Professor John Goodenough honored with Presidential Enrico Fermi Award

Dr. John Goodenough, photographed in his office on September 22, 2009.

AUSTIN, TEXAS—September 16, 2009

Enrico Fermi Award Medal

Professor John B. Goodenough, holder of the Virginia H. Cockrell Centennial Chair in Engineering, received the 2009 Presidential Enrico Fermi Award with Stanford University's Siegfried S. Hecker. Hecker was cited for his contributions to the metallurgy of plutonium and his leadership of the Los Alamos National Laboratory. The citation for Goodenough noted in particular his contributions to the lithium-ion batteries that enabled the wireless revolution as well as to those now under development for the hybrid electric car.

His body of work has earned Goodenough the highest awards of several societies: the 1989 Von Hippel Award of the Materials Research Society, the 1990 Senior Research Award of the American Society of Engineering Education, the 1997 John Bardeen Award of the Minerals, Metals, and Materials Society, and the 1999 Olin Palladium Award of the Electrochemical Society. He is also a laureate of the Japan Prize, 2001, as well as of the Presidential Fermi Award of 2009.

Goodenough states:

> The opportunity to participate in the transformation of metallurgy, ceramics, structural chemistry, and solid state physics into the robust field of materials science has been a great privilege and the many devoted experimental colleagues who have made this adventure possible a continuing joy. My call to a life in science remains a

January 2010 cover design for Chemistry of Materials, featuring a paper by Dr. John Goodenough and Dr. Youngsik Kim.

Related Links

- Dr. John B. Goodenough Faculty Directory Page
- Dr. Goodenough's Wikipedia page
- Texas Materials Institute

Books

- Magnetism and the Chemical Bond (1963)
- *Les oxydes des métaux de transition* (1973)
- Localized to Itinerant Electronic Transition in Perovskite Oxides (2001)
- Solid Oxide Fuel Cell Technology: Principles, Performance and Operations (2009)
- Witness to Grace (2008)

Award Links

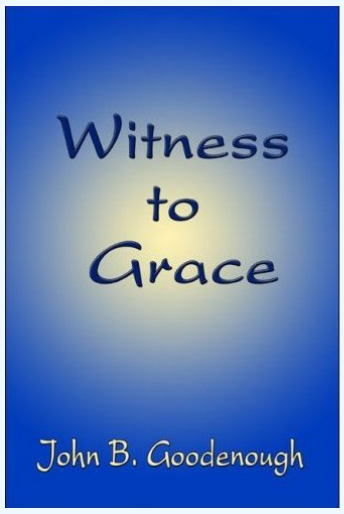
- Enrico Fermi Award, Department of Energy web site
- Goodenough's Biographical Sketch Departement of Energy Site, Fermi Award
- Von Hippel Award
- Materials Research Society
- John Bardeen Award

mystery for which I am most grateful.

To follow is Dr. Goodenough's biographical sketch, compiled from a conversation with him on September 22, 2009 in his office in the Mechanical Engineering Department at The University of Texas at Austin. At 87, he remains active with a full schedule leading graduate students and post docs in continued research on transition-metal oxides and lithium-ion battery design and production. His jovial demeanor, keen wit and wonderful laugh have made him a favorite of students, faculty and students alike since he arrived at the University of Texas at Austin in 1986.

How and why did you become a scientist?

After serving in the United States Army Air Force as a meteorologist in World War II, I was given the opportunity to study physics at the University of Chicago where I took two courses from Enrico Fermi: Quantum Mechanics and Nuclear Physics. On my arrival at the University of Chicago, the registration officer said to me, “I don't understand you veterans. Don't you know that anyone who ever did anything significant in physics had already done so by the time he was your age, and you want to begin?”

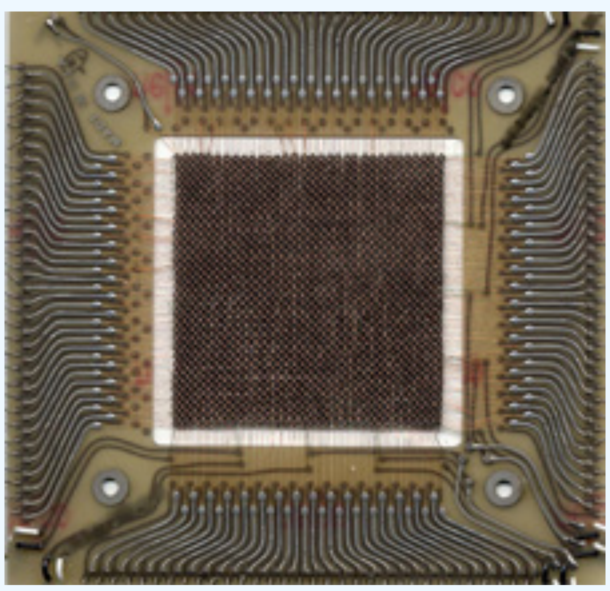


Cover of "Witness to Grace" by John B. Goodenough, 2008.

But it was not the atomic bomb that had attracted me to physics. While an undergraduate at Yale University, I had concluded that if there was an opportunity to go to graduate school after the war was over, I should study physics as it is fundamental to science and therefore to a great intellectual adventure of my generation. Consequently, given a surprising opportunity to study physics on my return to civilian life, I accepted the call to the University of Chicago even though I was aware that I lacked the precocious brilliance to which the registration officer had alluded. As I recorded in my little book,Witness to Grace (Publish America, 2008), my intellectual journey also included a religious quest for meaning in what or whom I would choose to serve with my life.

How did you become involved with magnetic materials?

On receiving my Ph.D. in solid state physics with Clarence Zener, I joined a group at the MIT Lincoln Laboratory charged with the development of a ferrimagnetic ceramic to enable the first random-access memory (RAM) for the digital computer. The air defense of the country depended on having a large digital computer, and the computer had no memory! The alloy rolled tapes first tried did not switch fast enough. Although the Europeans who had developed the ferrimagnetic spinels were convinced that it would be impossible to obtain the required squarish B-H hysteresis loop in a polycrystalline ceramic, themagnetic-core RAM was delivered within three years of my arrival with a read/rewrite cycle time of less than the required 6 microseconds.



Magnetic core memory extracted from a CDC 6600 computer, circa 1964
Click image to enlarge.

Four of my contributions to this project were (1) calculations showing that the squarish B-H loop and switching speed were possible as well as the conditions that needed to be met, (2) the recognition that cooperative ordering of localized-electron orbitals to remove an orbital degeneracy can lead to a displacive structural transition, a phenomenon now known as a cooperative Jahn-Teller distortion, (3) where the concentration of ions with an orbital degeneracy is not high enough to give long-range orbital order, dynamic site distortions can induce the formation of chemical inhomogeneities, given

Minerals, Metals, and Materials Society
Olin Palladium Award
Electrochemical Society
Japan Prize
Japan Prize — Biographical Sketch

Major Developments and Research Institutions

Massachusetts Institute of Technology
MIT Lincoln Laboratory
MIT Project Whirlwind, Wikipedia Entry
Dr. Goodenough's papers at the Whirlwind project
University of Oxford
Inorganic Chemistry Laboratory
Texas Materials Institute

Further information

Enrico Fermi
Magnetic core RAM
Jahn-Teller distortion
Goodenough-Kanamori rule
Squarish B-H hysteresis loop
Magnetic-core RAM
Transition-metal
Solid state chemistry
Charge-density waves
High-temperature superconductivity
Colossal magnetoresistance
Solid electrolytes
Three-Mile Island incident

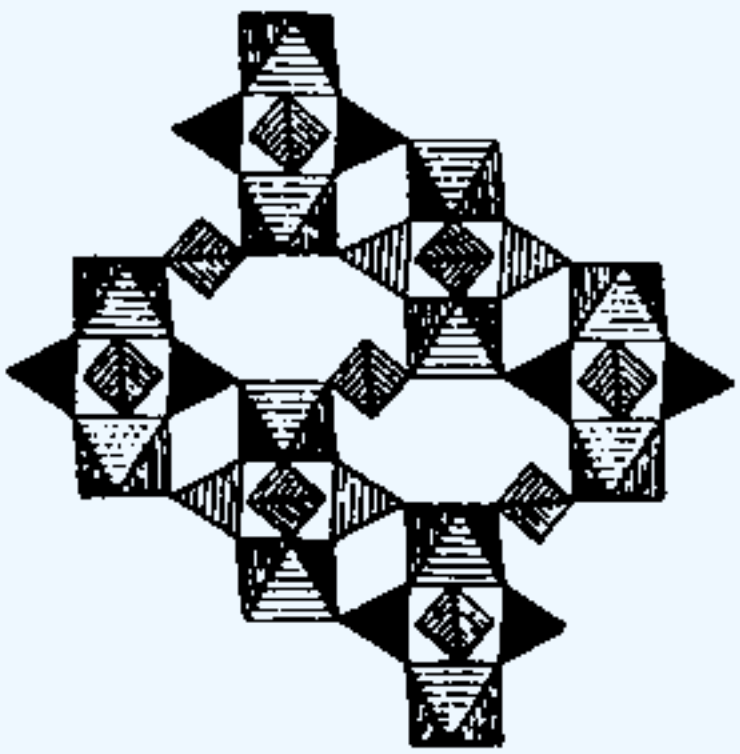
proper annealing conditions, to achieve stabilization from short-range-cooperative orbital fluctuations, a concept I showed to be critical to obtain the squarish B-H loop required for the RAM in a polycrystalline ceramic, and (4) demonstration that cooperative orbital order can give antiferromagnetic spin-spin interactions in one direction in a crystal and ferromagnetic interactions in another direction, which allowed me to articulate the rules for the sign, antiferromagnetic versus ferromagnetic, of spin-spin interactions.

These rules have subsequently provided a true guide to the design as well as the interpretation of the magnetic properties of solids; they are known as the Goodenough-Kanamori rules, and they inspired the title of my first book, Magnetism and the Chemical Bond (Interscience-Wiley, 1963).

What enabled you to switch from targeted to fundamental research?

I was subsequently put in charge first of a Ceramics Group and then of a Solid State Physics Group at the MIT Lincoln Laboratory. In these assignments, I had over a decade to pursue fundamental studies of transition-metal alloys and compounds. I had undertaken the transformation of solid state chemistry from its restriction to either purely structural chemistry or the handmaid of engineers to make it a scientific discipline to explore systematically the relationship between the chemistry, structure, and physical properties of solids.

As an example of this endeavor, I recognized that the transition-metal compounds permitted exploration, without interference from broad-band electrons, of the transition from the localized-electron behavior responsible for ionic magnetic moments to itinerant-electron behavior providing metallic properties and suppressing ionic magnetic moments. This exploration led to a long review article, *Metallic Oxides*, that was translated into French as my second book, ***Les oxydes des métaux de transition*** (Gauthier-Villars, 1973).



The NASICON framework structure that Goodenough developed with Henry Hong for fast Na^+-ion conduction. Na^+-ions occupy the interstitial space.

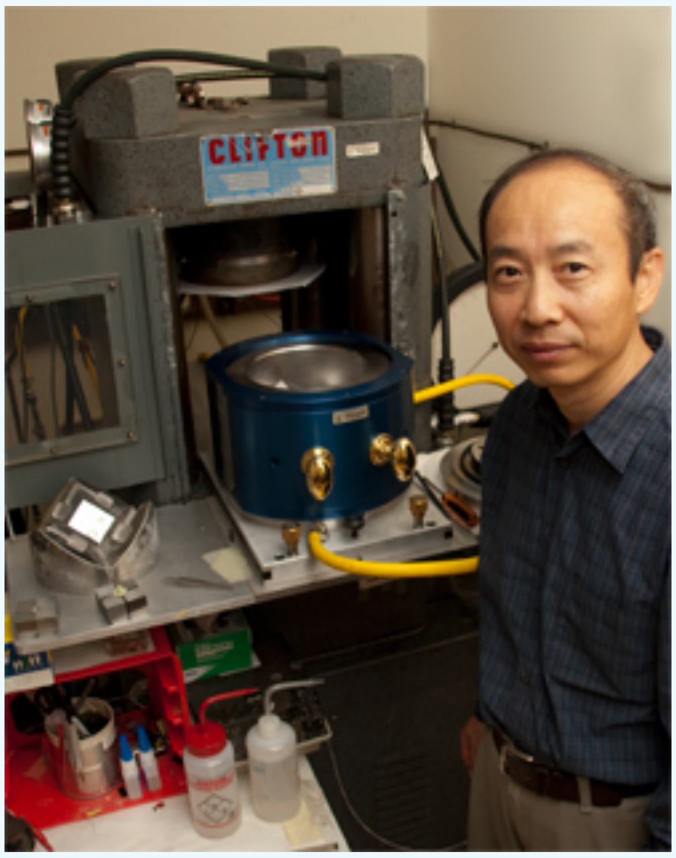
Exploration of the unusual physical properties that occur at the crossover from localized to itinerant electronic behavior was stimulated in the 1960s by the observation of charge-density waves and was revived in the late 1980s by the observation of high-temperature superconductivity in the copper oxides and a colossal magnetoresistance phenomenon in manganese oxides. But in the early 1970s, these fundamental studies were suppressed at Lincoln Laboratory by a decree from Congress, and I turned my attention to energy-related materials in response to the first energy crisis that revealed our national vulnerability because of our dependence on foreign oil. This change led to my development of framework structures for solid electrolytes.

How did you become involved in electrical energy storage?

Since my proposals to work on energy materials were assigned to the National Energy Laboratories because the Three-Mile Island incident had halted development in this country of nuclear-power plants, I accepted a position as Professor and Head of the Inorganic Chemistry Laboratory at the University of Oxford, England. This move recognized me as a chemist and enabled me to learn some electrochemistry. My work in Oxford included the development of cathode materials for the lithium-ion battery that enabled the SONY Corporation of Japan to introduce the cell telephone that launched the wireless revolution. These batteries are now also used in laptop computers and a variety of other hand-held electronic devices.

Lithium-ion batteries, as pictured on screen, power today's laptop computers, cell phones, digital cameras and many other devices.

How did you bring together the different strands of your research on your return to the US?



Professor Jian-shi Zhou in his lab, pictured with the multi-anvil press for high pressure synthesis of oxides; the press is capable of reaching pressures and temperatures of the earth's lower mantle (20 GPa and 2000°C).

With the approach of mandatory retirement in England in 1986, I was delighted with an invitation from the University of Texas at Austin to occupy the Virginia H. Cockrell Centennial Chair in Engineering. As a member of the ME and ECE Departments, I helped to establish the Texas Materials Institute. With the help of now Professor Arumugan Manthiram, who came with me from England as a postdoc in 1986, and of Professor Jian-shi Zhou, who came to me in 1987 as a Ph.D. student, I have been able to establish a laboratory that includes in one group solid state chemistry, structural characterization, electrochemistry, and a variety of physical measurements as a function of temperature and pressure.

This organization has enabled me to return to studies of the unusual physical properties imparted by orbital order, structural transformations, and the lattice instabilities encountered at the crossover from localized to itinerant electronic behavior, some of which is summarized in my volume Localized to Itinerant Electronic Transition in Perovskite Oxides (Springer-Verlag, 2001). It has also allowed me to develop cathodes for the high-power lithium-ion batteries under development to power the hybrid electric car and to explore materials that would enable operation of a solid oxide fuel cell at intermediate temperatures. (See his book with K. Huang: Solid Oxide Fuel Cell Technology: Principles, Performance and Operations, Woodhead Publishing Ltd. 2009)

Last modified on May 24th, 2013