High density soft magnetic composite core of nanocrystalline FeSiBPCu alloys

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Recently, growing concern about the global environmental and energy issues, the next generation vehicles (HEV, EV and FCV) and renewable energy (solar photovoltaic and wind generation) have been developed and become popular throughout the world. Therefore, down-sizing, high efficiency, and high power are demanded for those motor and power supply parts. As one of the candidate to meet the demand is a soft magnetic composite core manufactured by press forming process using soft magnetic alloy powder coated with insulating resin. There are several advantages of these cores, such as 3-dimensional magnetic isotropy, high flexibility of core design, high efficiency by reduction of eddy current loss and, low cost by a near net shape manufacture process. So, we have developed a composite core with high packing density and low loss using new high B_s nanocrystalline alloy powder produced by a high packing density forming method. In this paper, we have investigated magnetic properties of toroidal soft magnetic nanocrystalline composite cores and clarified the possibility of using high packing density nanocrystalline composite cores for high performance applications.

The base powder consists of FeSiBPCu nanocrystalline alloy powder with nearly 50 μm in median particle diameter and silicone resin of 2 wt% for electrical insulator and binder between the particles. The toroidal cores were formed by our method. Core loss at 400 Hz was evaluated by AC-BH curve tracer. Nanocrystalline structures were examined by X-ray Diffraction (XRD) with Cu-K_α radiation and analyzed by whole-powder-pattern decomposition method (WPPD).

Fig.1 shows the photo image of a nanocrystalline toroidal composite core of 56 mm in outer diameter 36 mm in inner diameter and 7 mm in thickness. In general, nanocrystalline alloy shows high hardness and it is difficult to high packing density forming. On the other hand, this composite core has high packing density of 83.4 %, as compared with normal press core of about 70 % in packing density.

Fig.2 shows the core loss at 400Hz of the nanocrystalline composite core as a function of maximum induction (B_m). The data of an Fe-Si composite core and non-oriented magnetic steel are also shown for comparison. The core loss at 400 Hz-1.0 T of the nanocrystalline composite core is 9.8 W/kg, corresponding to one-fourth of that of Fe-Si composite core, and superior to non-oriented magnetic steel[2)].

Fig.3 shows the XRD patterns of the nanocrystalline composite core. The core consists of α-Fe grains of about 30 nm in diameter estimated by WPPD. As a result, the magnetocrystalline anisotropy [3)] and magnetostriction[4)] of this alloy are reduced, and the nanocrystalline core exhibits excellent magnetic properties.

In conclusion, the soft magnetic composite core with high packing density and nanocrystalline structure shows low core loss and large core B_s and is suitable for high performance next generation magnetic devices.

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Reference
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Fig. 1 Photo image of nanocrystalline composite core.

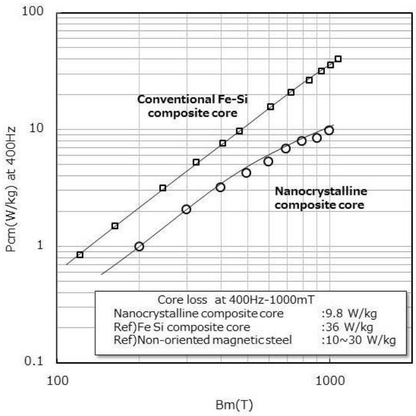

Fig. 2 Core loss at 400Hz of nanocrystalline composite core.

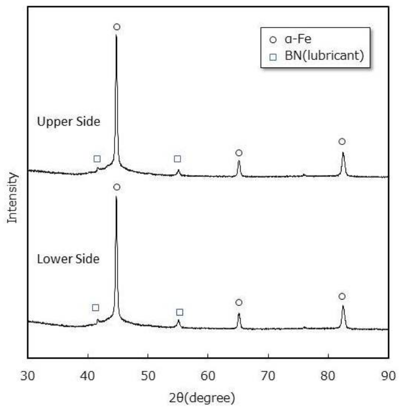

Fig. 3 XRD patterns of nanocrystalline composite core.