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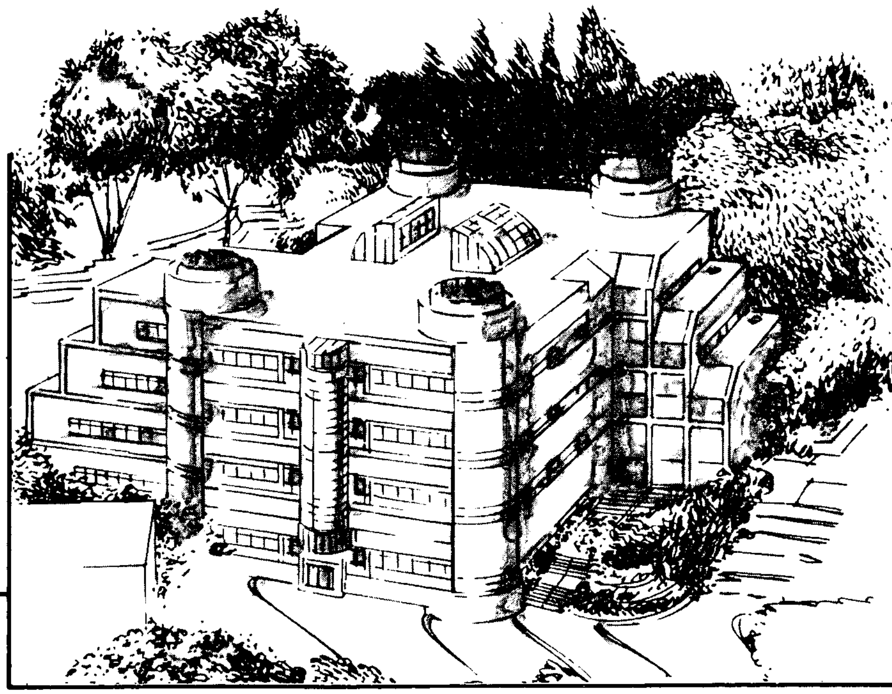

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CERAMIC PROCESSING FOR MAGNETIC APPLICATIONS

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Developments in the ceramics community have focused on the exploitation of chemical methods for the production of powders of high uniformity in size distribution and in chemical homogeneity.[1] Some of these chemical methods may offer significant opportunities in providing additional powder synthesis methods that can be of use in both particulate and thin or thick film magnetic applications. The opportunities follow from the possibility of producing micro- or nano-composite powders or films. Several methods have been used to coat particles, and these have been reviewed recently.[2,4] In particular, solution methods have been found effective to produce large quantities of composite powder.[2] A number of potentially interesting research opportunities relating to magnetic micro- or nano-composites are described here.

1. Coated Powders

Sol-gel methods in which, through controlled hydrolysis, alkoxide or other organometallic precursor are converted to oxides by hydrolysis, can be used to coat magnetic core particles with non-magnetic layers or vice versa.[2-3] One challenge here is to increase the possibilities for shape control of the core particles.[4-6,16] Progress has been made in using combinations of alkoxide and acetylacetonates to produce barium ferrite, plate-shaped particles of a controlled sub-micron size.[7] Further coating of such particles with a uniform layer of either polymer, metal, or ceramic may lead to interesting magnetic composites. It may, for example, be possible to coat an acicular core particle with an iron oxide precursor that can be reduced to iron at an appropriate oxygen partial pressure, to produce an Fe/core composite particle with high shape anisotropy. In another example, magnetic particles such as barium ferrites, can be coated with uniform polymer layers to produce a ferrite/polymer composite in which the magnetic particles are separate and aligned, having a ferrite volume fraction in the final composite of more than 50%. A volume fraction loading of even as much as 65% does, at this point, not seem impossible, although significant laboratory work will be needed to achieve such a degree of filling while maintaining sub-micron structural homogeneity.

The possibilities of coated particles for magnetics are, at this stage, rather broad and a new generation of micromagnetic composites would not seem unlikely.

The fundamental, and generic, problems reside in developing the appropriate solution chemistry. At the same time, coated particles - while commonly used in the drug and paint industries[9] - can find wide application in other materials areas as well, including the fabrication of highly homogeneous structural ceramics.[3] It is also likely that the chemical solution methods lead to coated and surface-modified powders that retain their useful modifications in the consolidated state.

2. Film Coatings: Coating or Spin Coating

Chemical methods, including sol-gel techniques, may be successfully used to produce uniform films or substrates. Sol-gel methods have, for example, been used successfully to produce antireflective coating in a variety of optical applications.[10]

For magnetic purposes a film thickness in the range of a few microns down to a few hundred Angstroms may be desired. The research challenge here is to produce the surface smoothness, uniformity, wear resistance, chemical durability, and compatibility with head materials that is required for advanced magnetic recording purposes.

An additional, and generic problem in producing supported thin films by sol-gel methods is to achieve full density, leaving no pores or holes. This requires a highly anisotropic consolidation process when the deposited film is transformed to a dense, final product. The use of very steep temperature gradients, such as provided by optical means (lasers, focused heat lamps) may prove beneficial in this regard. The fundamental processing question here is to examine how such deposited films respond during their densification in the ultra-steep gradients ($\nabla T > 10^3$ $^oC/cm$). Directional microstructures as well as directional densification should be expected. Other heating methods to effect densification, such as microwave heating or plasma enhanced sintering[11], should also be explored for the production of dense films from chemical deposits.

The chemical methods for film production are quite attractive due to their inherent simplicity and low capital investment compared to methods such as RF sputtering electron beam evaporation or molecular beam epitaxy.[12]

3. Metallic Fine Particles

In some applications, metallic fine particles of materials based on alloys may be desired.[17] Two methods are likely to be useful in this regard and require further exploration as to the effects of the processing conditions on their properties, including size, distribution and shape:

a. Chemical comminution:

Repeated hydrogenation/dehydrogenation can yield fine powders for a number of metals. The conditions that lead to the most useful powders could be explored further, including the best combination of gas pressures and temperature-time schedules.

b. Electrolytic formation:

Strongly reducing electrolytic baths, such as organic solvents with dissolved lithium-aluminum hydride,[12] may allow electrolytic deposition of "slush" of the rare earth alloys that have desirable magnetic properties.

4. Composite Coatings

Composite thin film production of magnetic/optic layer combination may usefully employ film coating of an electro optical layer[14] over a magnetic substrate. Sol-gel methods might be used to develop the electro-optical layer, rather than sputtering.[12] The nature of the interface that results and its effect on magneto-optic performance must be studied for such composite films. Important in this case are the issue of residual stresses and mechanical integrity (adhesion/spalling).[15]

5. Low Pressure Plasma Deposition

Interesting opportunities are indicated by some recent results in this relatively underexplored processing method. This method deposits films from carboxyls or metal alkyls via low energy plasma. The possibility exists to deposit a number of non-equilibrium phases of Fe and its alloys with C or N_2 to produce magnetic materials with unusual properties, including high values of $4\pi M_s$. In this case, the role of the non-metallic element, especially gases incorporated in low concentration, in determining the resulting magnetic properties requires further study.

Conclusion

A number of interesting and novel techniques may lead to a new generation of magnetic films, multilayer or magneto/electro-optical and particulate composites. With regard to the particulate composites, micro or nano-scale composite powders by chemical methods deserve immediate attention.

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References

1. "Better Ceramics Through Chemistry II," C. J. Brinker, D. E. Clark, and D. Ulrich, Eds., Materials Research Society, Pittsburgh, 1986.

   D. W. Johnson, "Innovations in Ceramic Powder Preparation," **Advances in Ceramics**, 21, 3-20, 1987.

2. A. Garg and E. Matijivic, "Preparation and Properties of Coated Inorganic Colloidal Particles," Langmuir, 4, 38-44 (1988).

3. A. Garg and L. C. De Jonghe, "Microencapsulation of Silicon Nitride Particles with Yttria and Yttria-Alumina Precursors," LBL 25751, 1988 (submitted to the Journal of the American Ceramic Society).

4. E. Matijevic, "Preparation and Interactions of Colloids of Interest in Ceramics," in "Ultrastructure Processing of Advanced Ceramics," J. MacKenzie and D. Ulrich, Eds., J. Wiley, New York, 1988, pp. 429-442.

5. E. Matijevic, "Colloid Science of Composite Systems," in "Science of Ceramic Chemical Processing," L. Hench and D. Ulrich, Eds., J. Wiley, 1986, pp. 463-481.

   E. Matijevic, "Colloid and Interface Aspects of Ceramic Powders," Advances in Ceramics, 21, 423-438 (1987).

6. R. Reistand II, Y. Oguri, H. Okamura, W. Moffatt, B. Novich, E. Barringer, and H. Bowen, "Synthesis of Submicrometer Ceramic Powders," ibid., pp. 482-496.

7. K. Kamiya and S. Naka, in "Fine Ceramics," S. Saito, Ed., Elsevier, 1988, p. 30.

8. R. Newnham, "Composite Electroceramics," Chemtech, 732 (1986); and

Chemtech, 38 (1987).

9. A.E. Sparks, "Microencapsulation," in "Encyclopedia of Chemical Technology, III," 15, 470-443; M. Grayson and D. Ekroth, Eds., J. Wiley, 1981.

10. R. Pettit, C. Aksley, S. Reed, and J. Brinker, "Antireflective Films from the Sol-Gel Process," in "Sol-Gel Technology for Thin Films, Fibers, Preforms, Electronics, and Specialty Shapes," L.C. Klein, Ed. Noyes Public. 1988, pp. 80-109.

11. D. Lynn Johnson and J.S. Kim, "Ultrarapid Sintering of Ceramics," Materials Science Monographs, 14, Elsevier, Amsterdam, 1982.
J.S. Kim and D. Lynn Johnson, "Plasma Sintering of Alumina,", Ceram. Bull., 62, 620 (1983).

12. For recent reviews see e.g. MRS Bulletin, 12,29 (1988), and R. F. Bunshah, "Deposition Technologies: An Overview," in "Deposition Technologies for Films and Coatings," R. Bunshah et al., Noyes Public., Park Ridge, N.J. (1982).

13. D. Couch and A. Brenner, "A Hydride Bath for the Electrodeposition of Aluminum," J. Electrochem. Soc., 99, 234-244 (1952).

14. K.-C. Chen and J.D. MacKenzie, "Crystallization of Oxide Films Derived from Metallo-Organic Precursors," Mat. Res. Soc. Symp. Proc., 72, 337-344 (1986).

15. R.M. Cannon, R. Fisher, and A.G. Evans, "Decohesion of Thin Films from Ceramic Substrates," Mat. Res. Soc. Sympos. Proc., 54, 799-804 (1986).

16. L. Formaro, "Magnetically Induced Variations in the Morphology of Fe_3O_4 Particles Precipitated from Solutions," Mat. Lett., 6, 295-296 (1988).

17. R. Ramesh, J.K. Chen, L. Rabenberg, and G. Thomas, "Microstructure and Properties of Rare Earth Magnets," LBL-24129, 1987.

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