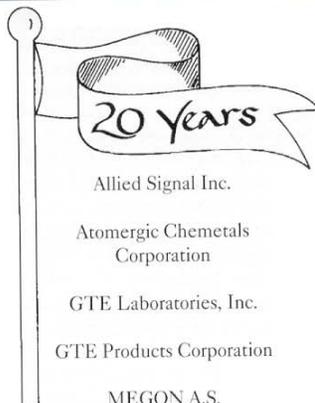
"R₂Fe₁₄B Materials: Intrinsic Properties and Technological Aspects" reviews the background and historical development of magnetic materials and includes basic properties and latest developments in rare earth permanent magnet technology. The paper, by J.F. Herbst, appears in *Rev. Modern Phys.*, 63, 819-98 (1991).

The eight-part report introduces the reader to the early development of magnetic materials and their use by the ancients up to their place in present technology and industry. The author presents the crystal structure and crystallography of Nd₂Fe₁₄B and R₂TM₁₇ (TM=transition metal), compares structures, and describes isomorphs. Workers in the field of rare earth permanent magnets will appreciate the information available on the magnetic properties and magnetization of these materials. Iron sublattice anisotropy, magnetic structure and information gleaned from Mossbauer studies will be useful to any rare earther working in the field of rare earth permanent magnets.

The paper continues with the electronic structure of R₂Fe₁₄B and isostructural materials and their properties after substituting constituent elements in the compounds. It is this section that contains a comprehensive table on the summary of research, complete with references, on R_{2-x}R'_xFe₁₄B compounds.

The technology section covers practical permanent magnets: melt-spun magnets including Nd-Fe-B, cobalt containing alloys, and other R₂Fe₁₄B-based materials, sintered magnets, magnetization reversal and coercivity mechanisms, preparation methods, and thin films.

Intense interest in the technological aspects of these compounds is a direct result of the high energy products of Nd₂Fe₁₄B magnets. These magnets feature economic advantages over the earlier Sm-Co magnets. ▲



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This year we have seven companies that we wish to honor for their 20 years of support. Allied Signal Inc., Atomergic Chemetals Corporation, GTE Laboratories, Inc., GTE Products Corporation, MEGON A.S., TH Goldschmidt AG, and Treibacher Chemische Werke AG, join the previous eleven companies on our growing list of long-time members. We wish to express our appreciation for their long and faithful support. ▲

Cerium/Aluminum Alloy

KBAlloys, Inc. of Reading, Pennsylvania, has 2,079 kg of aluminum master alloy available for immediate shipment. The product is in the form of 7.7 kg waffle ingots each with a dimension of 45 x 230 x 460 mm. The alloy contains 10.2% Cerium, <0.3% iron, <0.2% Silicon with the balance aluminum.

For more information contact: Robert G. Seese, Product Manager, P.O. Box 14927, Reading, PA 19612-4927; USA Tel:(215)670-3350; in PA (800)346-8383; outside PA (800)523-8457; Fax:(215)670-3376. ▲

Developments in Hard Magnetic Materials

Did you know that in a standard family car there are about 20 devices based on permanent magnets and that the number of permanent magnets in luxury cars may number 30 or more? Permanent magnets are used in many other domestic appliances such as computer peripherals, printers, actuators, spin imagers, guided wave pipes, bearings, power tools, sporting goods and acoustic devices. A review written by K.H.J. Buschow entitled "New Developments in Hard Magnetic Materials" [*Rep. Prog. Phys.*, 54, No.9, 1123-1214(1991)] covers the formation, crystal structure and magnetic properties of several classes of rare earth materials.

The intermetallic compounds that are important starting materials of permanent magnets include R₂Fe₁₄B, R₂Fe₁₄C and R₂Co₁₄B as well as the large class of ternary rare earth compounds having the tetragonal ThMn₁₂ structure. Special emphasis is given to the changes in magnetic properties of all these compounds observed after the introduction of interstitial C or N atoms. The magnetic properties of these compounds are discussed in terms of current models, based on intersublattice and intrasublattice exchange and the interplay between the rare earth sublattice anisotropy and 3d sublattice anisotropy.

The paper devotes a substantial portion to the various manufacturing routes of permanent magnets and also a description of the coercivity mechanisms operating in the magnets. A comparison is made of the performance and economic costs of dense sintered anisotropic and dense isotropic magnets. The author also makes a comparison of the magnetic properties of several commercially available permanent magnet materials and introduces examples of some novel applications. ▲

EUROPIUM was discovered in 1889 by Sir William Crookes.

International Symposium on Radiation Protection

The First International Symposium on Radiation Protection in the Mining, Milling and Downstream Processing of Mineral Sands will be held in Bunbury, Western Australia, March 18-20, 1993. The aim of the Symposium is to provide an international forum for the discussion and exchange of information on: radiation protection during production, and downstream processing of mineral sands in order to identify gaps in common knowledge; to set priorities for future research; and to provide practical guidance for the industry.

Topics to be covered in the program include processing technologies and the associated radiological hazards, occupational radiation protection and its optimization, environmental radiation protection and waste management, personal monitoring, and radiation research.

For further information on the Symposium contact: Minesafe Secretariat, The Chamber of Mines and Energy of Western Australia, 7th Floor, 12 St. George's Terrace, Perth, WA 6000; Tel:619 325-2955; Fax:619 221-3701. ▲

Rare Earth Minerals Conference

A two-day international conference entitled "Rare Earth Minerals: Chemistry, Origin and Ore Deposits" will be held April 1-2, 1993 at the Natural History Museum, London, UK. The conference aims to bring together scientists from around the world who are interested in rare earth minerals. The conference will cover numerous aspects of rare earth minerals including their structure and chemistry, origin, concentration, and alteration in all geological environments.

There will be three consecutive sessions: Chemistry-mineralogy, chemistry and structure; Origin-phase relations, equilibria, stability and mobility; Ore Deposits, including description and interpretation of existing and potential ore deposits, and an invited contribution on the needs and future of the rare earth industry.

For more information on registration for the conference and submission of abstracts, contact: Ms. Frances Wall, Department of Mineralogy, The Natural History Museum, Cromwell Road, London, SW7 5BD UK; Tel: 44 71 938 9357; Fax: 44 71 938 9268. ▲

Conference Calendar

* A NEWS STORY THIS ISSUE

July '92

2nd International Symposium on Physics of Magnetic Materials (ISPMM'92)
Beijing, People's Republic of China
July 3-8, 1992
RIC News, XXVI, [2] 2 (1991)

12th International Workshop on Rare Earth Magnets and Their Applications and 7th International Symposium on Anisotropy and Coercivity in Rare Earth Metal Alloys
Canberra, Australia
July 12-16, 1992
RIC News, XXVI, [2] 2 (1991)

Third International Symposium on Magnetic Bearings
Alexandria, Virginia
July 29-31, 1992
RIC News, XXVI, [3] 2 (1991)

September '92

International Conference on Strongly Correlated Electron Systems (SCES '92) formerly: *International Conference on Heavy Fermion and Strongly Correlated Electron Systems (HFSCS '92)*
Sendai, Japan
September 7-10, 1992
RIC News, XXVI, [4] 2 (1991)
RIC News, XXVII, [1] 2 (1992)

High- T_c Films by New Method

Researchers at AT&T Bell Laboratories of Murray Hill, New Jersey, have developed a new approach to molecular beam epitaxy (MBE) that uses an activated oxygen source to make high- T_c $YBa_2Cu_3O_{7-x}$ films [*R&D Magazine* 33, No.12, 23-4 (1991)].

AT&T's Raynien Kwo reports that the films perform as well as any reported before, that they have smooth surface morphology, and have excellent superconducting properties. "Superconductivity was achieved at 92 K with a critical current density of 5×10^6 A/cm²" she says. The major advance in processing the films was the development of a remote oxygen plasma source.

The high- T_c cuprate family of superconductors share a common crystal structure of a large perovskite chemical cell containing

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8th International Symposium on Halide Glasses

Perros-Guirec, Brittany, France
September 22-5, 1992
RIC News, XXVII, [1] 2 (1992)

March '93

International Symposium on Radiation Protection in the Mining, Milling and Downstream Processing of Mineral Sands
Bunbury, Western Australia
March 18-20, 1993
RIC News, XXVI, [4] 2 (1991)
*Also this issue

April '93

Rare Earth Minerals: Chemistry, Origin, and Ore Deposits
London, England
April 1-2, 1993
RIC News, XXVI, [2] 2 (1991)
*Also this issue

September '93

20th Rare Earth Research Conference
Monterey, California, USA
September 12-17, 1993
RIC News, XXVII, [1] 2 (1992)

Actinides-93

Santa Fe, New Mexico, USA
September 19-24, 1993
RIC News, XXVI, [3] 2 (1991)

multiple copper-oxygen planes interwoven with rare earth or alkaline earth oxide layers. The trick in growing good films of such complex structures is not only to use precise control of the chemical composition, but also to have the proper oxidation of all cations.

The in-situ MBE growth of oxides is accomplished by reacting metal flux with neutral radicals of oxygen at the substrate, which is at an elevated temperature. The resulting abundance of activated oxygen species enables oxidation of the cation layers at a partial pressure several orders lower than that needed for molecular oxygen. Using this new MBE approach, no external oxygen anneal step is needed. This approach also allows positive control in producing rare earth superconducting films. ▲

The Rare Earths 25 and I 25

In this issue we bring you a story from Meng Jian who earned his Master's degree in 1983 and is now an associate professor at Changchun Institute of Applied Chemistry, Academia Sinica, Changchun, 130022, China.

While a student at Jilin University, Prof. Liu Mingdeng told me of the many mysterious properties of rare earth compounds. These included YAG lasers, luminescent devices, hydrogen storage materials and new types of semiconductors. I wondered why these 17 elements have such fascinating behavior, so I decided to explore the secret of rare earth compounds.

I started working on the electrical properties of rare earth compounds during my graduate studies in Changchun Institute of Applied Chemistry, Academia Sinica. I chose to study the photoelectric properties of rare earths. After many investigations on the optical, electrical and photoelectric properties of rare earth monophosphides, I succeeded in finding that their optical gaps were about 1.0 - 1.46 eV and that they can form the p-n junction with p-type silicon. A LnP/Si device exhibited the photovoltaic effect and could rectify an electrical current.

By reviewing many books and journals, I learned more about the importance of the rare earths and became more interested in these mysterious 17 elements and the compounds they formed.

Subsequently, I continued to work in my mother institute and expand my studies to include structure, optical, electrical, and magnetic properties of rare earth compounds. Since the largest known deposits of rare earth minerals are in China, I think that makes us the richest of people in the world. Although Chinese have done much work in the field of rare earths, there are many new fields and applications of rare earths awaiting one to explore. We expect that many scientists all over the world will contribute in the study of rare earths. This will make our world more prosperous and more colorful.

This concludes the *Rare Earths and I* segment which started with the first story in the March 1, 1990 issue of the *RIC News*. This article is the 10th and last of the stories written by RIC readers and published in the *RIC News* commemorating our 25th year (1990). ▲

MEGON/EXTRATEC

The Metal Extractor Group of Norway (MEGON) has undergone some major changes which culminated in early 1992. In March 1991 a new company, EXTRATEC AS, was established as a spin-off of all the technical and consulting activities from MEGON. EXTRATEC focuses on the development of (1) extraction and purification processes for rare earths and other minerals and metals, and (2) processes to extract pollutants and/or recover valuable elements from industrial waste. They will also offer consulting services, strategic planning and marketing studies. MEGON will continue to produce and supply high purity Y_2O_3 and Sc_2O_3 , however, its production facilities have been moved from Kjeller to Oslo. Per H. Dybwad will continue to be chairman of MEGON and will have a major role in managing EXTRATEC. Gunnar Norum has been appointed as the new managing director of MEGON. Both companies are wholly owned by Norsk Hydro and occupy neighboring offices in Oslo.

For further information contact: EXTRATEC AS (or MEGON AS), Forskningsparken, Gaustadalleen 21, N-0371 Oslo, Norway, Tel:(EXTRATEC)+47 2 95 88 95;(MEGON)+47 2 95 88 91; Fax:(both companies)+47 2 60 44 27. ▲

New Magnet Process

Arnold Engineering Company of Marengo, Illinois, and its parent, SPS Technologies of Newtown, Pennsylvania, announce the development of a process for enhancing the corrosion resistance and thermal stability of Nd-Fe-B permanent magnets.

In Arnold's low-cost Aquanide process, water-milled powder is vacuum dried and then "passivated" by heating in nitrogen and/or CO_2 . During passivation, a protective layer of nitrides and/or carbides forms on the surface of the powder particle. The powder produced by this method is not pyrophoric and may be stored for prolonged periods in normal atmospheres without degradation or risk of spontaneous combustion. With Curie temperatures in excess of 400°C, the powder is also magnetically stable, making it suitable for use in bonded magnets as well.

For more information on the Aquanide process, contact the Arnold Engineering Company, 300 West Street, Marengo, IL 60152 USA Tel:(815)568-2000; Fax:(815)568-2228. ▲

CeO₂ Layers

Cerium dioxide (CeO_2) has been attracting increasing attention due to its chemical stability and close crystal structure with that of silicon. These characteristics give it its potential in electronics applications. These applications include silicon-on-insulator structures, stable capacitor devices for large scale integrated circuits, and stable buffer layers between high-temperature superconducting materials and silicon substrates.

T. Inoue et al. report in *Appl. Phys. Lett.* 59, No.27, 3604-6 (1991), the epitaxial growth of CeO_2 layers on silicon substrates during deposition by electron-beam evaporation.

Silicon substrates, with a resistivity of 2-6 ohms, were cut into 52 mm squares and then chemically cleaned. CeO_2 layers were then deposited epitaxially on the Si substrates which were heated to 800°C in an oxygen atmosphere at a pressure of 8×10^{-6} torr.

Subsequent x-ray diffraction measurements determined that the crystal orientation of this layer closely matched that of the silicon substrate. Cross-sectional high-resolution transmission electron microscopy and selected-area electron diffraction also clearly verified that the <100> direction in the CeO_2 (110) plane is parallel with the <110> direction in the Si (100) plane.

The experiment also showed the existence of a 60-Å-thick amorphous layer between the CeO_2 deposited layer and the Si substrate. There also appeared to be a large number of dislocations and low-angle boundaries at the interface of these layers. ▲

III-V Semiconductors

Rare earth-doped indium phosphide and gallium arsenide semiconductor single crystals are now manufactured and offered commercially from Russia. Leningrad State Technical University uses the Czochralskii process with established technology to produce these single crystals that can be doped simultaneously with up to three impurities. The crystals are grown from quartz containers which have a special coating, thus diminishing the concentration of residual donors, resulting in high-purity semiconductor material.

For more information on the availability and specifications of these semiconductors, contact Dr. L.F. Zakharenkov, Experimental Physics Department, Leningrad State Technical University, Politechnicheskaya str., 29, St. Petersburg, 195251, Russia; Tel:(812)5527817; Fax:(812)5527954. ▲

Russian Acquisitions

RIC has recently received two soft-cover books and a hard-cover book from Russia. We wish to thank those responsible for sending these Russian language books to us so that we can announce their availability.

The first book, written by Dr. K. P. Belov, is entitled *Magnitoteplovye Yavleniya v Redkozemel'nykh Magnetikakh (Magnetothermal Phenomena in Rare earth Magnets)*. It contains 96 pages and was published in 1990 by Nauka Publishers, 15 Leminsky Prospect, Moscow 117071, USSR. It was written with scientists and engineers in mind, who study and employ these magnetic materials and design technical devices utilizing these magnets. Detailed data on magnetocaloric effects, magnetic anomalies of heat capacity and heat conduction, and magnetization changes near magnetic phase transitions are presented. Technical applications such as, magnetic refrigerators and thermomagnetic memory devices, are discussed. It is divided into four chapters and has a total of 169 references.

The second book, also published in 1990 by Nauka, was edited by Dr. E. I. Semenov. It contains 200 pages and is entitled *Mineralogiya Ultraagpaitovykh Shchelochnykh Porod (Mineralogy of Hyperagpaitic Alkaline Rocks)*. The book claims to provide the first systematic description in Soviet or world literature of hyperagpaitic pegmatites and hydrothermalites not altered by weathering. These rocks are widespread in deep zones of the Khibina and Lovozero massifs in Russia. They are characterized by an abundance of minerals soluble in water and thus are easily altered under atmospheric conditions. They also are characterized by an extraordinary diversity of mineral species, including many containing rare earths, and their close relationship to rare metal-phosphate deposits. About 100 of the minerals of these rocks represent new mineral species for the USSR. The book has 320 references and was written for mineralogists, geochemists, petrologists, geologists, and specialists on deposits of alkaline formations.

The hard cover book is entitled *Teplofizicheskie Svoystva Metallov pri Vysokikh Temperaturakh (Thermophysical Properties of Metals at High Temperatures)* written by V. E. Zinov'ev. It contains 384 pages and was published by Metallurgiya, Moscow in 1989. Pages 137-219 are devoted to rare earths: 137-55 on scandium, yttrium and lantha-

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RE-doped Catalyst Supports

The modification of ZrO_2 catalyst supports, by the addition of rare earths, results in enhanced catalytic activity. ZrO_2 has been shown to be an effective catalyst support or promoter for the conversion of synthesis gas, the oxidation of methanol, and improving the durability of automotive catalysts. M. Ozawa and M. Kimura in *J. Less-Common Metals*, 171, 195-212 (1991) report that doping ZrO_2 catalyst supports with rare earths increases the surface area of the catalyst while exhibiting good thermal stability. The increase in surface area increases activity of the catalyst and provides for a more efficient catalytic reaction.

During the preparation of the ZrO_2 supports, the concentration of doped rare earths ranged from 0-50 mol.% La, Ce, and Nd, to 0-10 mol.% Sm, Gd, Dy, and Yb. In each case, the increase of RE concentration raised the crystallization temperature of ZrO_2 as did the ionic radius of each rare earth modifier. All of the elements were effective in stabilizing the tetragonal form of the ZrO_2 , with cerium stabilizing the support up to temperatures of 1200°C.

The authors show that neodymium-doped ZrO_2 supports improved the oxidation activity of iron. These results indicate that rare earth additives to ZrO_2 makes it potentially useful as a catalyst support. ▲

Ugimag Modernizes

The permanent magnet producer, Ugimag, Inc. of Valparaiso, Indiana, recently completed a comprehensive modernization program. This upgrade included the installation of; a new powder handling system that improves the protection of raw materials from contamination and oxidation, advanced materials processing equipment which can produce corrosion-resistant magnets, improved analytical equipment necessary to improve consistency of materials throughout the production process, and a new laboratory information management system, which includes an automated data acquisition and analysis.

For more information on products and services, contact Jean-Michel Escondeur, Ugimag, Inc., 405 Elm Street, Valparaiso, IN 46383-3620; Tel: (219)462-3131; Fax: (219)462-2569. ▲

num; 155-77 on light lanthanides; and 177-219 on heavy lanthanides. The text includes 490 figures, 101 tables, and 486 references. ▲

New Landolt-Börnstein Series

Landolt-Börnstein: Numerical Data and Functional Relationships in Science and Technology-New Series, Subvolume d1, *Rare Earth Elements, Hydrides and Mutual Alloys* (Volume 19 *Magnetic Properties of Metals* of Group III: *Crystal and Solid State Physics*), was published in 1991 and is edited by H.P.J. Wijn. To those who remember, the 1962 *Landolt-Börnstein* (6th edition), Vol. II, part 9, dealt with the magnetic properties on a wide variety of substances. Since then, the volume of published material on the subject has increased enormously and a new compilation was necessary, but this time, the information in Volume 19d1 specifically concerns the rare earth elements, alloys and rare earth hydrides.

This volume deals with the magnetic properties of rare earth metals, their hydrides, alloys and metallic compounds which contain at least one transition element. No attempt, however, was made to be very critical about the metallic character of the substances discussed. Not only are magnetic properties of the materials listed in tabular and graphic form, but also other physical properties which depend on the magnetic state of the magnetic system. Where appropriate, semiconductors and even insulators have been included. The data are not arranged according to specific magnetic properties, but follow the various groups of magnetic substances.

Sections which appear in subvolume d1 include: *Magnetic Properties of Rare Earth Elements, Alloys and Compounds* by H. Drulis and M. Drulis; *Alloys Between (Light, Heavy and Light, and Heavy) Rare Earth Elements* by S. Kawano and N. Achiwa; and *Rare Earth Hydrides* by R.R. Arons. It is in this final section on rare earth hydrides where a comprehensive collection of information on physical, magnetic, thermal, spectroscopic and electrical properties will prove to be an invaluable source for researchers in this important field. The vast majority of the information contained in this subvolume is arranged in a quick, user-friendly format for quick reference.

The 393-page *Rare Earth Elements, Hydrides and Mutual Alloys* contains 743 figures and is available from Springer-Verlag GmbH & Co. Auslieferung-Gesellschaft, Postfach 10 51 60, Hertschekstraße 8, D-6900 Heidelberg 1, Germany for 1,420DM (\$852 US). ▲

Tough Ceramics and Plastic Magnets

Japan New Materials Report, VI, No.4, 7-12 (1991) announces two new developments in materials science which have worldwide industrial applications.

High-Strength Composite Ceramic

Nisshin Flour Milling Company Ltd., Tokyo, and researchers from Nagoya University, Nagoya, Japan, have jointly developed a composite ceramic of ceria stabilized zirconia and lanthanum beta alumina which features high fracture resistance and improved toughness.

The company developed the new ceramic using an advanced powder technology in order to increase fracture toughness. "A key to increasing fracture resistance in ceramics is to prevent linear fractures," says Takashi Fujii of Nisshin's powder research laboratory. "We have been able to increase toughness to 11 on a SEPB scale as compared to 6 or 7 for ceria stabilized zirconia without any sacrifice in flexural strength through the distribution of long, thin lanthanum beta alumina crystals during sintering." This process also produces a high level of hydrothermic stability.

The company can produce about one metric ton per month and can provide samples of the sintered product, although it prefers to sell the material in the powdered form. The new ceramic can be used in cutting tools and structural components.

Better Plastic Magnets

Asahi Chemical Industry Company Ltd., Tokyo has developed an improved technique for producing plastic magnets which are theoretically capable of producing magnetic energy products approaching those of sintered rare earth permanent magnets. Plastic magnets are made of a rare earth magnetic powder in a plastic binder. Their advantage lies in their ability to be molded into complex shapes with high precision and low cost. Rare earth plastic magnets are currently used in small, high performance electric motors, which have increased performance as compared to other motors of the same size.

The new magnets use a new material made from iron nitride and samarium. It is produced by forming an alloy of samarium at a temperature of more than 1000°C, cooling, and then forming a nitride with the iron in successive atmospheres of hydrogen and ammonia. The alloy is then powdered, mixed with an epoxy resin and compression molded into the desired shape. ▲

Jobs for Superconductors

As research continues for the elusive "perfect" superconductor, many real world applications for these materials already exist. Currently, the three primary high- T_c materials that researchers are working with are Y-Ba-Cu-O (95 K T_c), Bi-Pb-Sr-Ca-Cu-O (108 K), and Tl-Ca-Ba-Cu-O (125 K). A fourth superconductor, a vanadium oxide-based material, developed at Hitachi's Superconductivity Research Center in Tokyo, exhibits T_c at 130 K but when exposed to air, degrades in only a few days [*R&D Magazine*, 33, No.12, 56-60 (1991)].

U.S. companies, universities, and the federal government hold a strong lead in the number of patents issued for high- T_c materials, processes, and devices. In 1990, the U.S. held 64% of the patents issued, with 29% going to Japan and the remaining 7% to Europe.

Among the current uses for superconductors:

- A 25 W, 2,500 rpm DC motor containing superconducting coils emerged in liquid nitrogen and powered by a 0.5 A current.
- Bulk high- T_c leads that can replace copper leads for transmitting electricity from room temperature power supplies to low- T_c devices operating at 4 K, such as the coils on MRI systems. Y-Ba-Cu-O leads can carry a record 2,000 A to MRI systems without conducting heat back to the liquid helium refrigerant, thus preventing boil-off and saving both energy and money.
- A commercially-available cryogenic liquid level sensor made of Y-Ba-Cu-O material that has uses in medical life sciences, biotechnology, and the cryopreservation industries.
- Sensitive infrared detectors employing Y-Ba-Cu-O thin films that are up to 50 times more sensitive than current room-temperature devices. These detectors have applications in laboratory spectroscopy, defense, and space-based environmental, ecological, and climatological studies.
- Integrated circuits in SQUIDS (Superconducting Quantum Interference Devices), which are used in delicate magnetic field measurements. They operate by converting hard-to-measure magnetic flux into easy-to-measure voltage and are the most sensitive magnetic field devices known.
- High- T_c interconnects for integrated circuits in computers is an area some major companies are exploring. Operating at 77 K, superconductors cut gate delays in half and

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Magnetism in the Nineties

North-Holland - Elsevier Science Publishers are commemorating the 100th volume of *Journal of Magnetism and Magnetic Materials* by publishing *Magnetism in the Nineties* in hard-cover. The 490-page collection of 33 papers provides an historical perspective of many of the developments that have taken place in magnetic materials since the mid-1970's. It identifies important issues and provides a perspective for developments anticipated in the 1990's.

Some of the topics covered in this volume include: rare earth-cobalt and Nd-B-Fe permanent magnets; rare earth intermetallics; giant magnetostrictive materials; valence fluctuation and heavy fermion behavior in rare earth and actinide based compounds; and quenching of spin fluctuations by high magnetic fields. Other papers focus on research on various materials including amorphous, magnetic and magneto-optic recording materials, strongly correlated electron systems and high- T_c superconductors.

The editors of this special tome conclude that studies of magnetism, both basic and applied, are experiencing a rapid rate of growth as driven by newly developed sophisticated experimental and theoretical techniques and novel discoveries. The 1990's look bright in the field of magnetism.

Magnetism in the Nineties is edited by A.J. Freeman and K.A. Gschneidner, Jr. and was published in 1991. For an opportunity to add this handsome volume to your collection, send \$87.00 US (170.00 Dfl) to: Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands; in the U.S.A. and Canada: Elsevier Science Publishing Co. Inc., P.O. Box 882, Madison Square Station, New York, NY 10159, USA. ▲

Bureau of Mines

The rare earth commodity experts of the Bureau of Mines, U.S. Department of the Interior, have moved to a new location: 810 7th Street NW, Washington, D.C. 20241. The contact person is James B. Hedrick, who can be reached at Tel:(202)501-9412; Fax:(202)501-3751. ▲

therefore can nearly double the speed of a computer.

As our knowledge of superconductors improves, and industry develops more practical uses for these high- T_c materials, our devices will operate faster, with greater sensitivity, higher resolution, all the while saving energy and eventually, money. ▲

RE Handbook 15

Volume 15 of the *Handbook on the Physics and Chemistry of the Rare Earths* is the latest in the series on rare earth reviews that started over a decade ago. Volume 15 places strong emphasis on the systematics, thermodynamics, and physical properties of rare earth carbides, halides, glasses, hydrates and inorganic complexes. This latest volume contains seven chapters which brings the total number of chapters in the series to 104.

The first chapter, by J.G. Sereni, reports on the low-temperature behavior of binary and intermetallic cerium compounds. The existence of ferromagnetism, antiferromagnetism, spin glass, valence fluctuations, heavy fermions and superconductivity are observed. The specific heat, magnetic and physical properties of these compounds adds significantly to the systematic, experimental low-temperature studies of the behaviors of cerium materials. The conclusions should provide new data against which the theory can be advanced.

The next chapter, by G.-Y. Adachi, N. Imanaka and Z. Fuzhong, provides a review of binary and ternary rare earth-carbon systems. The information on these carbides includes thermodynamics, phase diagrams, crystal structures and physical properties. The authors show that the carbides exhibit an exceptionally wide range of compositions and structures, both as solids and gases. Complex carbides with additional metal and non-metal components are also covered.

The systematics of rare earth metal-rich halides are reviewed in the 100th chapter in the series and includes classification of these compounds according to their structure, bonding, physical, magnetic and electrical properties. The chemistry of these compounds with an X/R ratio has become a rapidly growing field of research and this section provides a wealth of data on crystal structures of individual metal-halide compounds, clusters, and chains. The authors of chapter 100 are A. Simon, H.J. Mattausch, G.J. Miller, W. Bauhofer, and R.K. Kremer.

Chapter 101, by R.M. Almeida, deals with the preparation, structure, and chemical and physical properties of heavy-metal fluoride glasses. These glasses will accept large amounts of rare earths, making them useful for a variety of optical applications in the mid-infrared range as fiber optic glasses for transmission of information, optical wave guides, fiber lasers, and sensors.

The fifth review in the volume, by K.L. Nash and J.C. Sullivan, explores the chemi-

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Tunable Infrared Detector

The first internal photoemission response of a metal-Si-metal heterostructure is claimed by L. Pahun, et al. in *Appl. Phys. Lett.* 60, No.10, 1166-8 (1992). The novel IR detector, called "TIPS", (Tunable Internal Photoemission Sensor), may provide a new material for use in infrared detectors.

In their study, the authors find that the photoresponse of the Pt/Si/ErSi_{1.7} system can be strongly modified when a bias of a few hundred mV is applied between the two metallic electrodes. When a positive bias is applied to the front Pt electrode, the cutoff wavelength is shifted from 1.4 μm to above 5 μm, and the resultant quantum efficiency is increased up to 5% at 1.2 μm. These dramatic changes are attributed to a modulation of the effective potential barrier experienced by the photoexcited carriers when

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cal kinetics of solvent and ligand exchange in aqueous lanthanide solutions. Rate and equilibrium constants on these complexes are abundant in both the text and in tables.

Chapter 103, by E.N. Rizkalla and G.R. Choppin, considers the fundamentally important reactions of lanthanide ions with water. These interactions are discussed for both solids and solutions. The hydrated species are considered in detail for the aqueous solution, and the hydrolysis constants of mononuclear and polynuclear rare earth complexes are given as well. Additionally, the solubility data for the lanthanide hydroxides are included for quick reference.

The final chapter, by L.M. Vallarino, reviews macrocyclic complexes formed by the rare earths with dioxouranium(VI) ions as templates. The structures of these compounds appear as diagrams, and are useful in understanding these complexes. Synthesis and reactivity are also considered as well as potential uses for these intriguing wrap-around structures.

Volume 15 of the *Handbook of the Physics and Chemistry of Rare Earths*, edited by K.A. Gschneidner, Jr. and L. Eyring was published in 1991 by North-Holland and contains 530 pages. The cost is \$205.00 US (360.00 Dfl) [the subscription prices are \$175.00 US and 306.00 Dfl] and can be ordered from Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands; or in the U.S.A. and Canada from Elsevier Science Publishing Company Inc., P.O. Box 882, Madison Square Station, New York, NY 10159, USA. ▲

Corrosion Resistant Magneto-Optical Recording Disk

Amorphous rare earth-transition metal alloy films have a large potential for use as magneto-optical recording media. The lure of high-density memory, coupled with widespread applications, makes these materials ideal for expanded commercial development. The first commercial units became available last fall [*RIC Insight*, 4, No.7 (1991)]. A major drawback for magneto-optical recording however, is that TbFeCo films oxidize when exposed to air. This oxidation results in a degradation of the magnetic properties thus decreasing their value as a recording medium.

The corrosion and pitting resistance of TbFeCo recording disks are shown to be greatly improved by the addition 2-3 at.% niobium. F. Kirino, N. Ogihara and N. Ohta report in *J. Appl. Phys.* 70, No.4, 2242-50 (1991), that while corrosion was inhibited, magnetic properties were unaffected.

Corrosion which occurs on these films can be separated into three distinct types; pitting corrosion, dry corrosion, and wet corrosion. Each type of corrosion affects some aspect of the recording characteristics of the film in a different manner. Pitting corrosion usually changes the ability of the material to transmit light, while dry and wet corrosion degrade saturation magnetization and the Kerr rotation angle.

The authors conducted the wet corrosion and pitting experiment in an atmosphere of 60°C and 90% relative humidity for 2000 hours. No change was found in either the carrier-to-noise ratio or the defect error rate even after 10 million write/erase cycles. These results should open the way for further utilization of niobium-doped TbFeCo magneto-optical films. ▲

Continued from previous column ◊

crossing the Si film. It should be possible to significantly improve the TIPS quantum yield with an optimum choice of metal thicknesses, and also the intrinsic cavity formed by the Si layer. In addition, the cutoff wavelength could also be increased by replacing either the Pt layer with Ir, or one or both metallic layers with degenerate SiGe layers.

The authors suggest that the integration of TIPS focal plane arrays with existing Si signal processing technology could open the way to wavelength resolved IR imaging, covering the whole spectrum of existing Schottky detectors, i.e., from 1 μm to above 12 μm. ▲

Nd-doped Microchip Laser

Due to the increasing lifetime and power density of laser diodes, interest in microchip lasers is growing. Microchip lasers offer relatively simple technology at a lower cost than conventional lasers. In addition, these lasers may provide an efficient solution for converting the divergent and low coherence beam of the laser diode into a diffraction-limited, spectrally pure laser mode. Furthermore, the microchip laser is wavelength tunable and has recently even been Q-switched, thus opening the way to mode-locked operation and frequency doubling.

N. Mermilliod, B. Francois, and Ch. Wyon show that a $\text{LaMgAl}_{11}\text{O}_{19}$ (LMA) microchip laser doped with neodymium achieved an output power of 36 mW and an optical efficiency of 12% [*Appl. Phys. Lett.*, 59, No.27, 3519 (1991)]. This laser proved to be very stable with an intrinsic noise of 0.6% and an output power variation of only 5% for a 15°C temperature range of the pump laser diode. The half divergence of this microchip laser was found to be about 5 mrad.

Among the advantages of using Nd-doped $\text{LaMgAl}_{11}\text{O}_{19}$ is the broad absorption band of the material, about 25 nm at 800 nm. Consequently, its laser performance is only weakly affected by the use of a pump laser diode with a broad emission bandwidth. Even poorly thermally regulated laser diodes can be used to conveniently pump LMA. The large emission bandwidth (1.05-1.085 μm) of LMA is an advantage for tunability and certain applications, such as helium magnetometers. ▲

Rare Earth-Aluminum Alloys

The addition of rare earths to aluminum appears to have many beneficial effects, as found by Tang D-X. et al. [*J. Rare Earths*, 10, No.1, 66-71 (1992)]. The Chinese metals industry has been using rare earths to form aluminum alloys since the 1960's. Some of the applications for these alloys include: alumina-silicon materials for pistons in internal combustion engines, electrical transmission lines, and ferro-alumina materials for electric heating wire. It has been found that adding rare earths to aluminum wire has the effect of decreasing electrical resistance. Studies show that conductivity can be increased by 1-1.8%.

Rare earth-aluminum alloys are directly produced by electrowinning and molten salt electrolysis. The addition of rare earths to aluminum improves thermal stability, oxidation and wear resistance, strength, flow properties, moldability, and also reduces defects and gas content. Experiments show that as concentrations of rare earths in Al-alloys increase, physical properties improve. As Ce or Y is added to the composition, hydrogen content decreases, as does porosity and the occurrence of inclusions. The best results are obtained with 0.3 wt% RE.

Other applications of RE-Al alloys include; domestic food preparation utensils, electronics and structural components, bicycles and window screens. ▲

Australian RE Pilot Plant

The Australian Nuclear Science and Technology Organisation (ANSTO) has set up a pilot plant at Lucas Heights, which could enable Australia to capitalize on the rare earth market. An article in the March 3, 1992 daily newspaper *The Australian*, reports that ANSTO has set up a \$1 million (AUS) rare earth pilot plant to study the feasibility of processing the rare earth deposits found at Ashton Mining's Mount Weld facility, located northeast of Kalgoorlie in Western Australia. The plant should be in operation at the end of this year.

Experts say that if the ANSTO study yields favorable results, a follow-on project could lead to investments of \$75 million, creating 200 jobs during the development stage, with 80 positions for Western Australians during the 30-year life of the deposit.

Ashton Mining has also teamed up with two Japanese companies, Mitsui Mining and Smelting Co., which has its own rare earth separation technology, and Marubeni, rare earth marketing experts. ▲

John C. Fuggle

RIC has learned that Prof. Dr. John C. Fuggle passed away December 16, 1991. He was born in London in 1947 and after earning his Ph.D., began his lifelong interest in electronic properties. He is known in the field by his spectroscopic studies of rare earths and rare earth alloys and compounds, and has published more than 30 papers on the subject. Dr. Fuggle chaired the department of Physical Chemistry at the University of Nijmegen, The Netherlands, in 1983 where he stayed until his death. His most recent work concerned magnetic ordering and spectroscopic studies in magnetic materials while at the Research Institute for Materials, University of Nijmegen. ▲

Konrad Schubert

Professor Dr.-Ing. Konrad Schubert passed away March 19, 1992 at the age of 77. He was associated with the Kaiser Wilhelm-/Max Planck Institute fur Metallforschung of Stuttgart, Germany, and conducted research on the crystal structures of intermetallic and inorganic compounds (including rare earth materials). His book *Kristallstrukturen zweikomponentiger Phasen*, published in 1964 by Spinger-Verlag, Berlin, is considered a classic and has served as a valuable guide and reference book to many of us working with these materials. His most recent work on rare earths concerned rare earth fluorides. His contributions to the field will be missed. ▲

Letter to the Editor

The following is a letter received by the Editor of *RIC News* from Marie-Odile Ruault, Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay, France.

Dear Editor,

Referring to the article in the last issue of *RIC News* regarding "Superconductor Degradation" [*RIC News*, XXVII, No.1, 3 (1992)], you may be interested to see previous work on the same subject, published in 1988. Of course, many other workers have been active on the problem since that time.

Editor's response:

Thank you for your letter and the article published in *Europhys. Lett.*, 7 No.5, 435-9 (1988), which predates the Japanese claim to be the first to photograph the breakdown process of the Y-Ba-Cu-O superconductor [*Jpn. New Mater. Report* 6, No.3, 9 (1991)]. ▲

RIC News

Vol. XXVII, No. 2 June 1, 1992

Published quarterly in March, June, September, and December

by
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Handbook of Magnetic Materials

The sixth volume of *Handbook of Magnetic Materials*, edited by K.H.J. Buschow, is the final volume of the series previously entitled *Ferromagnetic Materials - A Handbook on the Properties of Magnetically Ordered Substances*. The series is the progeny of the late Professor E.P. Wohlfarth, who started the *Handbook* series in order to publish new developments in the field of magnetism and magnetic materials.

Handbook of Magnetic Materials, Volume 6, was published in 1991 and four out of the six chapters contain topics concerning the study of rare earth compounds and alloys, and the materials science of rare earth magnetic materials. The topics included in the volume are: magnetic properties of ternary rare earth transition-metal compounds by H.-S. Li and J.M.D. Coey; ternary intermetallic rare earth compounds by A. Szytula; magnetic amorphous alloys by P. Hansen; and the magnetism of hydrides by G. Wiesinger and G. Hilscher.

The reviews by leading authorities are based on the massive stock of literature on the subjects and are presented not only for the student who wishes to be introduced to the subjects, but also for the scientist active in magnetism research. The information in each chapter is compiled in a logical and easy-to-reference format with many tables and figures. Each chapter includes an extensive list of references. Author and subject indices are also included.

The 654-page book costs \$182.00 US (375.00 Dfl) and can be ordered from Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands. In the U.S.A. and Canada contact: Elsevier Science Publishing Co., Inc., P.O. Box 882, Madison Square Station, New York, NY 10159 USA. ▲

MISCHMETAL, a mixture of 43 percent lanthanum, 42 percent cerium, 8.4 percent neodymium, and 6.5 percent praseodymium, is the main ingredient in lighter flints and is also used as a metallurgical additive in desulfurizing during steelmaking as well as in zinc plating and the production of metal-hydride batteries.

DYSPROSIUM, atomic number 66, was discovered by Lecoq de Boisbaudran in 1886. He coined this name from the Greek word *dysprositos*, which means hard to get at, because it was one of the last rare earth elements to be discovered.

Supporters

★★★★★★★★★★★★★★★★★★★★

Since the March issue of the RIC News went to press, RIC has received financial support from five new family members, and renewed support from 35 other organizations. The supporters from the fourth quarter who wish to be listed, grouped according to their appropriate category, and with the number of years that they have contributed to the Center in parentheses, are listed below.

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