Incident power dependence on magnetoimpedance element with domain wall resonance.

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I. INTRODUCTION Magnetoimpedance(MI) sensor utilizes permeability changes of the material through skin effect and ferromagnetic resonance when the sensor is applied to a magnetic field, and it has a higher sensitivity [1]. The sensors, which are composed of amorphous wires, are currently commercialized as compasses in mobile phones, and researches advance their sensitivity still continue for application of biomedical research [2] and nondestructive testing [3]. On the other hand, thin-film MI elements which has the compatibility with miniaturized integrated electronic devices such as driving and detecting circuits, contributes to the miniaturization of sensor device with higher spatial resolution. However, one problem of using thin-film elements is higher operating frequency. Typically, operating frequency is above 100 MHz to GHz range for elements with several μm thickness; this is unsuitable for general-purpose driving and detecting circuits, which normally operate below 20–30 MHz. During our investigations about thin-film MI elements, we found an interesting behavior that the frequency profile of impedance shows double peak depending on the applied bias field, that is, another peak appears at lower frequency region [4]. Then we analyzed this profile based on the domain wall equation and indicated the changes in impedance is attributed to the domain wall resonance (DWR) [5]. We also showed a potential of the phenomenon applied for developing a highly sensitive sensor operated at frequencies around the dozen megahertz region. In such cases, more detailed investigations about incident power is required because the behavior of impedance changes strongly depends on input high frequency power and this behavior is not still clear. Thus, in this study, we evaluated experimentally the impedance profile around frequency where the DWR occurs when the incident ac power modulated, and discussed about the sensitivity of impedance changes. II. EXPERIMENTAL PROCEDURE The thin-film element having 20-μm wide, 2-μm thick and 1-mm long was fabricated using an amorphous $Co_{85}Nb_{12}Zr_3$ film by photolithography and sputtering processes. The element was then annealed in vacuum by applying a field of 3 kOe at 400 °C and its easy axis is controlled parallel to the width direction. After field annealing, a Cu/Ti electrode with 2-μm thick, was fabricated. The impedance of fabricated element was measured by a network analyzer and a wafer probe. The incident ac power was changed from –20 to 5 dBm. During impedance measurements, a dc external magnetic field was applied to the element along the longitudinal direction by a Helmholtz coil. III. RESULTS AND DISCUSSION Fig. 1(a) shows an example of a frequency profile of impedance and inductance with/without DWR and it also includes the definition of parameters evaluated here; resonance frequency f_r, and changes in impedance peak ΔZ_p. When incident power is –10 dBm, the profile shows a peak for impedance and a rapid reduction of inductance due to DWR around 8.5 MHz, while the profile does not show DWR for –20 dBm (we applied magnetic field of 6.5 Oe to the element). Fig. 1 (b) shows the applied dc field dependence of f_r when the ac incident power altered. If the plotted data does not exist, which means we cannot observe DWR on the impedance profile. The values of f_r increase with increasing applied dc field and we confirmed ΔZ_p shows similar tendency to the changes in f_r. If the incident power is smaller, the field range where DWR occurs becomes smaller; e.g. the DWR appears from 7 to 8 Oe for –15 dBm while from 2 to 6 Oe for 5 dBm. On the other hand, the changing range of f_r and ΔZ_p has maximum point: in this case, f_r changes 55 MHz and ΔZ_p changes 14 Ω for –5 or –7 dBm. Then we investigated the impedance change against applied dc field and the sensitivity, defined as the maximum slope of the impedance profile, at a fixed frequency. Fig. 2 (a) shows the field dependence of impedance at 30 MHz when incident power changes. In the results of –20 dBm, we cannot observe DWR in this case, the impedance has a peak of 7.5 Ω at around 8.5 Oe. When incident power is –10 dBm, the peak value of impedance change becomes maximum (12 Ω at 8 Oe), then the peak intensity decreases with increasing incident power (See Fig. 2(b)). Also, the field intensity where the impedance has a peak shifts to lower field as the incident power increases (See Fig. 2(b)). When the incident power becomes –10 dBm, the sensitivity becomes maximum (38 Ω/Oe), which indicate DWR enhances the sensitivity of thin-film MI elements at the relatively lower frequency compared with the case without DWR (5.5 Ω/Oe for –20 dBm). IV. CONCLUSION The dependence of incident ac power on thin-film MI profile when the DWR occurs were investigated. If incident power is smaller, the profile did not show DWR, whereas larger incident power induces DWR, which brings abnormal impedance peak and rapid inductance reduction at relatively lower frequency region. Additionally, the DWR enhances the sensitivity of MI elements around the dozen megahertz region compared with the change without DWR.

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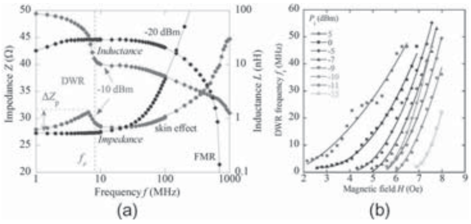

Fig. 1. (a) Example of frequency dependence with/without DWR and definition of parameters, DWR frequency f_r and peak in impedance change ΔZ_p. DWR occurs for –10 dBm while not for –20 dBm. (b) Relation between DWR frequency, f_r and applied dc field.

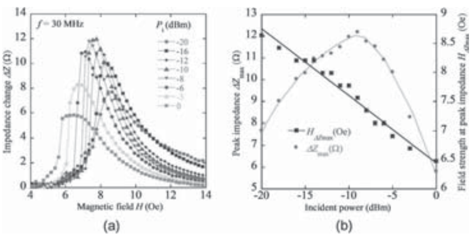

Fig. 2. (a) Applied field dependence of impedance at 30 MHz. (b) Incident power dependence of peak value of impedance and field intensity where impedance has maximum at 30 MHz.

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