Induction Pulse of Compound Magnetic Wires by the Large Barkhausen Jump

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Abstract-The compound magnetic sensors using twisted vicalloy and permalloy wire were composed and their basic characteristics were investigated. This compound magnetic wire could generate a pulse voltage with high S/N even when flux change was extremely slow. This type of magnetic sensor seems to be applicable for magnetic recording head when they are prepared as thin film device. Before applying to recording head, the basic magnetic characteristics of these wires and their pulse induction phenomena caused by large Barkhausen jump were precisely investigated and their induction principle was compared with that on Wiegand wire.

Key word: compound magnetic wire, permalloy wire, vicalloy wire, magnetic sensor, large Barkhausen jump, hard layer, soft layer, asymmetrical magnetic excitation,

1. INTRODUCTION

In general, an amplitude of detecting voltage generated by electromagnetic induction depends on the changing rate of the linkage flux of detecting coil. Therefore, as a method of increasing the detecting voltage, one may attempt to make the changing rate of the linkage flux of detecting coil high speed. However, the conventional detecting method has a fatal property that the output voltage is hardly detected when flux change becomes slow. Therefore, it is useful to create a method that induce the voltage same as that of high speed, though flux change is very slow. It is considered applying induction phenomenon of a large Barkhausen jump in compound magnetic layer to magnetic core of magnetic recording head. In the previous studies, authors prepared a compound magnetic wire by twisting the vicalloy wire and permalloy one, and composed a compound magnetic sensor[1], and announced the superior induction phenomenon of pulse voltage. However, these phenomenon are on bulk wire and compound magnetic structure and operating speed should be considered in magnetic thin film. In this paper, we explain the composition of compound magnetic wires and induction characteristics of output pulse voltage based on large Barkhausen jump and its operation principle. This operation principle is different from U. S. PAT. invented by J. R. Wiegand, as the following.

II. EXPERIMENTAL METHOD

A compound magnetic wire or layer are composed of

more than two kinds of magnetic material having different coercivity H_c , and take a cylindrical form or plane. The compound magnetic wire described in this paper, was made by twisting the magnetic wire drawn by the dice. In general, when torsion was applied to the wire, the outer part was twisted much, while the inner core little. Therefore, the magnetic property of outer shell was different from that of inner core, and the compound magnetic wire was formed[2].

Fig.1 Dependence of coercivity of Fe, Fe-Ni, Fe-Co-V wire on torsion stress.

Fig.2 Schematic illustration of compound magnetic sensor using Vicalloy wire

Fig.1 shows dependence of coercivity H_c on the twist number for vicalloy wire (40wt%Fe-50Co-10V), permalloy

Fig.3 Measurement circuit

wire (50wt%Fe-Ni) and iron wire (Fe), respectively, where wire diameter was 0.25mm, and 1 turn per 3cm was define as N of 1. As shown the figure, H_c decreased by applying the small torsion for vicalloy wire, while H_c increased when little stress was applied to other wire. To clear their inner magnetic characteristics, their diameter was decreased by chemical etching. The specimen wire with torsion stress possessed a compound magnetic characteristics as shown in Fig. 2 and H_c of inner part of the vicalloy wire is approximately 60 Oe, while H_c of the outer part is approximately 20 Oe. Therefore, vicalloy wire has hard layer with fixed magnetization in inner core of the wire, and soft layer with reversible magnetization in outer shell of the wire. In this case, it was confirmed that a soft layer was formed in the surface region from 0.25mm to 0.22mm in diameter at N of 2. Fig. 3 shows the schematic circuit to measure the pulse voltage V_s . The magnetic wire used in the experiment is a vicalloy and permalloy wires of 0.25 and 0.1 mm in diameter, respectively. Each specimen wires were drawn by dice that came to a diameter of 0.25 mm. The endpoint of the specimen wire with a length of 50 mm was fixed to plastic sticks. It was twisted at one end and the specimen wire is inserted into a bobbin of 5 mm in diameter wound with a 300 turn search coil. An asymmetric field was applied to compound magnetic wire, the magnetic field of plus side is a called reset magnetic field H_r , and the minus side is called a set magnetic field H_s . The Hysteresis loops of the wire were observed by integration of V_s . The measurement frequency was 50 Hz.

III EXPERIMENTAL RESULT AND DISCUSSION

Fig. 4 shows a relationship between the pulse voltage and the waveform of the exciting field in the asymmetric drive of a vicalloy wire. Fig. 5 shows the dependencies of pulse voltage V_s on the set field H_s for asymmetric and symmetric drives of a vicalloy wire. Although V_s was generated at H_s of 12Oe, and it become larger with increase of H_s for asymmetric drive, V_s took the maximum value at H_s of 20 Oe and decreased drastically at H_s higher than 20 Oe for symmetric drive. Fig. 6 shows B-H curves of a vicalloy wire at $N=2$, where (a), (b), (c) and (d)

Fig.4 Asymmetric drive wave form at H_s of 20 Oe with output voltage V_s in the same time scale.

Fig.5 Relationship between output voltage V_s and set field H_s ,
Asymmetric drive: constant reset field H_r of 80 Oe.

(a) 10 [Oe]

(b) 15 [Oe]

(c) 20 [Oe]

(d) 30 [Oe]

Fig.6 B-H curve and induced pulse.
Reset magnetic field: (a) 10 Oe, (b) 15 Oe, (c) 20 Oe, (d) 30 Oe

are corresponding to the external field of 10, 15, 20 and 30 Oe, respectively. The largest output pulse and the large Barkhausen jump of the B_r direction were obtained at the reset field H_r of 20 Oe. Fig. 7 shows the hysteresis loop of a permalloy wire of 0.1 mm in diameter [3].

Fig.7 Hysteresis loop of permalloy wire

When torsion stress was applied, the squareness ratio of hysteresis loop increased, but H_c were approximately 3 and 6 Oe at the twist number N of 0 and 1/4 respectively. Fig. 8 shows the dependencies of the pulse voltage V_s on the set field H_s for a permalloy wire. When torsion stress was applied to the wire, the induced pulse voltage becomes large. The direction of magnetization in the outer layers of these two kinds of wires is opposite to each other but large Barkhausen jumps occur in both wires.

Fig.8 Relationship between set field H_s and output voltage V_s (wire diameter : 0.1 mm)

Fig. 9(a) shows the change of the asymmetric field with set field H_s . The whole magnetic wire is magnetized rightward by the reset field H_r higher than 60 Oe[4]. Then, when the set field H_s was applied to the wire in the left direction, only the magnetization in the soft layer was reversed. This state is also stable due to uniaxial anisotropy of specimen wire. When the reset field H_r was applied again in the right direction, drastic magnetic reversal of the soft layer occurred by the bias field originated from the magnetization of the inner core. As shown in B-H loop in Fig. 9 (b) a large Barkhausen jump a-b appears at the critical field H_p in the course of increasing the reset field H_r . Consequently, the large induced pulse voltage V_s is generated, as shown in Fig. 9 (c). Fig. 9 (d) shows the

Fig.9 Waveform of B-H loop and $\pm V_s$
(a)Exciting waveform, (b)B-H loop.
(c)Output voltage, (d) Magnetization model

magnetization model of vic alloy wire. Since the vic alloy wire with torsion stress has uniaxial anisotropy, two magnetization states are stability. The wire developed by J. R. Wiegand[5] is different in magnetic composition from compound magnetic wire mentioned above, accordingly operation principle is also different. In the Wiegand wire called "Bistable magnetic device" [6], hard layer of outer shell and soft layer of inner core of the wire were magnetized to b point being the same direction when an exciting magnetic field H applied as o-a-b, as shown in Fig.10. When H was decreased as b-c-o, the soft layer of inner core reversed rapidly to stable state opposite direction to hard layer of outer shell at the c point. Then, pulse voltage was induced. "Switchable magnetic device"[7-8] developed afterwards by Wiegand, are also the wire having hard layer in the outer shell and soft layer in the inner core. However, the phenomenon that soft layer reverses rapidly to the same direction as hard layer and pulse voltage was induced when the reset field was applied the wire is similar to the compound magnetic wire mentioned above.

IV. CONCLUSIONS

The results obtained in this study are as follows;

1. In the compound magnetic wire composed of soft layer with low coercivity and hard layer with high coercivity, reversible soft layer can induce the magnetization reverse based on large Barkhausen jump.
2. In the compound magnetic wire made by twisting vicalloy wire and permalloy wire, induction phenomenon of pulse voltage observed when the wire was driven by asymmetrical excitation.
3. Difference of magnetic composition and operation principle from Wiegand wire was explained.

We think that this type of sensing element will be applicable for magnetic reading head when it will be prepared as thin film device.

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Fig.10 Operation principle of Wiegand Wire