Thinned Vitrovac® tape for microfluxgate core

Pavel Ripka[a], Nadine Wolf[b], Christian Riedel[b], Christian Polak[b], Jiri Maier[a], Mattia Butta Gonzales[a], Vojtech Petrucha[a], and Poki Chen[c]

[a] *Czech Technical University in Prague, Faculty of Electrical Engineering, Czech Republic*
[b] *Vacuumschmelze Hanau, Germany*
[c] *National Taiwan University of Science and Technology, Taipei*

Integrated fluxgate sensors require core from near-zero magnetostriction, low-coercivity material with low thickness. We show that 25 μm thick Vitrovac® 6025F tape can be brushed to the thickness of 10 μm. After relaxation annealing, the hysteresis loop is again flat, with 2 A/m coercivity. This makes Vitrovac® cores superior to sputtered and electrodeposited alloys for microfluxgate core. The working frequency for the thinned core can be increased up to 1 MHz.

Keywords: Thinning of ferromagnetic tape; fluxgate core

1. Introduction

Traditional fluxgate sensors are low-noise and precise devices, but large and expensive. The only microfluxgate on the market is TI DRV425, which has dual-rod magnetic core [1]. We have developed microfluxgate with 8 mm long core made of amorphous Vitrovac® 6025F core with racetrack shape, which gives better core saturation. The flat racetrack was cut by laser from the tape [2]. The problem with Vitrovac® is its large thickness of 25 μm. While such thickness is ideal for 30 mm long sensor, it causes excessive demagnetization and decrease of sensitivity for 8 mm long core. Another disadvantage of thick material is that its working frequency is limited by eddy currents. Penetration depth of Vitrovac® 6025 at 1 MHz is only 2.2 μm. At high frequencies the excitation field cannot saturate the central part of thick material, which leads to perming effect and excessive noise. At low excitation frequency (such as 100 kHz) the sensor sensitivity is not sufficient, which limits the field resolution. Despite these problems, we achieved a noise level of 2 nT/√Hz at 1 Hz, which is better than the noise of permalloy-based sensor. In this paper we describe the process of Vitrovac® thinning to 10 μm and application of such material for microfluxgate core.

2. Results and discussion

In order to reduce the thickness of amorphous Vitrovac® 6025F, we used a laboratory-brushing machine consisting of the PCB brushing machine Otto Dilg, OTTOMAT 3/4 combined with a controlled un- and rewinder system, which was custom-built for those thin foils. The thickness reduction is realized with a wet brushing process whereby the foil runs through two brushing stations consisting of an abrasive brush and a backpressure roller. The first stations brushes the bottom side and the second station the upper side. In order to achieve a uniform removal on each side, the two brushing stations have to be set up identically. FALCONBRITE Flap PU-impregnated brushes with a medium hardness as well as grit size and SiC grain type were used. The reduction of the thickness down to 10 μm was realized by applying the brushing process to the foil for three times.

The flat loop, very small coercivity and near-zero magnetostriction of Vitrovac® 6025F makes this material ideal for fluxgate cores [3]. Brushing affects the material properties by introduction of mechanical stress into the material, which cause increase of coercivity and decrease of permeability as shown in Fig. 1. The hysteresis loop was measured on 30 mm flat racetrack core, which is an enlarged version of microfluxgate core. The original magnetic properties can be partly recovered by relaxation annealing in zero field: Earth's field was compensated by Helmholtz coil pair with axis in the direction of local geomagnetic field. We have used non-magnetic contact oven, air atmosphere and 250 °C annealing temperature (over the Curie temperature and well below the crystallization temperature). The heating rate was 30 °C/min and cooling rate was 2 °C/min.

We have also tried annealing in 0.37 T magnetic field in the sheet plane, perpendicular to the core length. This annealing brought similar results as relaxation annealing.

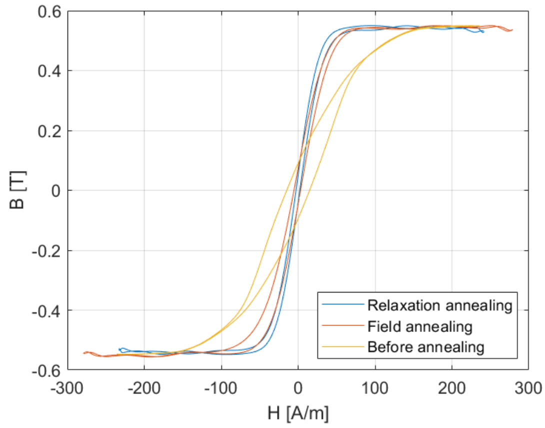

Figure 1: Hysteresis loops of 10 μm Vitrovac® 6025F measured at 1 Hz on racetrack sample: after brushing, after relaxation annealing, and after field annealing

We will present the results of FEM simulations including the effects of eddy currents and compare them with measured results both on enlarged model and on microchip. We will also show how the domain pattern is affected by annealing

References

[1] M. F. Snoeij, V. Schaffer, S. Udayashankar et al., IEEE J. of Solid-State Circuits **51** (2016), 1684-1694
[2] J. Maier, P. Ripka, and P. Chen, Sens. Act. A 379 (2014), 115886.
[3] P. Ripka, Magnetic Sensors and Magnetometers, 2nd ed., Artech House, Boston, London

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