Dr. Croat's Research: Invention of the Neodymium Magnet and the Rapid Solidification Process

In 1972 Dr. Croat joined the Magnetic Materials Group of the General Motors Research Laboratories whose mission was to develop high performance, low-cost permanent magnets for use in automotive components. The world economy was confronted with the 1973 OPEC oil embargo which significantly increased gasoline prices worldwide and greatly stimulated the search for lighter weight automobiles with greater fuel economy. Although $SmCo_5$ magnets had been discovered in the 1960s, all permanent magnet researchers dreamed of discovering a lower cost permanent magnet composed of the more abundant, lower cost rare earth elements Nd and Pr in combination with Fe.

In 1982 Dr. Croat discovered the ternary intermetallic phase $Nd_2Fe_{14}B$ while investigating the effect of various "glass forming elements" like silicon, carbon and boron on the properties of rapidly solidified Nd-Fe and Pr-Fe alloys. This intermetallic phase is the basis of all families of NdFeB permanent magnets currently being produced. The rapidly solidified material became the basis for a new family of magnetically isotropic bonded permanent magnets. Although the magnetic strength of these bonded magnet is lower than that of a sintered magnet, the alternate method for producing NdFeB magnets, thin-walled bonded ring magnets with high thermal stability can be rapidly produced that have found wide application in small motors for a wide range of industrial, consumer electronic and computer peripheral applications. Such thin-walled ring magnets are almost impossible to produce by the sintering process.

Dr. Croat's process was later developed into a hot-deformed process in which nanocrystalline magnetic powder made by the rapid solidification process is hot-deformed in a mold. This led to the development of a family of hot-deformed neodymium magnet that possessed an equivalent strength to that of a sintered magnet. Notably, the process was capable of producing thin-walled, axially oriented ring magnet that are currently being used in high-end servo and stepper motors.

Dr. John J. Croat

Former President, John Croat Consulting Inc.

Born

May 23, 1943, Iowa, U.S.A. (U.S.A. citizenship)

Education

1965	BA Degree, Simpson College, Indianola Iowa, U.S.A.
1968	MS Degree, Iowa State University, Ames Iowa, U.S.A.
1972	PhD Degree, Iowa State University, Ames Iowa, U.S.A.

Employment History

1972-1980	Research Metallurgist, General Motors Research Labs., Warren Michigan (USA).
1980-1984	Senior Research Metallurgist, GM Research Labs., Warren Michigan.
1984-1986	Asst. Chief Process Engineer, Delco Remy Div. GM Corporation
1986-1990	Chief Engineer, Magnequench, Delco Remy Div., GM Corporation
1990-1996	Managing Director, Magnequench, Delco Remy Div., GM Corporation
1996-2004	President, Advanced Magnetic Materials (AMM) Korat, Thailand
2004-2017	President, John Croat Consulting Inc.

Prizes and Honors

1985	Applications of Physics Prize, American Institute of Physics
1985	Distinguished Alumni Award, Iowa State University
1986	International Prize for New Materials, American Physical Society (now James C. McGroddy Prize for New Materials)
1994	Outstanding Engineering Achievement Award, American Society of Metals.
2022	IEEE Award for Environmental and Safety Technology

Publications

- Books

1. Rapidly Solidified NdFeB Permanent Magnets, Elsevier Published, Published 2018.
2. Modern Permanent Magnets, Elsevier Publishing, Published 2022. Co-edited with John Ormerod.

- Journal Publications

1. The Properties, Preparation and Handling of Pure Rare Earth Metals, Proc. Interamerican Conference on Material Technology, San Antonio, TX, May 20-24, 1968.

2. The Preparation and Properties of "Ultra Pure Metals", Proc. International Conference on Rare Earth Metals, Paris, France, Vol. I, Page 27 (1969).
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4. Magnetic Properties of High Purity Yttrium, Lanthanum and Lutetium and the Effects of Impurities on These Properties, J. Chem. Phys., 59, No. 5, 2451 (1973).
5. Preparation and Coercive Force of Melt-Spun Pr-Fe Alloys, Appl. Phys. Lett. 37(12) 1096 (1980).
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8. Observation of Large Room Temperature Coercivity in Melt-Spun Nd0.4Fe0.6, Appl. Phys. Lett. 39(4), 357 (1981).
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19. Neodymium-Iron-boron Magnets by Rapid Solidification, J. Mater. Eng., Vol. 10, No. 1, 1988.
20. Manufacture of Nd-Fe-B Permanent Magnets by Rapid Solidification, J. Less Common Metals, 148, 7 (1989)
21. Properties of Bonded NdFeB Anisotropic Magnets, J. Appl. Phys., 70(10), 6465 (1991).
22. Microstructure of Rapidly Solidified Nd-Fe-Co-B Alloys, IEEE Trans. Magn., 28 (5), 2853 (1992).
23. Current Status and Future Outlook for Bonded Neodymium Permanent Magnets, J. Appl. Phys., 81 (8), April 15, 1997.