Commentary

The following is a condensation of a presentation at the Materials Week 1993 Hard & Soft Magnetic Materials Symposium, Session I on "Past, Present Status and Future Outlook on Magnetics Technology in Pittsburgh."

The Role of Pittsburgh in the Development of High Energy Magnets*

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Performance characteristics (energy products and coercivity) of permanent magnets have been increased 50-fold in the last 50 or 60 years. Materials research by the Pittsburgh technical community has contributed significantly to these developments. Nassau, Cherry, and Wallace[1] revealed in 1960 the coupling systematics for alloy systems involving rare earth and Fe or Co. Coupling is invariably ferromagnetic for light and antiferromagnetic for heavy rare earths, respectively. This discovery has provided and is still providing guidance in the search for new high energy magnetic materials; the discovery of $Nd_2Fe_{14}B$ exemplifies this. Quantum mechanics has been applied to Sanker et al.[2] to elucidate the powerful magnetic anisotropy of $SmCo_5$. Auger spectroscopy has been used[3] to establish the fine particle nature of $SmCo_5$ magnets. In the following, a few comments are made about each of these three important developments.

Coupling Systematics: Nassau, Cherry, and Wallace discovered that the strongly magnetic heavy rare earths couple antiferromagnetically to Co or Fe and hence such materials as $HoCo_5$ are useless for magnet fabrication. Only rare earth-cobalt or rare earth-iron intermetallics in which the rare earth is light, e.g., Pr, Nd or Sm, are useful in producing strong magnets.

Magnetic Anisotropy of $SmCo_5$: Large coercivity requires a material with strong magnetic anisotropy. If anisotropy is absent or weak, magnetism reverses easily and coercivity is small. S.G. Sankar *et al.* showed in 1975 by use of quantum mechanics that the ellipsoidal shape of the Sm^{3+} ion gives rise to the observed strong anisotropy, enabling one to use $SmCo_5$ to fabricate very strong permanent magnets.

Auger Spectroscopy of Fine Particle $SmCo_5$ Magnets: $SmCo_5$ in bulk form is not a high energy magnet, although it has powerful magnetism when in fine particle form. Elbicki *et al.*[3] elucidated the source of this difference using Auger spectroscopy. On $SmCo_5$ magnets that were fractured under ultrahigh vacuum conditions, they were able to chemically characterize the surfaces of the magnet particles. This work showed that $SmCo_5$ magnets consist of an assemblage of magnetically very weakly interacting particles. This behavior occurs because of a 50 Å dead layer that insulates one particle from neighboring particles. This insulation is essential for the utility of $SmCo_5$ or $Nd_2Fe_{14}B$ as high energy magnet materials.

The Pittsburgh group discovered the coupling systematics that showed which materials had the magnetic potential for high energy magnet fabrication. This was one of the essential ingredients in this developmental effort. Understanding magnetic anisotropy and the elucidation of the microstructure pointed the way to high coercivity. This basic information led to the production of $SmCo_5$ and $Nd_2Fe_{14}B$ magnets, now a multibillion dollar industry.

References

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