

Low-frequency magneto-impedance effect in electrodeposited multilayers $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_N$ on the Cu-PCB

Frengdi Maulana¹, Nuryani¹, B Purnama^{1,a)}

Physics Department, Post Graduate program Universitas Sebelas Maret,
Jl. Ir. Sutami 36A Kentingan Surakarta INDONESIA 57126

E-mail: frengdimaulana270@gmail.com , ^{1,a)}bpurnama@mipa.uns.ac.id

Abstract. Abstract. It has been observed magneto-impedance effects of electrodeposited $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ multilayers on substrate Cu PCB. The ratio MI (Magneto-impedance) evaluate the dependence for both of PCB Cu substrates-geometry and the frequency modification. The characterization results showed the geometry dependence of the ratio of the MI tends to increase with the increase of angle. In addition, the MI ratio magnitude increases in increasing the frequency measurements. Finally, the highest MI ratio of 8.23% occurs for the sample C.

1. Introduction

Magneto-impedance effect (MI) is a changed of impedance in a magnetic material under induced magnetic field. The phenomenon correlate to the changes of the skin depth in wire material magnetic as well as in both thin films and multilayers [1-4]. Recently, the MI effect attractively realizes on a flexible substrate that modifies of the crystalline structure with in result the change of magnetic characteristic [5]. The application of the MI sensors such as industry, navigation, vehicle detection, military, geomagnetic, and bio-medical measurements such as heart, neutron systems in the human body [6-8].

In this study, the geometry dependence of the MI effects in multilayered $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ are evaluated in the low-frequency region ($f < 100$ kHz) [7]. The samples preparation are carried out by electrodeposition method for both the magnetic layer $\text{Ni}_{80}\text{Fe}_{20}$ and the spacer layer Cu. A Substrate of a patterned Cu PCB is used for the whole experiments. The MI effect evaluates by measurement of the total impedance Z ($Z^2 = R^2 + X^2$) under the modified magnetic field. Then, the MI ratio calculates by difference total impedance when the zero and under magnetic field divided by impedance when under magnetic field.

2. Numerical Methods

The samples films used in this experimental are prepared electrodeposition method with Pt electrode. The sample characterization in the multilayered structure of $[\text{Ni}_{80}\text{Fe}_{20}(800 \text{ nm})/\text{Cu}(200 \text{ nm})]_3$ carried out by XRF and XRD characterization (not presented here). Procedure for the samples deposition is done similar with previous method [9]. Modification of patterned Cu PCB (substrate A, B, and C) are used for the whole experimental. Here, the angle of $\alpha = 60^\circ$ is called substrate A. The angle of α for both B and C substrates are 105° and 180° respectively. Substrates are cleaned with ultrasonic cleaner in ethanol and acetone for several time. The sample modification is show in Figure 1.



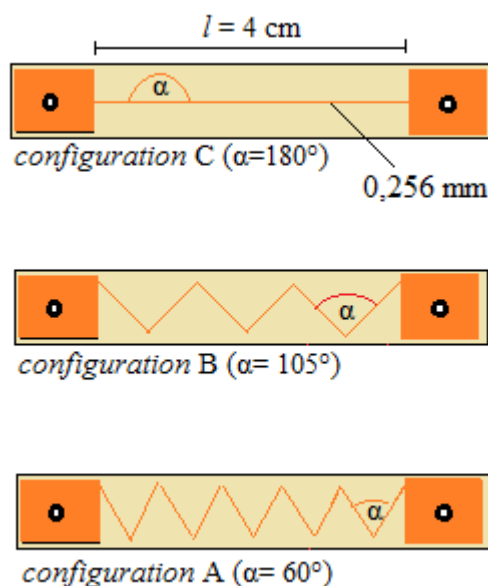


Figure 1. the modified substrates of Cu PCB use in the experiment.

An electrolyte bath for $\text{Ni}_{80}\text{Fe}_{20}$ layers and Cu spacer layer are displayed in Table 1. During experimental, the electrolytes bath keep for constant pH of 2.6 [10-12]. Diagram schematic of the electrodeposited procedure and the MI measurement set-up present at Figure 2 and Figure 3. The deposition rate for both the $\text{Ni}_{80}\text{Fe}_{20}$ layer and the Cu layer are 15.5 mA/cm^2 and 8 mA/cm^2 respectively. Thus, separately a fresh-electrolytes bath are promptly prepared before fabrication process. Electrodeposited are performed at room temperature and atmospheric pressure condition. The obtained multilayered $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ are measured the MI characteristic for different geometry substrates and frequency measurement.

Table 1. The composition of the electrolytes bath solution for $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$.

Desired layer	Composition	Concentration
NiFe	$\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$	0,009 M
	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	0,012 M
	H_3BO_3	0,149 M
	$\text{C}_6\text{H}_8\text{O}_3$	0,002 M
	H_2SO_4	1 drop
	Aquades	120 ml
Cu	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	0,065 M
	$\text{C}_6\text{H}_{12}\text{O}_6$	0,002 M
	H_2SO_4	1 drop
	Aquades	120 ml

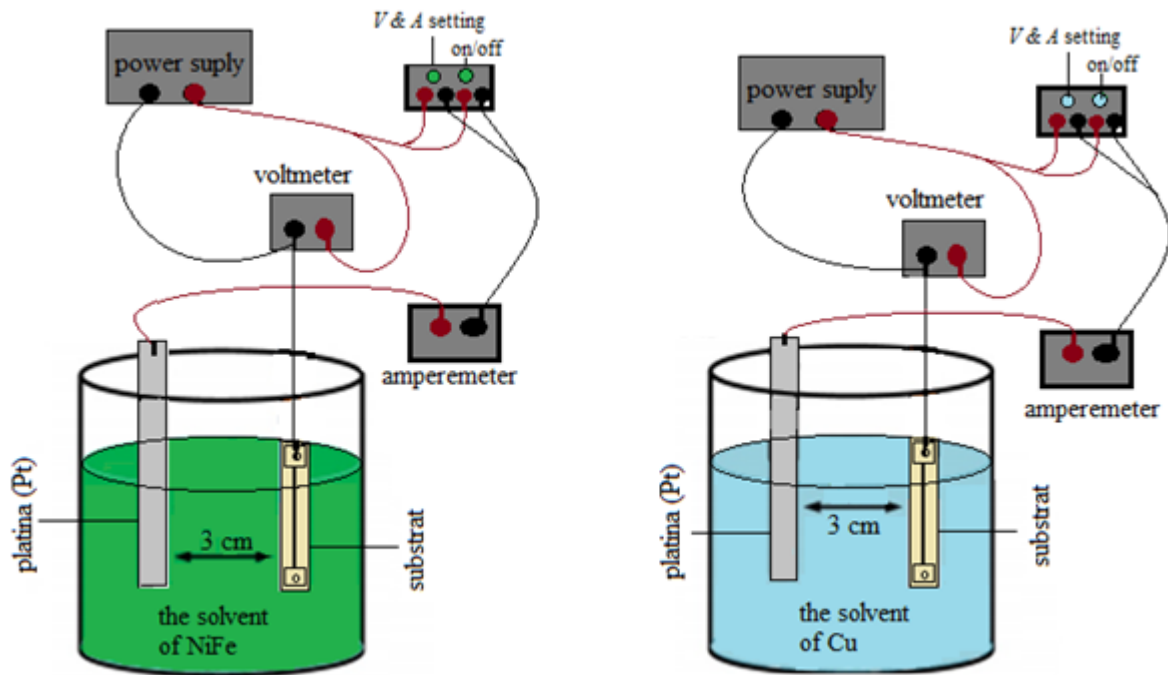


Figure 3. experimental set up for electrodeposition of the multilayers $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$.

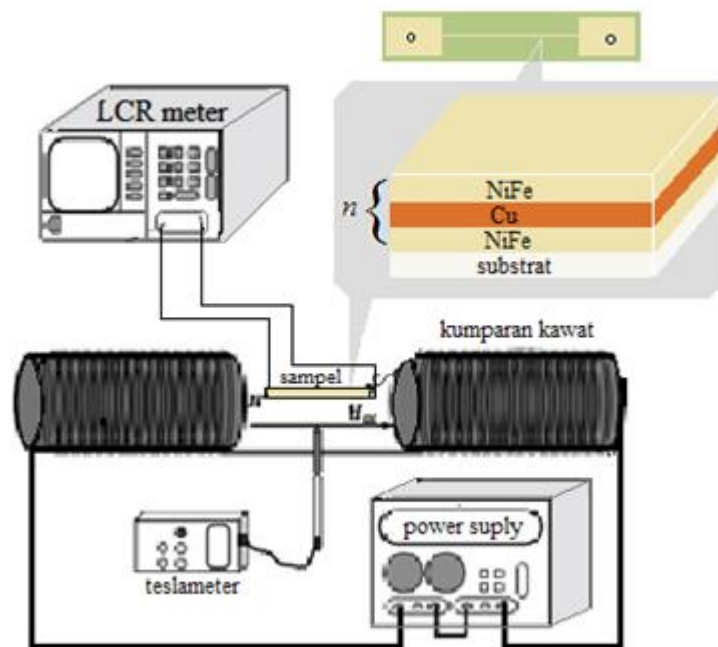


Figure 4. The schematic of magneto-impedance measurement for multilayer samples of $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$.

3. Results and Discussion

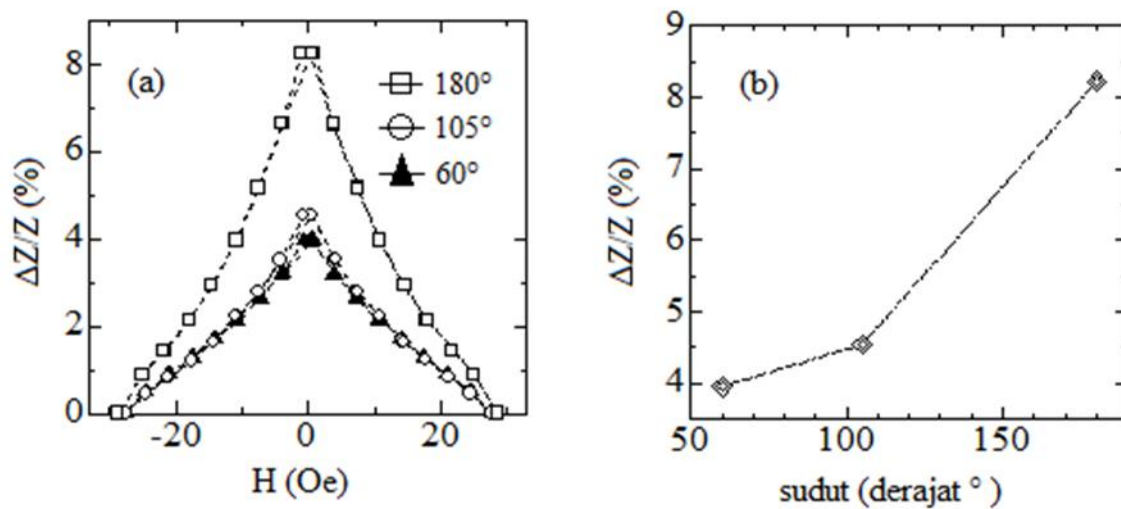


Figure 5. (a) The MI curve for multilayered $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ samples with variation angle of geometry modification measure at a frequency of 100 kHz and (b) the ratio of MI as a function of angle.

Figure 5 shows the expression MI value/ratio as a function of the changes of H . For the whole samples, the MI ratio maximum realize when the magnetic field of $H = 0$. Then the MI ratio gradually decreases with the increase of H . The MI ratio maximum of 8.19% observe for sample C (with the angle α of 180°). Whereas the maximum ratio of samples A and B are 3.28% and 4.36% respectively. This interesting results may attribute the different configuration of a magnetic domain for individual samples. In case samples A and B, the magnetization realizes in pattern geometry owing compensated region of magnetization for each and other. Contrast, for sample C, the magnetic domain configuration realize in single plane direction. So that, the resultant of magnetic configuration will uniformly respond to the magnetic field. Within result, the high MI ratio due to significantly different configuration under zero magnetic field.

In general, the MI effect dominantly supports by magneto-inductive [6]. For multilayered structure films, the MI effect support by the ratio of magnetic and conductive layers [13] and also skin effect [14]. For the recent report, the MI of multileyer structure attribute by an open flux of the magnetic domain configuration [15]. For our experiments results that the geometry modification of the multilayered samples will potentially form the open-flux magnetic domain configuration within result high MI ratio.

Another expression of the frequency dependence of the MI curve present is depicted Figure 6. Clearly observed from the figure that the MI ratio significantly increases with frequency. The MI ratio of 0.059% occurs at frequency f of 20 kHz. Then the MI ratio drastically increases of 8.23% when the measurements carried out at frequency f of 100 kHz. The MI ratio become 140 times ($=8.23/0.059$) much larger in increasing 5 times ($=100/5$) of frequency. This is indicated that the MI effect dominantly realizes by skin effect [14].

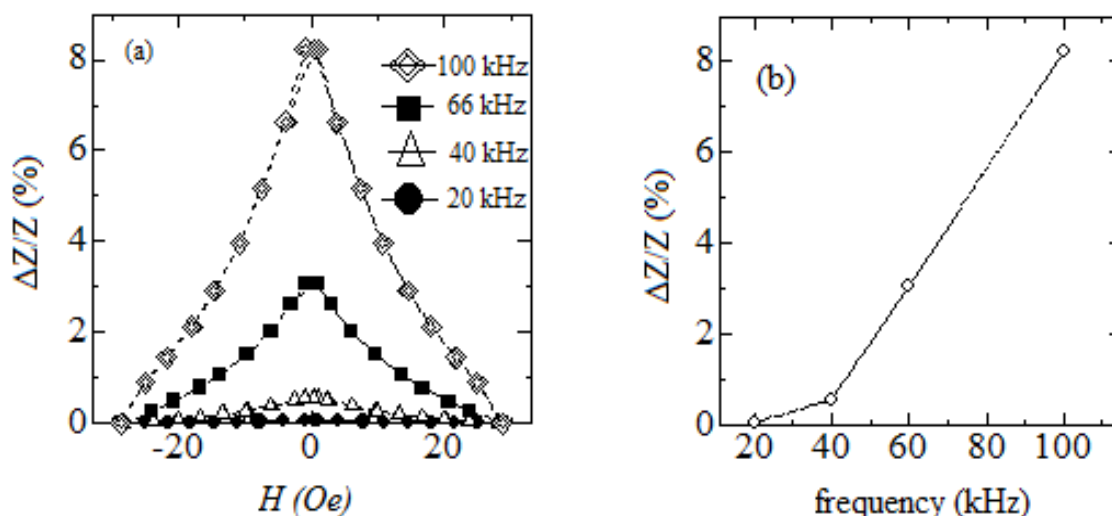


Figure 6. (a) curve MI multilayers $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ in the measurement frequency of 20 kHz to 100 kHz sample C, (b) graphs the ratio of MI function of frequency.

4. Conclusion

In conclusion, the magneto-impedance effects in samples of $[\text{Ni}_{80}\text{Fe}_{20}/\text{Cu}]_3$ multilayers have discussed. The dependence for both of PCB Cu substrates-geometry and the frequency measurement of the ratio MI have evaluated. The experimental results showed the geometry dependence of the ratio of the MI tends to increase with the increase of angle. In addition, the MI ratio magnitude increases in increasing the frequency measurements. Finally, the highest MI ratio of 8.23% occurs for the sample C.

References

- [1] Cortes M, Peng T, Woytasik M, and Moulin J 2015 *Journal of The Electrochemical Society* 162 no.7, 129-132
- [2] Chaturvedia A, Ruiza A, Leb A T, Tungc M T, Mukherjeea P, Srikantha H, and Phana M H 2014 *Science Jet* 3:48 1-4
- [3] Ismail, Nuryani, and Purnama B 2016 *AIP conference Proceedings* 1710 .030002
- [4] Wicakson B A, Nuryani, and Purnama B 2015 *Jurnal fisika dan aplikasinya* 11, no.3
- [5] Talaat A, Ipatov M, and Zhukova V 2014 *Proceedings of the 8th International Conference on Sensing Technology*, Sep. 2-4, 2014, Liverpool, UK
- [6] Phan M H and Peng H X 2008 *Progress in Materials Science* 53 323-420
- [7] Kurlyandskaya G V, deCos D, and Volchikov S O, *Defektoskopia* 2009 45 (6), 13-42 [Russ. J. NonDestructive Testing 45 (6), 377-398
- [8] Tuan L H, Huy N T, and Huy P T 2009 *journal of physics*, 187(1), 1-5
- [9] Amiruddin M, Utari, and Purnama B 2014 *Jurnal Fisika dan Aplikasinya*, 10 No. 2, 95-98
- [10] Bedir M, Bakkaloglu O F, and Oztas M, 2006 *Pramana Journal of Physic*, 66 No. 6, 1098-1104
- [11] Aydogmus E, Kaya H, Atalay F E, Atalay s, and Avcu D, 2014 *Acta physica Polonica A* 125, 227-229
- [12] Hanafi E P, Utari, and Purnama B, 2013 *Jurnal Fisika & Aplikasinya*, 9 No.2 63-65
- [13] Panina L V and Mohri K 2000 *Sensors and Actuators* 81 71-77
- [14] Marques M S, Mori T J A, Schelp L F, Chesman C, Bohn F, and Corrêa M A 2012 *Thin solid films* 520 2173-2177
- [15] Garcia-Arribas A, Fernandez E, Svalov A, Kurlyandskaya G V, and Barandiaran J M 2016 *Journal of Magnetism and Magnetic Materials* 321-326