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To cite this version:
H. Yoshida, H. Fujimori, T. Kaneko, S. Abe, H. Morita. ATTENUATION OF SURFACE ACOUSTIC WAVE THROUGH SPUTTERED MULTI-LAYERED NICKEL FILMS. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-1795-C8-1796. <10.1051/jphyscol:19888819>. <jpa-00229075>

HAL Id: jpa-00229075
https://hal.archives-ouvertes.fr/jpa-00229075
Submitted on 1 Jan 1988

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ATTENUATION OF SURFACE ACOUSTIC WAVE THROUGH SPUTTERED MULTI-LAYERED NICKEL FILMS

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Abstract. — The magnetic field dependent-attenuation of SAW delay lines with sputtered single- and two-layered nickel films was investigated. It is found that the attenuation change induced by field for the two-layered Ni/W film is twice as large as that for the single-layered film.

Feng et al. have reported that the nickel film delay line prepared by an evaporation technique shows an attenuation peak in a magnetic field parallel to the film plane which strongly depends on film thickness, temperature, and magnetic field [1]. They have also found that the field dependence of attenuation is similar to that of ac magnetic susceptibility. Yoshida et al. [2, 3] have studied in details the effect of nickel film thickness and frequency on the attenuation of the SAW (Surface Acoustic Wave) for evaporated Ni films. They reported that the attenuation vs. thickness curve shows a maximum around 200 Å and the maximum attenuation induced by field is about 40 dB/cm. It is thus impossible to prepare thicker single-layered Ni film presenting stronger attenuation. The present authors have also reported that for the multi-layered Ni/W films prepared by the ac sputtering technique, it is possible to increase the effective thickness of Ni without changing ac susceptibility. They pointed out there that multi-layering of Ni/W film will enhance the field-induced attenuation beyond the maximum attenuation obtainable with the single-layered Ni film [4].

In this paper, we present the experimental results on the field dependence of ac susceptibility and SAW attenuation for the multi-layered Ni/W films produced by a dual-type ac sputtering method.

The samples were prepared by an ac plasma sputtering using two pure Ni and W targets. The initial vacuum was $2 \times 10^{-6}$ Torr, the sputtering argon gas pressure being $1.5 \times 10^{-2}$ Torr. Ni/W multi-layered films were made on the ST-cut quartz substrate, on which three kinds of interdigital transducers for SAW with the frequencies of 168, 231 and 300 MHz are set beforehand. The deposition rate and the sputtering time allow us a crude estimation of the thickness. In the Ni/W films prepared above, the thickness of Ni and W films is estimated to be 125 Å and 50 Å, respectively. The attenuation of SAW was measured using a spectrum analyser in dc magnetic field up to about 60 Oe. The ac magnetic susceptibility was also measured in dc magnetic fields up to 60 Oe. For doing that, the primary and secondary coils were set along the applied magnetic field.

Figure 1 shows the ac susceptibility vs. magnetic field curves for single- and two-layered thin films. In figure 2 are shown the results of the attenuation measurements of SAW with 300 MHz for each film as a function of the field. As seen in figures 1 and 2, the field dependence of the ac susceptibility and of the attenuation is rather similar. We define the zero field susceptibility (ZFS) and zero field attenuation (ZFA) as the difference of values of ac susceptibility and attenuation at 0 Oe and 40 Oe, respectively. As shown in figure 2, the ZFS for the two-layered film takes about two times larger value than that for the single-layered film. On the other hand, from the results in figure 2 the ZFA value for the two-layered film is also obtained to be 0.12 dB/cm which is about two times larger than 0.06 dB/cm for the single-layered film. It should be noted that both the ZFS and ZFA values for the two-layered film are obtained to be twice as large as those for the single-layered film. This result indicates that the attenuation induced by field for the multi-layered film can be enhanced by a factor of number of layers compared with that for the single-layered film as pointed out in reference [4]. Therefore, the multi-layering of Ni films with W is considered to be one of the best method for getting a Ni base SAW device with higher efficiency. The ZFA values obtained in the
present work are much smaller than those previously reported for the vacuum evaporated Ni films. The reason for the small attenuation in the case of our Ni film and Ni/W layered films seems to be connected with the microstructure of these sputtered films. According to the previous work [2, 3], Ni film evaporated in a vacuum exhibits an inplane magnetic anisotropic susceptibility. In that case, large attenuation induced by field is observed. Our sputtered films behave isotropically for the inplane susceptibility [4]. This difference seems to be of major importance for explaining the small attenuation in observed films. We believe that the sputtered films are made of islands in which each island has an elongated shape but is populated at random. Then the magnetization of the observed film is isotropic.

In order to obtain much enhanced attenuation of SAW for the sputtered film, we are examining the sputtering conditions to make a multi-layered Ni/W film in which the Ni layer film consists of the island structure with a preferred orientation in each elongated island.

The preliminary experiment was carried out to examine the frequency dependence of the ZFA of sputtered film. The field dependence of attenuation was measured for the single-layered Ni film at 700 MHz which is one of higher harmonics of 231 MHz SAW. The results are shown in figure 3, in which the curve (a) represents the values measured under $H$ perpendicular to the SAW propagation vector $k$ and (b) the values measured under $H$ parallel to $k$. The maximum value of the attenuation induced by field is about 1 dB/cm.

This value of the ZFA at 700 MHz is much larger than those observed at 300 MHz mentioned above. Such a frequency dependence of the ZFA was observed for the Ni films evaporated in vacuum [3]. Further detailed studies for the frequency dependence of the ZFA for sputtered films are now in progress.