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Thickness Effect of Gold Film on Dynamics of Second Harmonic in Nonlinear Surface Acoustic Wave

非線形弾性表面波における第二次高調波のダイナミクスに及ぼす金膜厚の効果

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1. Introduction

Nonlinear surface acoustic wave (NLSAW) has been interested in application to signal processing devices such as convolver, parametric amplifier, and memory correlator. [1-3] Recently, higher-order harmonics in NLSAW have attracted much attention because of their nonlinear behavior such as chaos, fractal, and soliton. We reported that the second-order harmonic (2^{nd} HMC) in NLSAW generated on $LiNbO_3$ substrate showed soliton–like characteristics. [4-6] Especially, the full width at half maximum (FWHM) value of 2^{nd} HMC was unchanged on $LiNbO_3$ substrate with and without gold (Au) film, whereas those of fundamental (FUN) component in NLSAW increased when a Au film was formed. [7, 8] We also introduced a novel photonic signal processing device using soliton-like characteristics of 2^{nd} HMC on Au-coated $LiNbO_3$ substrate. [9] Thus, nonlinear behavior of 2^{nd} HMC generated on $LiNbO_3$ substrate with Au film has been interested. In this study, we investigate the effect of Au film with various thicknesses on the characteristics of 2^{nd} HMC on $LiNbO_3$ substrate.

2. Experimental procedure

Figure 1 shows an illustration of an experimental sample. 128^o-rotated Y-cut X-propagating $LiNbO_3$ single crystal was used as substrate. The 20 pair interdigital transducer (IDT) was formed on the $LiNbO_3$ substrate, in which their center frequency was around 50 MHz. A space between two IDTs was fixed at 20 mm. The RF burst signal was introduced to the IDT through RF connector, in which its duration time and duty cycle was 250 ns and 0.05 %, respectively. Au film was deposited on the center of the sample by vacuum evaporation, in which its area was 10x10 mm^2, and their thickness ranged from 20 to 90 nm. He-Ne laser beam with 300 μm in diameter was used for probing of 2^{nd} HMC. The probing beam was irradiated on sample surface, and the diffracted light

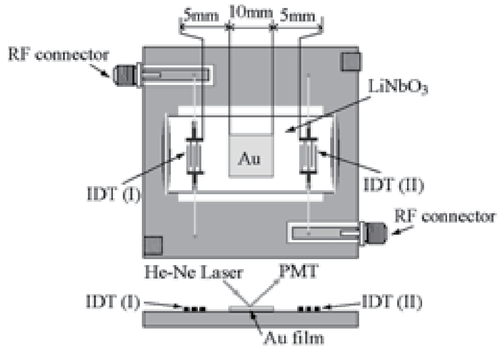

Fig.1 Illustration of an experimental sample

was detected by photomultiplier tube (PMT). The dynamic characteristics of 2^{nd} HMC were measured using optical diffraction method. The amplitude and power density values of FUN and 2^{nd} HMC were evaluated from measurement of the diffracted light intensity.

3. Results and discussion

To know the effect of Au film, the dynamic characteristics of NLSAW on $LiNbO_3$ substrate with and without Au film were investigated. **Figure 2(a) and 2(b)** show the variation of normalized diffraction light intensity as function of distance from input IDT on the sample with and

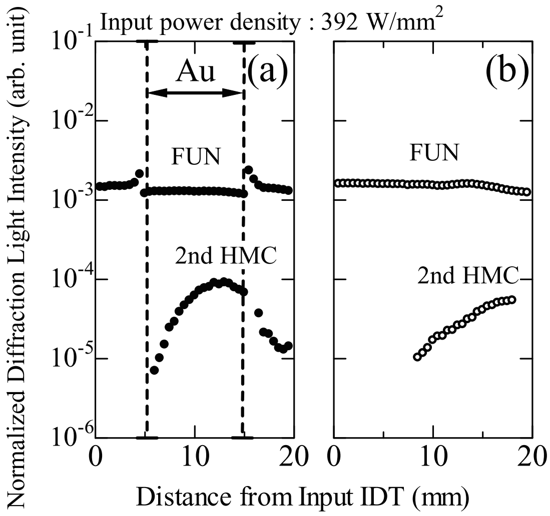

Fig.2 Variation of normalized diffraction light intensity (a) with and (b) without Au film

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without 50-nm-thick Au film, in which the input power density was fixed at 392 W/mm^2. The light intensity diffracted only from 2nd HMC was enhanced by existence of Au film, whereas that from the FUN was slightly decreased by Au film.

The input power dependence of the light intensity diffracted from 2nd HMC was also investigated, in which the input power density ranged from 156 to 392 W/mm^2. **Table 1** shows the relationship between input power density and normalized light intensity diffracted from the sample surface with and without 50-nm-thick Au films. The maximum diffracted light intensity of Au-coated sample was independent on the input power density and it was obtained at the distance of approximately 13 mm from input IDT. The diffraction light intensity ratios at the input power of 156 and 392 W/mm^2 were about 3.6 and 1.7, respectively.

Table 1 Input power density vs. normalized light intensity

Input power density (W/mm^2)	156	248	312	392
with Au (x10^{-6})	19.1	43.2	61.8	91.3
without Au (x10^{-6})	5.3	18.4	33.0	54.2
Ratio	3.6	2.3	1.9	1.7

To clarify the thickness effect of Au film on the propagation of NLSAW, the normalized diffraction light intensity as function of distance from input IDT was measured when the samples with various film thicknesses were used. **Figure 3** shows the variation of the normalized light intensity diffracted from FUN and 2nd HMC, in which the thicknesses of the Au films were 0, 20, 50, and 90 nm. The input power intensity was fixed at 392 W/mm^2 in this experiment. The light intensity diffracted from the FUN decreased with increase of the Au film thickness. On the other hand, the peak position of the normalized light intensity in the area of Au film was shifted toward the shorter distance from input IDT by increase of the Au film thickness. It is known that the diffraction light intensity of propagating harmonic wave shows a spatial periodic variation and velocity dispersion owing to the loading of the film is translated by the nonlinear effect. [10, 11] Therefore, it is suggested that these results are occurred by velocity dispersion. However, the FWHM value of the 2nd HMC was independent on thickness of the Au film. Therefore, we assume that the dynamic characteristics of 2nd HMC in NLSAW are determined by an interaction between nonlinearity

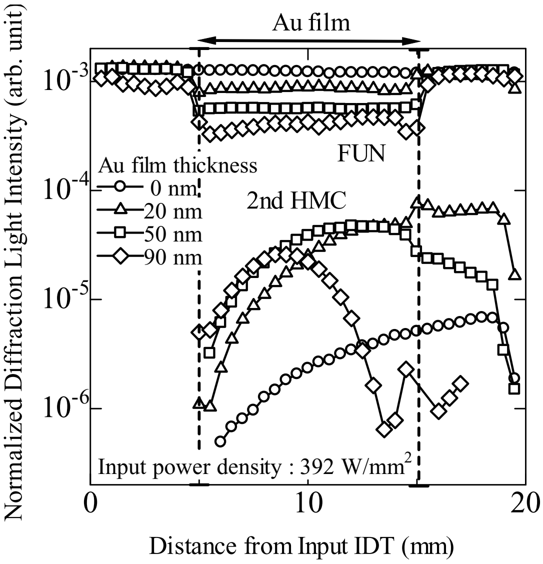

Fig.3 Variation of normalized light intensity diffracted from FUN and 2nd HMC as function of Au film thickness

and strong dispersion in the area of Au film.

4. Conclusion

We investigated the thickness effect of Au film on dynamic characteristics of 2nd HMC in NLSAW. The amplitude of 2nd HMC was enhanced by Au film and the FWHM value of the 2nd HMC were not changed by Au film thickness. We conclude that 2nd HMC in NLSAW generated on metal-coated $LiNbO_3$ substrate has unique characteristics for application to novel NLSAW devices.

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