



# RARE-EARTH INFORMATION CENTER NEWS

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## 1971 EUROPEAN VISIT

The editor was honored and privileged to present a number of seminars at the Free University of Berlin and the Ruhr University at Bochum, Germany, and a talk at the rare earth conference at Durham, England. It was a wonderful opportunity to exchange views and have many fruitful discussions with a number of European scientists on a variety of problems.

My visit to Berlin centered on Professor Stefan Hufner's physics group. These scientists are primarily using Mössbauer measurements to probe the nature of rare earth intermetallic compounds. Magnetic susceptibility, nuclear magnetic resonance and spectral studies are being used as complementary research tools.

The Ruhr University at Bochum is an instant university. It is about four years old and has an enrollment of 10,000 students. It is an atypical European university, not only in age but also in location; it lies in the countryside on the edge of the city of Bochum. My hosts at Bochum were Professor E. Kneller and his able assistant Dr. D. Feldman. Their main emphasis of research is on electronic and magnetic properties of materials and is more on the applied, engineering side rather than on the fundamental side. A variety of materials are being studied, some of which contain the rare earths. These scientists are in close contact with Professor S. Methfessel, who heads one of the Physics Institutes at Bochum, and who is concerned with the electronic and magnetic properties of rare earth materials, but from a more fundamental viewpoint.

The last stop on my 2½ week visit was Durham to participate in the Conference on Rare Earths-Actinides. The Conference papers and private discussions were interesting and stimulating. Professor W. D. Corner and his organizing committee are to be commended for both their industry in making this Conference a success and their kind hospitality.

## Pallila Honored



F. C. Pallila

F. C. Pallila, General Telephone and Electronics Laboratories, Inc., received the second Annual Award from the Electronics Division of the Electrochemical Society during the Spring Meeting, May 9-12, 1971, in Washington, D. C.

The award was based on Pallila's work on  $\text{Eu}^{3+}$ -activated phosphors and his contributions to research on rare earth phosphors. Major studies by Pallila include: luminescence studies with rare earth phosphors, especially as they relate to host-activator interactions; excitation mechanisms, primarily for excitation under cathode rays; energy transfer mechanisms of the nonradioactive multipolar type; and commercial applications of rare earth phosphors, e.g., cathode ray tube phosphors, x-ray phosphors, phosphors for light-emitting diodes, and lamp phosphors.

## RIC Supporters

To date 16 of the world's leading rare earth producers and manufacturers of rare earth products have contributed or pledged to contribute to the support of RIC during the fiscal year, July 1971 through June 1972. Currently financial support is being received from:

- General Electric Co., U.S.A. (2)
- Th. Goldschmidt A. G., Germany (3)
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- Indian Rare Earths, Ltd., India (3)
- Leico Industries, Inc., U.S.A. (3)
- Metal Extractor Group of Norway, Norway (3)
- Mobil Research and Development Corporation, U.S.A. (1)
- Molybdenum Corporation of America, U.S.A. (4)
- Reactor Experiments, Inc., U.S.A. (2)
- Ronson Metals Corp., U.S.A. (4)
- Rare Earth Industries, Inc., U.S.A. (1)
- Royal Sulphuric Acid Works, Ketjen, Ltd., The Netherlands (2)
- Sel-Rex Corporation, U.S.A. (2)
- Shin-Etsu Chemical Industry Co., Ltd., Japan (3)
- Typpi Oy, Finland (3)
- United States Radium Corp., U.S.A. (2)

The number in parenthesis behind each contributor's name indicates the number of years of RIC support including Fiscal Year 1972.

## Organic Shift Reagents

Two paramagnetic lanthanide chelates investigated by R. E. Sievers and R. E. Rondeau, Wright-Patterson Air Force Base, Ohio, are being used to resolve the NMR spectra of organic Lewis bases which in turn makes spin-decoupling experiments possible.

The chelates are complexes of Eu(III) and Pr(III) with 1, 1, 1-2, 2, 3, 3-heptafluoro-7, 7-dimethyl-4, 6-octanedione, designated Eu(fod)<sub>3</sub> and Pr(fod)<sub>3</sub>, respectively. The addition of the Eu chelate causes downfield shifts of the proton NMR of the organic compound being studied, while the Pr chelate causes upfield shifts. The fod chelates are soluble in organic solvents to complex the shift reagent with all of the organic Lewis base. The peak shifts can then reach a constant value which can be used in identification of compounds, determination of formation constants and the relation of shift magnitude to structural features of the molecule.

## SEMICONDUCTION

The literature of the last 20 years (1947-1967) on rare earth semiconductors is reviewed in a chapter in *Crystal Chemistry and Semiconduction in Transition Metal Binary Compounds*, J. P. Suchet (Academic Press, New York, 1971) 380 pp., \$22.

About one-half of the book is a review of the literature on the crystal chemistry and crystal physics of semiconducting compounds, including oxides, chalcogenides and group IIIB, IVB and VB compounds. The other half of the book contains a discussion of the theory of bonding and electrical conduction and a presentation of some problems and possible applications of magnetic semiconducting materials, such as magnetoelectric effects and electro and magnetooptical effects. Subject, author and formula indices make information easily available.

## Rare Earths In the News

### YTTRIA GLASS

A study by the United Aircraft Research Laboratories shows that glass based on the cordierite composition with beryllia and rare earth oxide additions promises improved strength and elastic properties. One of the new glasses selected for extensive processing investigations contained 30 wt. % Y<sub>2</sub>O<sub>3</sub>. The new glass is readily drawn into fibers even at high rates.

### ELECTRON MICROSCOPE

The Ultrascan Co., Cleveland, Ohio, has produced a new scanning electron microscope with Auger analysis capabilities. The microscope has an LaB<sub>6</sub> filament gun which permits a resolution of 100Å or better.

### FLUORIDE COATING

Honeywell has developed a hard and durable antireflection coating for Ge-Se-As glass using either LaF<sub>3</sub> or NdF<sub>3</sub>. The coating was intended to increase peak transmission to at least 90% at 10.5 μ and maintain at least 70% transmission over the 8 to 14 μ waveband. Single-layer coatings of LaF<sub>3</sub> or NdF<sub>3</sub>, if deposited at 450° F or if post-heat-treated to 500° F, passed all the physical tests with no degradation in optical performance.

## RE's for Steelmaking

RIC's latest report, "Thermochemistry of the Rare Earth Carbides, Nitrides and Sulfides for Steelmaking," IS-RIC-5, tabulates the heats and free energies of formation of these compounds in the temperature range 278° to 2700°K (77° to 4401°F). The report includes 4 two-color figures comparing the free energies of formation of the rare earth compounds with the corresponding non-rare earth carbides, nitrides and sulfides. The methods which were used to calculate the thermodynamic values are discussed briefly in each section.

The preparation and publication of IS-RIC-5 was sponsored by Molybdenum Corporation of America. Copies of this report may be obtained free from RIC or from Molycorp, 280 Park Avenue, New York, NY 10017, USA.

## Ultra Trace Analysis

A new system of quaternary oxide host materials has been developed which allows the detection of rare earths by x-ray excited optical fluorescence in nuclear materials at the part per giga (part per 10<sup>9</sup>) level, report A. P. D'Silva, E. L. DeKalb, and V. A. Fassell in *Anal. Chem.* 42, 1846-1847 (1970).

The quaternary oxides are prepared by simple solid state reactions at an appropriate temperature and have the general formula  $aR_2^{1+}O \cdot bR^{2+}O \cdot cR^{4+}O_2 \cdot dWO_3$ . The most successful phosphors which have been developed are 2Li<sub>2</sub>O · SrO · UO<sub>2</sub> · 2WO<sub>3</sub> and Na<sub>2</sub>O · 2SrO · 2ZrO<sub>2</sub> · 3WO<sub>3</sub>. These host materials allow the detection of Dy and Gd at the 1 to 10 part per giga level. An internal standard can be added to the oxide host during preparation, eliminating the need to dissolve the sample prior to analysis.

## Durham Conference

The 1971 *Conference on Rare Earths and Actinides*, sponsored by the British Institute of Physics, was held in the pleasant and picturesque city of Durham, July 5-7. The Conference was primarily concerned with the physical behavior of the metals and their alloys and intermetallic compounds. A complete listing of the papers presented is given on the following page.

*Most of the papers will appear in the conference proceedings which is expected to be available in early September. All conferees will receive a copy. Copies may be purchased by others for £5 (£3.50 for members of the Institute of Physics) from Dawsons of Pall Mall, Cannon House, Folkestone, Kent, England.*

**SESSION 1**

Introductory Paper (Invited). R. J. ELLIOTT

**SESSION 2**

Physical Metallurgy and Alloy Theory of Rare Earth Alloys and Intermetallic Compounds (Invited). K. A. GSCHNEIDNER, JR.

Rare Earth Single Crystals. Uniaxial Stress and Hydrostatic Pressure Effects. H. BARTHOLIN, J. BEILLE, and D. BLOCH

Theory of Ferromagnetic Resonance in Terbium and Dysprosium. M. S. S. BROOKS

Contributions of the Conduction Electrons to the Crystalline Electric Field in Rare Earth Metals. D. K. RAY

On the Nature of Collective Excitations in the Rare Earth Metals. M. S. S. BROOKS

The Pr-Tb System. D. CHATTERJEE, K. N. R. TAYLOR and M. W. STRINGFELLOW

**SESSION 3**

Recent Developments in Neutron Scattering from Rare Earths (Invited). W. C. KOEHLER

Magnetic Properties of the Light Rare Earth Metals. K. A. McEWEN

Magnetic Excitations in Praseodymium. B. D. RAINFORD and J. GYLDEN HOUMANN

Magnetic Field Dependence of the Magnetic Structure of Neodymium. B. LEBECH and B. D. RAINFORD

The Thermoelectric Powers of Light Rare Earth Metals at High Temperature. M. V. VEDERNIKOV

Slow Neutron Scattering Studies of Rare Earth Hydrides. D. G. HUNT and D. K. ROSS

**SESSION 4**

Transport Properties of Actinides (Invited). J. E. LEE

The Low Temperature Electrical Resistivity of Some Plutonium-Neptunium Alloys in the  $\beta$  Phase. R. O. A. HALL and C. J. PURSER

High Pressure Measurements on the Superconducting Transition of Some Uranium Alloys. M. J. MORTIMER

Hybridized  $6d-5f$  Virtual Bound States Theory for Actinides Metals. E. GALLEANI D'AGLIANO, R. JULLIEN and B. COOBLIN

**SESSION 5**

Magnetic Properties of Actinides. M. B. BRODSKY

Magnetic Susceptibility of Alloys Containing Plutonium. J. P. GATESOUBE, CH. DE NOVION

Hyperfine Interactions of  $^{220}\text{Rn}$  and  $^{224}\text{Ra}$  in Fe via PAC. F. ABILDSKOV, E. J. ANSALDO, B. I. DEUTCH, G. M. HEEDSTAND, H. RAVN and A. G. SERGEEV

Hyperfine Fields in NaCl-Type Actinide Compounds—The Crystal Field and Relativistic Effects. S. K. CHAN and D. J. LAM

**SESSION 6A**

Alloy Chemistry of Rare Earth and Actinide Elements. M. V. NEVITT

The Spin-Lattice Relaxations in Some Magnetic Compounds of Lanthanides and Actinides. M. FIBICH and J. GRUNZWEIG-GENOSSAR

Mössbauer Study of Chemical Ordering in Intermediate Phases of the  $\text{UFe}_2\text{-UX}_2$  ( $X=\text{Al, Ga}$ ) System. C. W. KIMBALL, R. H. HANNON, C. L. HUMMEL and G. SHENOY, A. E. DWIGHT

The Effect of Carbon on the Occurrence of  $\text{Cu}_3\text{Au}$ -Type Structures in Actinide- and Lanthanide-Platinum Metal Systems. H. HOLLECK

Metastable Gd-Ag Alloys. S. W. CHARLES, J. POPPLEWELL and P. A. BATES

**SESSION 6B**

Electronic Structure of Rare Earths and Actinides (Invited). B. COOBLIN

Exploratory Band Structure Calculations for Rare-Earth and Actinide Compounds. H. L. DAVIS

The Number of Band Electrons in Rare Earth Metals. D. E. G. WILLIAMS

$4f$  and  $5d$   $6s$  State Distributions in Rare Earth Metals and Their Oxides. C. BONNELLE and R. C. KARNATAK

UV-Photoemission on Eu, Yb, Er and Sm. G. BRODEN

**SESSION 7**

Intermetallic Compounds of Rare Earth Elements with  $3d$ -Transition Elements (Invited). K. H. J. BUSCHOW

Thermal, Magnetic and Electrical Characteristics of  $\text{PrNi}_5$ . W. WALLACE, R. S. CRAIG, N. MARZOUK, V. U. S. RAO, E. SEGAL and S. G. SANKAR

Time Dependent Magnetization in  $\text{Dy}(\text{Co, Ni})_2$  Compounds. D. MELVILLE and K. N. R. TAYLOR

Magnetic Properties of Intermetallic Compounds  $\text{RE}_6(\text{Mn, Fe}_{1-x})_{23}$  ( $\text{RE}=\text{Tb, Dy, Ho, Er}$ ). G. HILSCHER, H. KIRCHMAYR and G. WIESINGER

Moment Variation in  $\gamma(\text{Fe, Co})$ ;  $\gamma(\text{Co, Ni})$  Intermetallic Pseudobinary Compounds. G. A. POLDY and K. N. R. TAYLOR

Magnetic Thin-Wall Coercivity in RE Compounds. H. ZIJLSTRA

**SESSION 8**

The Presently Known Electronic and Magnetic Properties of Uranium Monopnictides and Monochalcogenides. M. KUZNIETZ

Study of Magnetic Ordering in Uranium Monochalcogenides by Neutron Diffraction. F. A. WEDGWOOD and K. KUZNIETZ

Magnetic Properties of Uranium Compounds with  $\text{Th}_3\text{P}_4$ -Type Crystal Structure. W. TRZEBIATOWSKI, R. TROC, W. SUSKI and C. BAZAN

Electronic Properties of  $(\text{U}_x\text{Th}_{1-x})\text{S}$  Monosulfides. J. DANAN, J. P. GATESOUBE, B. GRIVEAU, J. P. MARCON and CH. DE NOVION

Inner Sternheimer Shielding Factor,  $R_{5f}$ , for Np (VI). G. K. SHENOY, G. M. KALVIUS and B. D. DUNLAP

**SESSION 9A**

Low Temperature Specific Heat, Electrical Resistance and Thermopower of the Intermetallic Compounds,  $\text{CeCo}_2$  and  $\text{CeRu}_2$ . J. R. COOPER, C. RIZZUTO and G. OLCESSE

Spin Disorder Resistivity of Some Dilute Rare Earth Zinc Compounds. A. M. STEWART

Anisotropic Exchange Interaction in Rare-Earth Metals. PER-ANKER LINDGARD and JENS GYLDEN HOUMANN

Magnetic Properties of Cubic and Hexagonal  $\text{ErAl}_3$  and of the System  $\text{Er}_x\text{Y}_{1-x}\text{Al}_2$ . G. WILL and M. O. BARGOUGH

**SESSION 9B**

Mössbauer Spectroscopy of  $\text{EuLn}_2\text{S}_4$  Chalcogenides. G. K. SHENOY, W. POTZEL, G. M. KALVIUS and W. ZINN

The Magnetic Structure of  $\text{CeSb}$ . B. LEBECH, P. FISCHER and B. D. RAINFORD

Neutron Scattering by Nd-Va Compounds: Magnetic Properties and Crystal Field Effects. P. FISCHER, A. FURRER, H. HEER and W. HALG, P. SCHOBINGER-PAPAMANTELLOS and A. NIGGLI, D. VOGT, J. KJEMS and B. RAINFORD

Preparation, Optical and Magneto-Optical Properties of Samarium Chalcogenide Thin Films. R. SURYANARAYANAN, C. PAPANODITIS and J. FERRE

**SESSION 10A**

Nuclear Orientation Measurements on Dilute Alloys of Ce. J. FLOUQUET

Magnetic Structures of  $\text{CeZn}_2$  and  $\text{TbZn}_2$ . D. DEBRAY, M. SOUGI and P. MERIEL

Magnetic Properties and Magnetic Structure of  $\text{TbGa}$  and  $\text{ErGa}$  Compounds. B. BARBARA, C. BECLE, N. N. NGUYEN and E. SIAUD

**SESSION 10B**

Synthesis and X-ray Investigation of Some Tetravalent Cerium Containing Phosphates and Silicates. R. HEINDL, E. FLEMKE and J. LORIERIS

The Precipitation and Some Properties of Orthovanadates of Rare-Earth Elements. V. S. KRYLOV, V. I. POPOV, Kh. S. BAGDASAROV and R. L. MAGYNOV

Neutron- and X-Ray Diffraction Study of the Magnetic and Crystallographic Phase Transitions in  $\text{DyVO}_4$  and  $\text{DyAsO}_4$ . G. WILL, W. SCHAFER and E. GOEBEL

Crystal Field Study of the Behavior of  $\text{Er}^{3+}$  Ion in Solids. VISHWAMITTAR, S. P. TANEJA and S. P. PURI

The Vibrational Spectra and Structures of Some Rare Earth Borates. J. H. DENNING and S. D. ROSS

A New Method for Rare Earth Isotope Separation. G. J. BEYER, E. HERRMANN, A. PIOTROWSKI, V. J. RAIKO, H. TYRROFF

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# MEETING

## NINTH RE CONFERENCE

The Committee for the Ninth Rare Earth Research Conference which is to be held at Blacksburg, Va., Oct. 10-14, 1971, has announced a tentative list of invited speakers. They include:

WILLARD F. LIBBY, Univ. of California, Los Angeles. "Auto Exhaust Catalysis by Rare Earth-Transition Metal Oxides"—Plenary Address.

HELMUT BÄRNIGHAUSEN, Univ. of Karlsruhe, Germany. "The Crystal Chemistry of the Salt-like Rare Earth Di-Halides and the Determination of the New Structure Type  $\text{Ln}_3\text{O}_4\text{Br}$ ."

JUDGE BEVAN, Flinders Univ. of South Australia. "Studies in Rare Earth Oxides-Fluorides."

R.L. COHEN, Bell Telephone Laboratories, Murray Hill, N. J. "Mössbauer Spectroscopy in Rare Earths."

R. J. ELLIOTT, Oxford Univ., England. "Magnetism in the Rare Earth Metals—A Review."

J. FLAHAUT, Univ. of Paris. "The  $\text{L}_6\text{B}_2\text{C}_2\text{X}_{14}$  Family."

H. A. C. MCKAY, Atomic Energy Research Establishment, Harwell, England. "Solvent Extraction of the Rare Earths."

K. N. R. TAYLOR, Univ. of Durham, England. "Pulsed Field Magnetization Measurements of Rare Earth Transition Metal Compounds."

J. A. GLASEL, Univ. of Connecticut, Storrs. "Studies of Lanthanides in Biological Systems."

D. W. DARNALL, New Mexico State Univ., University Park. "Rare Earth Metal Ions as Probes of Calcium Ion Binding Sites in Proteins."

E. NIEBOER, Laurentian Univ., Sudbury, Canada. "The Lanthanide Cations as Nuclear Magnetic Resonance Probes of Biological Systems: Studies of Lysozyme and *Staphylococcus* Nuclease."

A. V. XAVIER, Oxford Univ., England. "The Lanthanide Cations as NMR Conformational Probes."

J. REUBEN, Weizmann Institute, Rehovoth, Israel. "Gadolinium(III) as a Paramagnetic Probe for Magnetic Resonance Studies of Biological Macromolecules."

R. A. DWEK, Oxford Univ., England. "Molecular Confirmation Determinations of Inhibitor/Enzyme Complexes with Respect to the Gd(III) Reporter Site."

P. D. MAHLUM, Battelle Northwest, Richland, Wash. "Physico-Chemical and Biological Interaction in Rare Earth Metabolism."

A. LINDENBAUM, Argonne National Laboratory, Argonne, Ill. "Metabolism of Monomeric and Polymeric Plutonium in Mice Following Intravenous Injection."

## BUBBLE REVIEW

For those of you who are non-experts in the workings of magnetic bubbles, there is an excellent review by A. H. Bobeck and H. E. D. Scovil in the June 1971 issue of *Scientific American* 224 [6] 78-90.

The article explains the formation of magnetic bubble domains and the maneuvering and use of these devices in a new type of computer memory which combines data storage with logic in a single miniature device.

### FREE

Copies of *Rare Metals* by O.A. Songina and of *Rare-Earth Metals in Steels*, IS-RIC-4, are still available from RIC.

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The authors point out that recent improvements in bubble materials and circuitry make possible, within a three-inch cube, a bubble memory with a storage capacity of  $10^7$  bits by using stacks of processed garnet wafers. Only 10 watts is needed to move data at a rate of 200,000 bits per second, thus making possible large-capacity information storage at low cost.

## CARBIDES

The rare earth carbides are discussed along with other metal-carbon systems in *Carbides, Properties, Production and Applications*, T. Ya. Kosolopova (Plenum Press, New York, 1971) 298 pp., \$30. The original Russian text was published in 1968.

Tables in the introductory chapter summarize the known data on the crystal structures, hydrolysis products, thermodynamic, electrical, magnetic and mechanical properties of the carbides including the rare earth carbides. The discussion of the carbides in the main part of the text is organized according to groups of the periodic table and deals primarily with phase diagrams and methods of preparation. Applications are presented in the last chapter. This volume contains 921 references of which about one-half are to Russian literature.

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