RARE-EARTH INFORMATION CENTER

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CLEARY AWARD WINNERS

K. J. Strnat

J. C. Olson

Capt. G. I. Hoffer

The Cleary Award of the Air Force Materials Laboratory (AFML) has been presented to Dr. Karl J. Strnat, John C. Olson and Capt. Gary I. Hoffer. They were honored for their work on magnetic materials which entailed a study of the anisotropic magnetization behavior of ferromagnetic intermetallic compounds.

The Cleary Award was established in memory of Charles J. Cleary, a member of AFML for 25 years who was assistant chief of the Laboratory at his death in 1945.

The research specifically cited for the award was reported by the three in a paper, "Permanent Magnet Properties of YCo_5 Powders," presented at the Sixth Rare Earth Research Conference in May of 1967. They have been granted a patent for a method of producing RCo_5 magnets (U.S. Patent No. 3, 424, 578) and a second patent covering the products (magnets containing RCo_5 alloys) is pending.

Dr. Strnat, principal investigator of the research, is an internationally recognized authority on magnetic materials and is credited with organizing the magnetic materials exploratory development program at AFML. Now a professor of electrical engineering at the University of Dayton, Strnat is organizing a magnetic materials laboratory at that institution.

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Polarized Electron Beams

The use of Eu(Gd)S to produce polarized electron beams has been discussed by G. Obermair (Z. *Physik* **217**, 91 [1968]). In this paper Obermair describes the theory of field emission from ferromagnetic solids in which the two spin sub-bands of the conduction band are split. He concludes that highly polarized beams (as high as 100%) are possible by using ferromagnetic $Eu_{1-x}Gd_xS$ with $x = 0.055$ as the optimum concentration of gadolinium.

Polarized electron beams (8% polarization) have been produced using ferromagnetic gadolinium metal (M. Hofmann, *et al., Phys. Letters* 25A, 270 [1967]). But the use of Eu(Gd)S should lead to much more highly polarized beams.

Obermair also notes that field emission studies from ferromagnetic solids should also yield valuable information about the magnetic and band structures of these materials.

Rare Earths In the News

EXPANDS RE LINE

Molycorp has added seven additional rare earths to its product line bringing to 15 the number of rare earths it offers for sale. The seven rare earths are Tb, Dy, Ho, Er, Tm, Yb and Lu. The addition of these elements to Molycorp's line was made possible through a cooperative marketing arrangement with Shin-Etsu Chemical Industry Co., Ltd. Shin-Etsu, Japan's largest rare-earth producer, will separate Molycorp's raw material.

HOT LASER

A pulsed laser capable of heating materials to 20 million°F has been developed at Sandia Laboratories, Albuquerque, N.M. The laser incorporates four neodymium-doped glass rods. Discharging 50 joules of energy in 10 picosecond bursts, the laser's output peaks to 5×10^{12} watts, the highest power yet generated by a pulsed laser, says Sandia's Dr. Garth Gobeli.

UP RARE-EARTH STOCKPILE

In a revision of strategic stockpile objectives, the Government revised upward its stockpile objectives for rare earths. The new objective is for 6500 short dry tons, more than double the previous 3000-ton stockpile.

RE CHROMITE ELECTRODES

A new ceramic part for electrodes made of rare-earth chromite has been developed. Electrodes

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Neutron Scattering and Rare Earth Research at ORNL

The Solid State Division of the Oak Ridge National Laboratory has two neutron scattering groups which are actively studying rare-earth metals, compounds, and alloys.

The neutron diffraction group consists of W.C. Koehler, J.W. Cable, H.R. Child, and R.M. Moon as permanent staff and one graduate student, A.H. Millhouse. This group had, with M.K. Wilkinson and E.O. Wollan, first determined the complex magnetic structures of the heavy rare-earth metals by elastic scattering from single crystals.

As part of a long range program of study of the magnetic properties of the rare earths a number of alloy systems have subsequently been investigated. Most recently, the magnetic structures of single crystal specimens in the Er-Dy, Er-Tb, Er-Gd, Er-Ho, and Dy-Ho systems have been determined. Conclusions relating to the nature of the exchange interactions and of the origin of the anisotropy of the rare earths have been derived from these studies.

Recently, a large single crystal specimen of low capture cross section ^{160}Gd has been grown and the group is currently investigating the form factor of metallic Gd by means of its new polarized neutron facility at the High Flux Isotope Reactor (HFIR). The group is also studying, in collaboration with members of the neutron spectrometry group, the spin wave scattering from Gd.

The neutron spectrometry group, consisting of H.G. Smith, H.A. Mook, R.M. Nicklow, M.K. Wilkinson, with guest scientist J.C.G. Houmann and graduate student J.G. Traylor, is concerned with measurements of the inelastic scattering of neutrons from solids. Its rare earth-related projects include the determination of the phonon dispersion relations of Ho, Tb, and ^{160}Gd, and the magnon dispersion relations in the spiral regions of Ho, and Tb. This work is being done at

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Crystal Growing Methods Reviewed

New crystal growing devices and growth techniques developed over the past two years are summarized in *J. Cryst. Growth* 3, 4, 60-807 (1968). This issue comprises the Proceedings of the Second International Conference on Crystal Growth, Birmingham, U.K., July 15-19, 1968. Those papers devoted to rare-earth materials are briefly described.

Neodymium-doped calcium and yttrium aluminum garnet single crystals for solid state lasers which exhibit linear optical effects were grown by the Czochralski method. Their performance in the laser cavity varied and depended on structural defects.

A hollow cathode floating-zone melting process was also used to grow yttrium aluminum garnet and yttrium aluminate crystals. The latter compound is metastable and crystalizes incongruently from the 1 Y_2O_3/1 Al_2O_3 melt. Addition of 10% $NdAlO_3$ eliminates this. Yttrium aluminum garnet has nearly optimum properties for a laser host material. The limiting factor is the difficulty of preparing crystals with activator ions such as neodymium. Experiments to increase concentrations of these activators were conducted.

Yttrium iron garnet films were grown from molten salt solutions. Crack-free films 0.5 to 100μm thick were grown on gadolinium garnet substrates. An imperfect substrate surface tended to cause film cracking and line broadening.

Some additional compounds investigated were EuTe, EuSe and EuS grown by chemical transport and sublimation, and PrP by reaction with iodine in a closed system.

Lanthanum hexaboride is of interest for its thermoemissive properties. It was prepared in a very small crystal form by two methods: vapor-phase and liquid-phase crystallization. Its electro-optical properties were also measured.

Single crystals of Gd, Tb, Dy, Ho and Er metals were prepared by three methods: (1) RF induction floating zone technique under high purity argon, (2) recrystallization in the solid state, and (3) by DC solid state electrolysis.

Other topics included the growth of mixed cation iron garnets from flux in yttrium gallium and yttrium calcium silicate systems, and growth of Ce_2O_3 and La_2O_3 by an arc transfer process.

Binary rare-earth oxide solid solution crystals such as La_2O_3-Er_2O_3 were grown by the Verneuil method.

REFRACTORY PrP

The highest melting point ever observed for a rare-earth compound was reported by K.E. Mironov in a description of his method of preparing PrP [*J. Cryst. Growth* 3, 4, 150 (1968)]. The melting point reported by Mironov was 2850±50°C.

The next highest reported melting point is that of YB_6, 2800°C. Next in line are ScN and YN which melt at 2550°C; Lu_2O_3 at 2490°C, the highest melting oxide; CeS at 2450 °C; and GdC_2 and YC_2 at 2415°C.

Although PrP's high melting point makes it a potentially attractive refractory material, other data reported earlier indicate that its high temperature applications may be limited. For example, K.A. Gingerich found that PrP has a phosphorus partial vapor pressure of 10^{-5} to 10^{-9} atm. between 820 and 1275°C (*J. Am. Chem. Soc.* 87, 1660, [1965]). Furthermore Mironov and co-workers found that PrP will oxidize in air above 700°C (*Dokl. Akad. Nauk SSSR* 176, 841 [1967]; English translation, *Doklady Chem.* 176, 873 [1967]).

Faculty Award To LeRoy Eyring

LeRoy Eyring

Dr. LeRoy Eyring, chairman of the chemistry department, Arizona State University (ASU), Tempe, Ariz., has received the ASU Alumni Association's Faculty Achievement Award for 1969.

In naming Eyring as the 1969 recipient, the Alumni Association cited his achievements in solid state chemistry research, his worldwide reputation as an authority on rare-earth oxides, and his ability, as department chairman, to stimulate and encourage the research and teaching excellence of the faculty.

A member of the ASU faculty since 1961, Dr. Eyring in his eight years as chemistry department chairman has built the chemistry department into one of the strongest in the ASU College of Liberal Arts. His was one of the first two departments at ASU to qualify to offer doctor of philosophy degree programs.

Dr. Eyring has been active in the field of rare-earth research for about 20 years and has lectured extensively in Europe and the United States. He was chairman of the Third Rare Earth Research Conference in 1964.

Dr. Eyring has published more than 40 papers in scientific journals and is the editor of three review volumes dealing with the rare earths and with high temperature chemistry.

He is only the sixth ASU faculty member ever named for a Faculty Achievement Citation.

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prepared with the new ceramic are electrically conductive from ambient temperature up to their melting temperature. The inventor is M. Foëx of the French Atomic Energy Commission.

Transparent RE Oxides

Transparent Y_2O_3 has been obtained by pressure forging techniques, Spriggs and Atteraas, p. 701 in *Ceramic Structure,* Fulbrath and Pask, eds., Wiley, New York (1968). Several other desired properties resulting from this technique include enhanced densification rates, controlled porosity or full density, composite fabrication, pressure bonding single and polycrystalline ceramic materials together, and oriented microstructure.

Single-phase Y_2O_3 has shown crack-free, dense, and highly transparent properties after press-forging as compared to the opaque sample which is obtained from conventional pressure-sintering. Microstructures showed elongated grains perpendicular to direction of pressure and x-ray texture studies revealed preferred orientation in pressure-forged samples. Other materials of interest to which the technique was successfully applied were lanthana, samaria and ceria.

Stone is Grace V.P.

R.L. Stone, head of W.R. Grace & Co.'s rare-earth department, has been named a vice president of the firm's Davison Chemical Division, the parent division of Grace's rare-earth department.

RE Industry Reappraisal

The rare-earth industry, which experts (including *RIC News*) predicted would have its greatest year in 1968, is currently the subject of intensive review as prognosticators try to figure out what happened. More accurately, they are trying to figure out *why* it happened.

One of the big markets for rare earths, the color television industry, did not come through even as it had expected. Color television sales of 5 million sets in 1967 were supposed to climb to 7 million sets in '68, but leveled off at 5.6 million sets.

Some say that the industry is in the same position it was prior to the color television boom—waiting for a research "find" to create new markets. Despite the current lag in rare-earth demand, the industry is still considered a growth industry.

This optimism stems from the flexibility of the industry itself. Many producers are looking toward specialized markets and are tailoring production accordingly.

Another reason for optimism stems from the problem of rare earth separation—you cannot separate one without separating them all. In producing one or several rare earths for a specific market, you cannot help but increase the availability of the rest of the series. This ready availability of many rare earths not presently used extensively is expected to attract other manufacturers to them.

For a worldwide review of the rare-earth industry see *Industrial Metals* No. 14, Nov. 1968, pp. 9-27, and No. 16, pp. 35 and 36, where supplemental discussions of Japan's and India's rare-earth industry appear. India's rare-earth industry is also reviewed in *Nuclear News* 12, April 1969, pp. 22 and 24. The United States industry was featured in *Chemical and Engineering News* 47, No. 13, Mar. 24, 1969.

NEUTRON FILTER

Scandium is aiding researchers at Idaho Nuclear in their investigation of the nuclear properties of structural and fuel materials that will be used in the fast breeder reactors.

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NEW BOOKS

SPECTRA AND ENERGY LEVELS

An excellent book by the late G.H. Dieke, edited by H.M. and Hannah Crosswhite, *Spectra and Energy Levels of Rare Earth Ions in Crystals* has been published by Interscience, New York (1968). The cost of this book is $13.95.

There are two valuable chapters in this book which one might not expect to find in a volume such as this. They are "Crystals Available for Study" and "Experimental Procedure." In addition to these two, there are twelve more chapters: "Introduction"; "Historical"; "The Rare Earths"; "Spectra and Levels of the Free Ions"; "The Crystal Field"; "Crystal Symmetry and Structure of the Spectrum"; "Intensities, Selection and Polarization Rules"; "Comparison with Empirical Data"; "Zeeman Effect and Magnetic Properties"; "Divalent Rare Earth Ions in Crystals"; "Review of the Empirical Data"; and "Line Structure."

The book is well illustrated and contains many tables, some of which may be as long as 6, 11 or 30 pages. The original literature is well documented with more than 650 references. Author and subject indexes are also included.

This 400+ page volume should be of value to those of us who are working on the spectra, optical behaviors, magnetic properties, NMR, EPR and other solid state properties, especially those involving the crystalline environment of these elements and their ions.

SCAN DE UM

There is much interest these days in the physical behavior of scandium and scandium-rich alloys as evidenced by the number of papers presented on this topic (six) at the American Physical Society Meeting in Philadelphia, March 24-27, 1969. Most of the work, both theoretical and experimental, is being carried out at the Argonne National Laboratory, and in part in collaboration with Northwestern University.

Earlier work which showed some unexplainable anomalies in the low temperature elastic constants and heat capacity is the apparent stimulus for this current flurry of activity.

These papers dealt with electron transport properties from both a theoretical and an experimental approach, nuclear magnetic relaxation measurements, magnetic anisotropy, and the calculated band structure and Fermi surface of scandium. As a result of the theoretical studies, a new type of dynamic interaction, an electron-antiparamagnon interaction, was proposed to explain the observed behaviors.

The sixth paper, from Iowa State University, described the phonon dispersion curves of scandium as measured by inelastic neutron scattering.

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Scandium permits 2 keV neutrons to pass through it but stops neutrons of all other energies; in effect, it acts as a neutron filter. An 84 cm (33 in.) long piece of scandium metal placed in one of the beam holes in Idaho Nuclear's Materials Testing Reactor yields a high intensity monoenergetic beam of 2 keV neutrons.

The scandium beam experiements are used by designers to determine how the safety of a fast reactor is affected as the temperature increases.

MEETING

8TH RARE EARTH CONFERENCE

Arrangements are going ahead for the 8th Rare Earth Research Conference which will be held in Reno, Nevada, April 19-22, 1970. T.A. Henri, chairman, has sent word that sessions will be held in the meeting rooms of the Reno Chamber of Commerce with supplemental facilities being made available in the municipal theater-auditorium. Advance notices concerning the conference are now in preparation.

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Olson and Hoffer are still members of the Air Force Materials Laboratory staff.

The development of the rare earth-cobalt magnetic materials has sparked worldwide interest in the new magnetic material. Bell Telephone Laboratories, General Electric and Raytheon in the United States, Philips in Holland, and Matsushita Company in Japan all have been working with the Strnat, Olson and Hoffer-developed materials. They have prepared magnets with outstanding properties mostly based on a $SmCo_5$ alloy.

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the computer controlled triple axis spectrometer at the HFIR. Work is planned for isotopically enriched specimens of Dy and Er.

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