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Magneto-surface-plasmon effect in magnetic/nonmagnetic films

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Abstract

Magnetic control of surface plasmon polaritons (SPPs) is a key technique for combining spintronics and plasmonics for future devices. Combination between a non-magnetic noble metal and a ferromagnetic material is important for induction of large magneto-surface-plasmon effect. Magnetic response of SPPs in nonmagnetic/magnetic Ag-Co and ferrite/Au films were investigated by an attenuated total reflection method with applied magnetic field.

1. Introduction

Surface plasmon polaritons (SPPs), which are charge density waves propagating at an interface between a metal and a dielectric, attract much attention to be new functional devices, such as a biosensor, SPP waveguides and circuits for nano-scale photonic/plasmonic elements, SPP lasers, solar cells and so on. Especially, the SPPs have also been studied to apply magnetic devices, such as a heat assisted magnetic recording (HAMR) [1-5], and helicity dependent all-optical magnetic recording (HD-AOS) [6]. The optical near-filed, which is generated at a plasmon antenna by the SPPs propagated through in a plasmonic waveguide, makes a tiny heat spot on the magnetic medium in HAMR. The SPPs transfer light energy efficiently from a source to the magnetic medium. In the HD-AOS, the SPPs can make a tiny circularly polarized light smaller than diffraction limit [7-10]. These are indirect relation between SPPs and magnetic phenomena.

Direct interaction between the SPPs and a magnetic phenomenon has been reported by J. B. González-Díaz et al. They reported the change in reflectivity, which was related to generation of SPPs, was changed by the applied magnetic field in the Au/Co/Au multilayered films [11]. This shows the SPPs generation can be controlled by the magnetic field. We reported magneto-surface-plasmon effect for a new high sensitive magnetic sensor [12, 13].

In this study, we investigated magneto-surface-plasmon effect in magnetic/non-magnetic films, such as Ag-Co films and ferrite/Au films, to obtain large effect easily from a viewpoint of design to select material combination.

2. Experimental Procedure

Metal films were fabricated by RF magnetron sputtering at room temperature on a glass substrate. Ferrite films were grown on $SrTiO_3$ single crystal substrates by pulsed laser deposition.

The SPPs were excited by attenuated total reflection (ATR) method with Kretchmann-Raether configuration with or without magnetic field in perpendicular to the film plane. Magnetic response of SPPs were evaluated by using following figure of merit (FoM);

$$\Delta R = \{R(H) - R(0)\} / R(0)$$

where, $R(0)$ and $R(H)$ are reflectivity without and with applied field H, respectively. Examples of reflection curves (ATR curve) and a curve of figure of merit ΔR as a function of incidental angle are shown in Figs. 1 (a) and (b), respectively.

3. Design for large magneto-surface-plasmonic effect

Two kinds of materials are required for induction of magneto-surface-plasmon effect. A kind of material such as, Au, Ag, Cu, Al and so on, can be generate SPPs well. The other kind of materials can be changed dielectric parameters magnetically. Ferromagnetic materials is one of candidates. In order to obtain large magneto-surface-plasmon effect, high efficiency of generation of the SPPs and large magnetic change in dielectric parameters are demanded.

Generation of the SPPs is evaluated from the depth of the dip in the ATR curve. The film thickness is a most im-

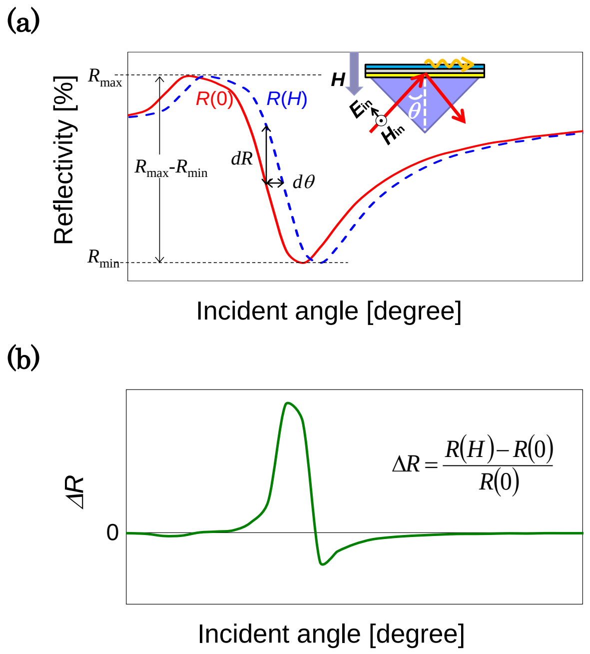

Fig. 1 (a) Reflectivity curves with/without magnetic field as a function of incident angle. (b) Reflectivity change by magnetic field ΔR as a function for incident angle.

portant parameter to obtain sharp dip and large change in reflectivity, R_{max}–R_{min}. On the other hand, dielectric change is evaluated from the change in the angles of dip. This is strongly dependent of ferromagnetic materials.

4. Magneto-surface-plasmon effect

Non-solid solution films

Reflectivity curves of a $Ag_{75}Co_{25}$ single layer film and a Cu/Co multilayered film as a function of incident angle are shown in Fig. 2. The single layer film can be easily optimized film thickness, however, optimization of multilayer film is difficult because plasmonic properties are related each layer thickness and total thickness. The R_{max}-R_{min} was 44% for the Cu/Co film but 76 % for the Ag-Co film.

Figure of merit ΔR of the Ag-Co single layer film and the Cu/Co multilayered film as a function of incident angle are shown in Fig. 3. The ΔR of the Ag-Co film is 0.29, and one of the Cu/Co film is 0.20. This difference is dependent of R_{max}-R_{min}.

Non-metal magnetic material films

Reflectivity curves of a $CoFe_2O_4$/Au film with wavelength from 405 – 780 nm as a function of incident angle are shown in Fig. 4. Film thicknesses of the $CoFe_2O_4$ layer and the Au layer are 50 nm. In this material system, only Au thickness is related to dip structure in ATR curve because SPPs propagates in the metal at the interface. By tuning the Au thickness, deep dip can be obtained. In our films we obtain ΔR of ~0.2 in the $CoFe_2O_4$/Au film.

5. Conclusions

Magneto-surface-plasmon effect was reported to apply to a magnetic sensor. Non-solid solution single layer films and non-metal magnetic films are candidate materials for magneto-surface-plasmon effect. The FoM ΔR of ~0.29 is obtained in the $Ag_{75}Co_{25}$ films.

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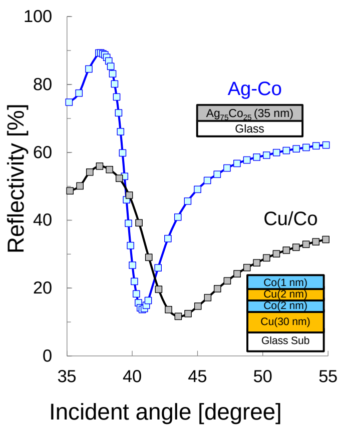

Fig. 2 Reflectivity curves of Ag-Co single layer film and Cu/Co multilayered film as a function of incident angle.

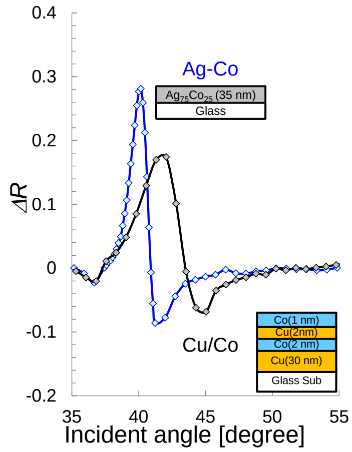

Fig. 3 Figure of merit ΔR of a Ag-Co single layer film and a Cu/Co multilayered film as a function of incident angle.

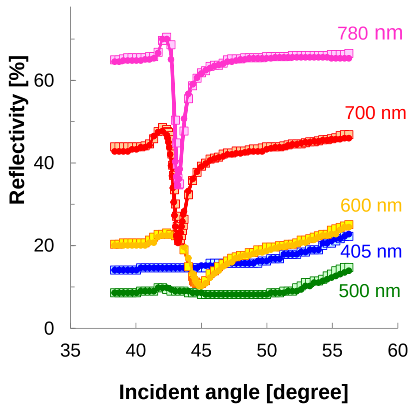

Fig. 4 Reflectivity curves of $CoFe_2O_4$/Au film with wavelength from 405 – 780 nm as a function of incident angle.

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