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Magnetic Properties of FeCuNbSiB Nanocrystalline Alloy Powder Cores Using Ball-milled Powder

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1. Introduction

Ribbon type nanocrystalline alloy cores have shown excellent soft magnetic properties in the high frequency range because of small crystalline anisotropy and nearly zero magnetostriction[1]. In present, however ribbon alloys gives some limit in applications such as a large inductor and reactors of PFC circuit, which are required good DC bias property and low loss in the high frequency. Powder alloys with ultra fine grain structure can be an important way to overcome this kind of disadvantage, and to improve the high frequency soft magnetic properties in conventional metallic powder cores[2]. In this study, we have investigated high-frequency magnetic properties as a function of powder size, insulator quantity and insulation materials for cold pressed nanocrystalline powder core using ball-milled powder.

2. Experimental procedure

$Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ amorphous ribbons were nanocrystallized upon annealing at 550 ℃ for 1 h in vacuum, and then milled with a planetary ball mill for 5 ~ 30 min. Afterwards milled powders were sieved in fraction ranging from 20 to 850 ㎛. The magnetic properties of milled powders were measured using a vibrating sample magnetometer (VSM) with an applied magnetic field of 5 kOe. The powder cores were produced from each detached powders by cold pressing at a pressure of 15 ton/㎠ with from 1 to 8 wt% glass binder. The powder cores have inside and outside diameters of 7.4 and 12.8 ㎜, respectively, and a height of about 4 ㎜. Annealing of these powder cores was carried out at 400 ℃ for 1 h in N_2 gas atmosphere to reduce the press-induced internal stress and to increase the isolation effect by softening the glass binders. The magnetic properties of the annealed powder core were measured by using the LCR meter for the effective permeability μe, the quality factor Q, and DC bias property, and the B-H analyzer for core loss.

3. Results and discussion

Figure 1 shows the frequency dependence of effective permeability and quality factor for nanocrystalline alloy powder cores with different particle size and 5 wt% glass binder annealed in N_2 gas for 1 h at 400℃. For the cores composed of larger particles, higher permeability and quality factor in the entire frequency range were obtained. Moreover the permeability of the 300 ~ 850 ㎛ powder cores is nearly not changed up to 800 kHz. And the quality factor shows a maximum at the frequency of 50 kHz, and then decreases with increasing frequency. However, the permeability of the small particle(20 ~ 45 ㎛) cores is low and decreases at the frequency of 100 kHz, and the quality factor exhibits peak at the frequency of 10 kHz. These frequencies are much lower than the case of cores with larger particle.

The powder core made from large particles has relatively good insulation state as compared with the powder core made from small particles. For the higher insulation state of powder core, the eddy current loss is reduced and the permeability persists up to higher frequency.

Figure 2 shows the frequency dependence of effective permeability and quality factor for nanocrystalline alloy powder cores made from 300 ~ 850 ㎛ particles with different contents of glass binder. The core having 2 wt% insulator shows a stable permeability of 110 up to 200 kHz and maximum level 26 of quality factor at the frequency of 20 kHz, whereas the core with 8 wt% insulator shows a stable permeability of 85 up to 1 MHz and maximum level 34 of quality factor at 80 kHz. Although the high insulator content reduces the level of the permeability, an improve frequency dependence of effective permeability and quality factor can be obtained.

4. Conclusions

The effect of particle size on soft magnetic properties of FeCuNbSiB nanocrystalline alloy powders was measured, and also it was investigated how the magnetic properties at high frequency of the cold pressed nanocrystalline powder cores changed upon various magnetic powder sizes (20 ~ 850 ㎛) and contents of insulation glass binders (1 ~ 8 wt%). For the cores made from large particles of 300 ~ 850 ㎛, the enhanced effective permeability and quality factor at high frequencies. Furthermore the powder cores with large magnetic particles exhibited more homogeneously distributed insulating glass binder leading to better interparticle insulation. Therefore the better high-frequency magnetic properties of large particle cores were considered to be due to the good soft magnetic properties of the powder and the improved insulation state between magnetic particles. In addition, the cores with high contents of glass binder showed more improved frequency dependence of effective permeability and quality factor.

5. References

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[2] M.Muller, A.Novy, M.Brunner and R.Hilzinger, J. Magn. Magn. Mat. 196-197 (1999) 357

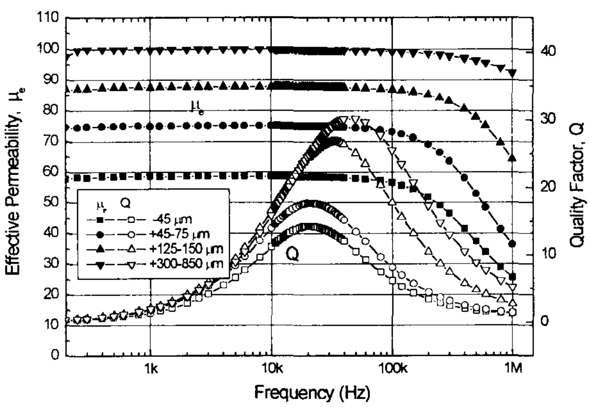

Fig. 1 Frequency dependence of effective permeability and quality factor for nanocrystalline alloy powder cores with different particle size.

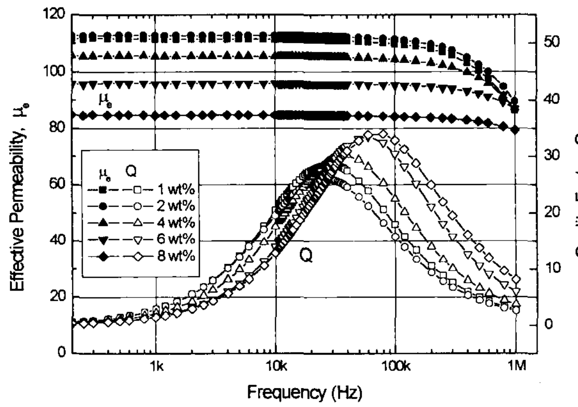

Fig. 2 Frequency dependence of effective permeability and quality factor for nanocrystalline alloy powder cores with different contents of glass binder.