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Temperature Stable, Low Ringing Noise Memory Cores

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온도에 안정하고 잡음이 적은 메모리코어에 대한 연구

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초 록

$Zn_{0.105}$ $Co_{0.025}$ $Li_{0.435-1/2x}$ Ni_x $Fe_{2.435-1/2x-y}$ Mn_y O_4 조성의 메모리코어 특성과 Nb_2O_5 및 V_2O_5의 소량 첨가가 square-loop 성질에 주는 영향을 연구하였다. 위의 조성에서 닉켈의 양 x는 0에서 0.15까지, 그리고 망간의 양 y는 0.05에서 0.25까지 변화시켰다. Nb_2O_5와 V_2O_5의 양은 각각 위의 화학식에 대하여 0.005에서 0.015까지 변화시켰다.

실험결과에 의하면 Mn^{+3}를 octahedral 자리에 첨가하였을 때에는 잡음이 감소되었고 메모리코어의 spuareness와 보자련의 온도계수가 증가하였다. 닉켈을 첨가하였을 때에는 메모리코어의 squareness와 잡음이 증가하였다.

Nb_2O_5를 소량 첨가하였울 때에는 square-loop 성질이 개선되었음에 비하여 V_2O_5를 소량 첨가하였을 대에는 square-loop 성질이 나빠졌다.

Introduction

The ferrite cores widely used as information storage elements in high-speed computers must exhibit rectangular magnetic hysteresis loops. "Square-loop cores" today are fabricated from materials chosen from several ferrite solid-solution systems which include copper-manganese ferrites, magnesium-manganess ferrites, lithium-manganese ferrites, and lithium-nickel ferrites. If the cores are to be used as memory devices which are subjected to changes in temperature, the temperature coefficients of the coercive force force and "knee-current" are important properties. In order to make a memory device operate satisfactorilly over a wide temperature range, changes in "knee-current" must be compensated by changing the amplitude of current pulses used to switch the cores. Therefore, cores with small temperature coefficients lead to improved performance and simpler memory design. The temperature coefficient of the "knee current", however, is increased by substitution of zinc and by most of the other elements which are introduced for various purposes[1)2)].

Small temperature coefficient have been found in nickel-manganess-ferrous ferrite system[3)4)] and cobalt substituted lithium ferrite system[5)]. Memory cores made from the cobalt substituted lithium ferrite exhibit almost temperature independent "knee-current" in the temperature range from −50°C to 100°C, but also exhibit

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*Present Address: The Korea Advanced Institute of Science Seoul, Korea larger magnetostrictive ringing voltages as well as larger disturbed noise. This ringing voltage is a source of noise in a high-speed core memory and is undesirable in practical application of large memory systems[6].

In this work it is shown how the disturbed noise of the cobalt substituted lithium ferrite memory cores can be decreased by the substitution of very small quantities of niobium pentoxide and the magnetostrictive ringing voltages can be decreased by the substitution of manganese.

Experimental Procedure

A number of compositions in the system $Zn_{0.105}$ $Co_{0.025}$ $Li_{0\ 435-1/2x}$ Ni_x $Fe_{2.435-\frac{1}{2}x-y}$ Mn_y Mn_y O_4 were studied. Zinc and cobalt were included in the formulation to obtain coercive force low enough for 18 mil (0.46mm) cores and to reduce temperature coefficient of I_k (knee current). Compositions with various content of vandium pentoxide (Fisher certified reagent) or niobium pentoxide (Alfa spec. grade) were also made. Each powder was prepared by mixing lithium carbonate (J.T. Baker), cobalt carbonate (J.T. Baker), manganese carbonate (J.T. Baker), nickel oxide (J.T. Baker), and iron oxide (Columbian Carbon Co.). This mixture was treated by calcining, mixing again with ball mill, reacting at high temperature and ball mill grinding to produce a fine powder. Cores were prepared from this powder by tape method: the powder was mixed with a large quantity of a suitable binder and solvent by ball milling, coated on base film, dried and peeled off from the base film, and calendered into a strip of the desired thickness from which cores were cut out with the aid of a punch press. The cores sintered in a tube furnace in air atmosphere. The sintering temperature and the soak time were adjusted for each composition to obtain cores with optimum magnetic properties. For several batches, X-ray powder diffraction pattern were obtained and it showed to be a single spinel phase. The cores after sintering were, in size, approximately 0.46mm outside diameter, 0.28mm inside diameter and 0.11mm thick.

Measurements of memory-core characteristics were performed with a Computer Test Corporation 1700 core tester using a standard dV_1 program (dV_1 is the disturbed voltage output signal). (The definitions of symbols are given below Table Ⅰ). The ringing noises per one hundred cores excited by nonswitching currents with amplitude of 800ma, risetime (t_R), and fall time

Table 1 Memory-Core Characteristics of $Li_{0.435-x/2}$ Ni_x $Zn_{0.105}$ $Co_{0.025}$ $Fe_{2\ 435-x/2-y}$ Mn^{3+}_y O_4

#	x (Ni)	y (Mn^{3+})	dV_1 (mv)	dV_z (mv)	t_s (nsec)	I_k (ma)	C_k(ma/°C) −25°C to 25°C	C_k(ma/°C) 25°C to 25°C	V_R+ (mv)	gain (mv/ma)
1	0.10	0.05	28	12	175	460	0.42	−0.20	5.0	.24
2	0.10	0.10	46	8.3	195	470	0.0	−0.55	2.5	.21
3	0.10	0.15	45	7.1	215	476	0.0	−0.64	1.5	.21
4	0.10	0.2	44	6.0	222	470	0.0	−0.86	0.5	.21
5	0.10	0.25	37	8.7	202	474	0.64	−0.52	0.0	.22
6	0	0.15	36	9.0	195	474	0.50	−0.34	0.5	.22
7	0.05	0.15	43	7.6	205	475	0.40	−0.36	1.0	.21
8	0.10	0.15	54	7.1	215	475	0	−0.64	1.5	.21
9	0.15	0.15	44	6.8	213	480	0	−0.68	2.0	.21
10*	0	0.12	47	4.2	233	495	0.40	−0.52	0.8	.21
11**	0	0.12	27	7.0	215	455	—	—	—	—

I_f=720mA, I_p=450mA, $t_R=t_f$=50nsec, t_d=300nsec

+ : ringing voltage per one hundred cores

* : with addition of 0.010 formula unit of Nb_2O_5

** : with addition of 0.010 formula unit of V_2O_5

I_f : full read or write current

I_p : partial read or write current

I_k : knee current

dV_1 : disturbed one lotvage ouptut

dV_z : disturbed zero voltage output

t_s : switching time of dV_1

C_k : temperature coefficient of knee current

(t_f) equal to 50 nsec, and pulse width (t_d) adjusted to obtain maximum ringing noise were measured.

The microstructures were examined with a scanning electron microscope.

Result

Memory-core-characteristics of compositions given by $Li_{0.435-x/2}Ni_xZn_{0.105}Co_{0.025}Fe_{2.535-x/2-y}Mn_yO_4$ are listed in Table 1. Samples here were sintered at 1038°C with varying soak time to be tested under the same drive-current conditions. The disturbed noise (dV_z) decreases with increasing manganese content. The composition with Mn equal to 0.20 gives the greatest value of the signal to noise ratio dV_1/dV_z, which is a measure of the squareness of a core under the test condition. A further increase of manganese content causes a decrease of squareness and the sample with manganese equal to 0.25 shows marginal squareness for memory-core operation. The temperature coefficient of knee current C_k, however, increases with increasing manganese content. The disturbed noise dV_z decreases with increasing nickel content, and composition with Ni equal to 0.15 gives the best squareness. The ringing noise (V_R), on the other hand, decreases sharply with increasing manganese content and increases with increasing nickel content. It can be seen here that material without nickel (composition #6) gives lower ringing noise but also give low value of signal to noise ratio dV_1/dV_z. However, addition of small quantity of

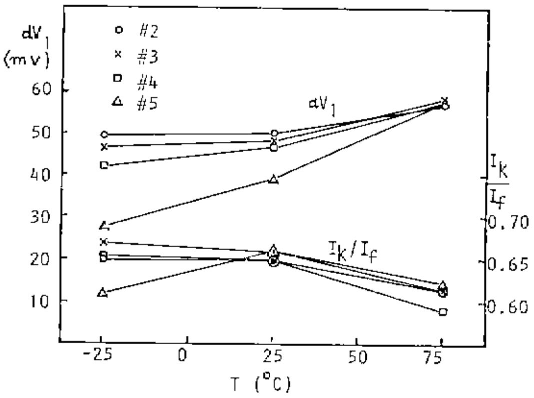


Figure 1 Memory core characteristics as a function of temperature for various manganes content. I_f=800mA, $t_R=t_f$=50nsec, t_d=300nsec.

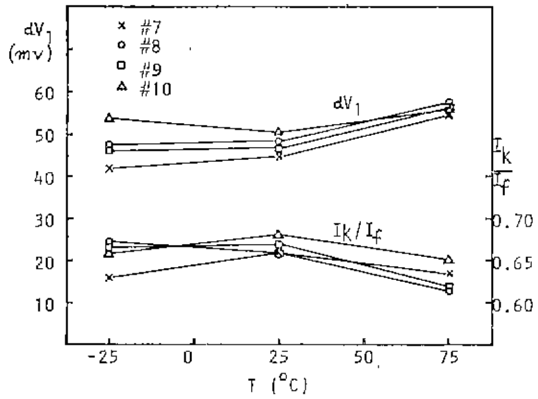
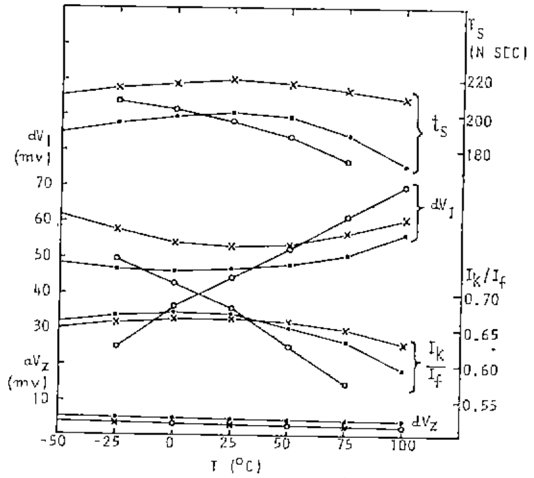


Figure 2 Memory core characteristics as a function of temperature for various nickel content. I_f=800mA, $t_R=t_f$=50nsec, t_d=300nsec.



○—○ $Li_{0.40}Zn_{0.05}Mn^{2+}_{0.07}Ni_{0.08}Mn^{3+}_{0.30}Fe_{2.10}O_4$
●—● $Li_{0.385}Zn_{0.105}Ni_{0.10}Co_{0.025}Mn^{3+}_{0.15}Fe_{2.235}O_4$
×—× $Li_{0.43}Zn_{0.10}Co_{0.027}Mn^{2+}_{0.033}Nb_{0.01}Mn^{3+}_{0.12}Fe_{2.28}O_4$

Figure 3 Memory core characteristics as a function of temperature for
$Li_{0.40}Zn_{0.05}Mn^{2+}_{0.07}Ni_{0.08}Mn^{3+}_{0.30}Fe_{2.10}O_4$
$Li_{0.385}Zn_{0.105}Ni_{0.10}Co_{0.025}Mn^{3+}_{0.15}Fe_{2.235}O_4$
$Li_{0.43}Zn_{0.10}Co_{0.027}Mn^{2+}_{0.033}Nb_{0.01}Mn^{3+}_{0.12}Fe_{2.28}O_4$
I_f=750mA, I_p=375mA, $t_R=t_f$=50nsec, t_d=300nsec.

niobium pentoxide to this type of (composition # 10) gives extremely high value of dV_1/dV_z.

The disturbed voltage output signal dV_1 and the disturb ratio I_k/I_f both as a function of temperature for various manganese and nickel content are shown in Figure 1 and Figure 2 respectively, It can be seen that the temperature dependence of dV_1 is rather small with the exception of sample with manganese equal to 0.25.

The temperature dependence of dV_1, dV_z, the disturb ratio I_k/I_f, and the switching time (t_s) are shown graphically in Figure 3 for lithium-manganese ferrite which is widely used today, and cobalt substituted lithium-manganese with and without addition of Nb_2O_5. It is seen here that I_k for the cobalt and niobium containing material is almost temperature independent (TIN* core). The result is a very small temperature dependence of the dV_1 and switching time t_s.

A typical microstructure of cobalt substituted lithium manganese ferrite is shown in Figure 4a, and those of lithium manganese ferrite with 0.01 formula unit of V_5O_5, and Nb_2O_5 are shown in Figure 4b and 4c respectively.

Discussion

The material characteristis which cause the occurance of square hysteresis loops in polycrystalline magnetic ferrites have been described by wijn et al. as follows (7). The preferred direction of magnetization in individual crystallites of cubic symmetry should be in the crystal [111] direction, a condition described by a negative value of the crystal anisotropy constant K_1. The crystal anisotropy must dominate the shape and stress anisotropies. This condition will be met if the magnetostriction coefficient in the preferred direction of magnetization λ_{111} is very small. A low porosity in the material is also a necessary candition for the occurance of square loops. The square-loop properties observed for compositions in the system $NiFe_2O_4$–Fe_3O_4[7], $NiFe_2O_4$–Fe_3O_4–$MnFe_2O_4$[3], $NiFe_2O_4$–Mn_3O_4 and $Li_{0.5}Fe_{2.5}O_4$–Mn_3O_4[8], and $Li_{0.41-x/2}Co_xZn_{0.12}Ni_{0.06}Fe_{2.41-x/2}O_4$[5] have been explained on the basis of these material characterstics. The value of K_1 for lithium ferrite is negative, $-9\times10^4 erg/cm^3$[9], and λ_{111} is small, values of -3.8×10^{-6}[10] and $+2.7\times10^{-6}$[11] have been reported. The values of λ_{111} for nickel ferrite has been measured as -21.6×10^{-6} at 20°C[12]. An accurately measured value of λ_{111} for cobalt ferrite has not been reported but it appears to be large and positive, approximately $+130\times10^{-6}$[13]. It was reported the presence of Mn^{3+} in octahedral site in the lithium ferrite contributes to positive λ_{111}[9]. The greatest squareness was observed when the value of Co^{2+} is 0.010 in iithium nickel zinc ferrite[5], and when the value of Mn^{3+} is 0.30 in lithium nickel ferrite[8].

The data in Table 1 show that in the compositions containing cobalt a smaller quantity of substituted manganese is required to produce maximum squareness, y equal to 0.20. This was, at first, a surprising because the values of λ_{111} for cobalt is positive and was thought to be be sufficient to make $\lambda_{111}\approx0$ when the value of cobalt equal to 0.010, and thus any addition of Mn^{3+} would make $\lambda_{111}>0$ reducing the squareness. It has been found, however, that the effects of cobalt is diluted when zinc is present[5,14]. Thus we may speculate that effects of cobalt is also diluted when manganese is present. This diluting effect is also manifested in the temperature dependence of dV_1 as can be seen in Figure 1, i.e, the temperature dependeness of dV_1 with increasing manganese content are similar to those of dV_1 with decreasing cobalt content with no manganese[5].

The decrease of the ringing noise with increasing manganese content and the increase of the ringing noise with icreasing nickel content can be explained in terms of effective magnetostriction coefficient λ_{eff}, i.e the substitutions of manganese decrease λ_{eff} and the substitution of nickel increase λ_{eff}.[6,15]

The extremely high value of the signal to noise ratio observed in Nb_2O_5 substituted material (#10) appears to be related with higher density and uniform grain size whereas very poor properties observed in V_2O_5 substituted material is related with lower density and nonuniformity in grain size, as shown in Figure 4A, B&C.

It should be pointed be pointed out that with substitution of V_2O_5 a reasonably high value of signal to noise ratio can be obtained for large size and low drive cores as reported by others[16,17,18,19].

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*Ampex trade name for temperature independent memory core.

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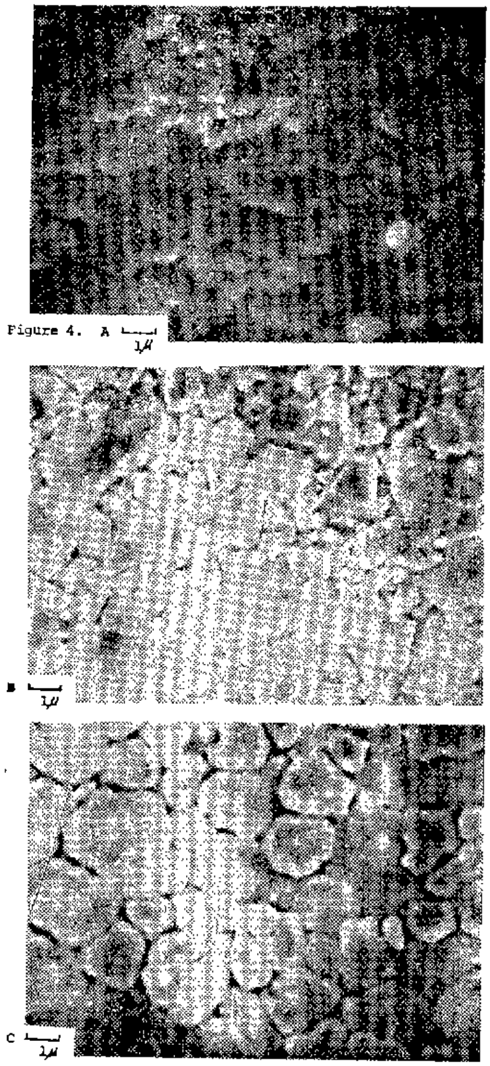

Figure 4 A typical microstructure of lithium manganese ferrite with and without "flux"
a) no flux
b) with 0.01 formula unit of V_2O_5
c) with 0.01 formula unit of Nb_2O_5

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