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Localized-Field Permanent Magnet Array for the Thick-Film Read Only Store

Matick, Pleshko, Sie and Terman[1] have described the thick-film read only store (TFROS), a semipermanent storage device utilizing changeable cards containing permanent magnets as the storage medium. The purpose of these magnets is to provide a saturating field for the film bit locations in the TFROS. The intention of this Communication is to describe briefly the process used to obtain these magnets and the way they are utilized in the TFROS. The required magnetic properties are covered in Ref. 1 and will not be discussed in detail in this Communication.

The fabrication method was developed to provide an economically feasible and reproducible way of making permanent magnet arrays for the TFROS. The material chosen for the permanent magnets had to be amenable to batch fabrication, have a fairly high remanent flux so that the bulk of material necessary to get the proper field is not excessive, and a coercive force high enough to prevent a magnet from demagnetizing when subjected not only to its own demagnetizing field but also to the stray fields of adjacent magnets.

Fabrication

Photoetching arrays of magnets out of a continuous sheet would have been a convenient, standard technique. Since no such material was available, a particle magnet material was selected for simplicity of fabrication. Barium ferrite was chosen since it met the magnetic and structural requirements.

Plastiform,* a rubber-bonded material, possesses many of the characteristics displayed by isotropic barium ferrite sintered magnets without the disadvantages of being a hard ceramic. Since the rubber-base binder can be removed and replaced by a more suitable binder that permits machining to any desired pattern, Plastiform was chosen for fabricating the bias magnet.

The material is received from the manufacturer in the form of comparatively large isotropic chips in a rubber-base binder. It is first fired at 425°C for four hours to drive off the binder and then ball milled in alcohol.

Tenzer[2] indicates that the coercive force peaks at a given particle size. The peak is due to reduction of particle size to a point where the particles are single domains, since most magnetic materials having domain boundaries can be magnetized or demagnetized by the motion of these boundaries in response to relatively weak applied fields.

The particles were ball milled to about 4 μ and then suspended in a binder. Several binder systems were tried, all of which consisted of an organic solvent for a plastic bonder, a plasticizer, and a wetting agent if desired. In the magnet fabrication, the specific agents used were:

Organic solvent: 60% by weight toluene, 40% by weight ethanol
Wetting agent: tergitol
Binder: polyvinyl chloride
Plasticizer: dibutyl thalate
Particulate: 60 to 70% by weight barium ferrite.

Two techniques were used to produce the magnet arrays. In the first, a sheet of magnetic material was fabricated by knife coating on a nonporous plastic carrier material. The ferrite binder system is forced to flow onto the plastic carrier tape under the knife edge, where the gap between the knife and tape determines the thickness of the magnetic sheet. While still wet, the sheet is placed in a magnetic field of about 2400 gauss and allowed to air dry until cured. The magnetic field aligns the magnet particles and induces maximum anisotropy. After drying, the continuous magnetic sheet is milled into an array of discrete magnets of the proper size by cutting away the unwanted material.

In the second method, a modified casting technique, holes of the proper size and spacing are punched in a plastic sheet. The magnet thickness is determined by the thickness of the sheet. The sheet is backed on one side with a nonporous material, placed in a magnetic field, and the holes filled with the ferrite mix, which is then allowed

* Registered trademark, The Leyman Corporation.

to cure. After curing, the array is removed and cleaned of any excess. Although no significant difference between magnets made by the two techniques was observed, the second method proved to be more economically feasible.

Although application of the alignment field after air curing results in a weaker magnet, further investigation has indicated that modification of the particle size and dimensions of the magnet will allow realignment of magnetization after curing. This could be accomplished by a narrow-gap, high-field recording head which could demagnetize and/or realign the direction of magnetization of any given magnet.

Properties

It is desirable to achieve maximum packing density of the magnetic material in order to obtain a maximum field for a given volume. The magnetic moment per gram of the material in the various stages of processing was measured on a vibrating sample magnetometer. The results are given below:

Condition	*Magnetic moment*
As supplied by the manufacturer	57 emu/gm
After processing	62.5
After recombination in binder	53

The last figure is about the maximum that can be achieved with a sufficient structural bond and abrasion resistance.

Vibrating sample magnetometer measurements also indicate that the described process will increase the remanent induction by about 20% over the material as received from the manufacturer. Studies have indicated that barium ferrite magnets with $H_c > 2200$ Oe show no significant remanence changes over a long term.[3] Thus, for the magnets described herein, the effect of remanence flux decay should be negligible.

Properties of the particle magnets produced for the memory are given in Table 1, along with similar properties for Plastiform and sintered nonoriented barium oxide ferrite.

Typical demagnetization factors of an individual magnet approximated by ellipsoidal geometry are given in Ref. 4. For a 28-mil square magnet of 5.6-mil thickness, the demagnetizing factors are 0.125 in the equal dimensions, and 0.75 in the thin dimension. It can be concluded that demagnetization of the fabricated magnet will not have a pronounced effect.

Arrays of square magnets of varying thickness and lateral dimensions were made and tested for the ability to bias off a film spot and for lack of interaction with adjacent bits. A single isolated magnet was used for the former, and a 3 × 3 array pattern with the center magnet missing for the latter.

From 4-mil thick sheets, square magnets of 20, 25, 30 and 35 mils on a side were cut into test patterns and evaluated with a 35 × 45 mil 30 kÅ isotropic film bit and a 2.6 Oe, 5 ns risetime READ field. In every case the single magnet biased off the film, and for all cases except the 35-mil square magnet, the fringing field did not reduce the ONE signal in the center of the test pattern. For the 35-mil square magnets a fringing field of 13 Oe was measured on the adjacent ONE bit position.

To determine the allowable latitude in magnet thickness, arrays of 28-mil square magnets were fabricated in thicknesses of 2, 3, 4, 5, 6 and 9 mils. Effective field as a function of thickness is given in Table 2. The two- and three-mil magnets did not effectively bias off the isotropic film, but all others did; none of the arrays had fringing field effects.

Reproducibility of the magnet strength was tested by measuring about 30 magnets of each thickness.

The fabrication procedure described herein provides reproducible localized field magnetic arrays for use with the thick-film read only store. The present memory structure incorporates 3-mil thick magnets when 10 kÅ anisotropic films are used and 5-mil thick magnets for use with 30 KÅ isotropic films.

Table 1 Comparison of residual induction and coercive force for three magnetic materials

	Plastiform (*measured*)	*Sintered, nonoriented* $BaFe_{12}O_{19}$ (*published*)	*Barium ferrite particle magnet* (*measured*)
Residual induction (Gauss)	2.2×10^3	2.2×10^3	2.7×10^3
Coercive force H_c (Oersted)	1.48×10^3	1.70×10^3	$>2.2 \times 10^3$

Table 2 Measured field and field variation of 28-mil bias magnets of various thicknesses

Magnet thickness (mils)	*Measured bias field* (Oe)	*Measured field variation* (Oe)
2	10.5	—
3	19.5	18–21
5	32.0	31–36
6	33.5	27–37
9	55.0	—

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