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Improvement of Brillouin light scattering signal by using anti-reflection coating layer for magnetic multilayers

Jinyong Jung[1], Nam-Hui Kim[1], Kwonjin Park[1], Hee Kyeong Hwang[1], June-Seo Kim[1], Chun-Yeol You[1*]

[1] Daegu Gyeongbuk Institute of Science & Technology (DGIST)
333 Techno Jungang-daero, Hyeonpung myeon, Dalsung-gun, Daegu 42988, South Korea
Phone : +82-10-6354-1012, E-mail: cyyou@dgist.ac.kr

Abstract

We introduced an additional anti-reflection layer to the magnetic multilayers in order to improve the Brillouin light scattering (BLS) signals. Since the physical origin of the BLS is based on magneto optical Kerr effect (MOKE), we found that the BLS signal can be improved when the MOKE signal is optically enhanced by the anti-reflection coating. We showed a strong and clear correlation between BLS and MOKE signals for ferromagnetic multilayers with the additional anti-reflection layer.

1. Introduction

Brillouin Light Scattering (BLS) is one of the basic probing instruments in the study of the spin dynamics. It can capture the spin wave excitation energy for a given spin wave vector, and we can obtain spin wave dispersion relations, which is an essential information to understanding spin waves.

Recently, importance of BLS is emphasized in the study of interfacial Dzyaloshinskii-Moriya interaction (iDMI) in the inversion symmetry broken systems such as oxide layer/ferromagnet or heavy metal/ferromagnet layers [1,2]. The iDMI has caught much attention as it could open new paths to manipulate information based on skyrmion, which is nano-scale topologically stable object. Because the skyrmion state is strongly depend on iDMI energy density, more exact and reliable method in the quantitative determination of iDMI energy density is highly demanded. Among many kinds of measurement techniques for observing the iDMI energy, BLS is powerful tool which can directly determine the iDMI energy density [3,4]. However, measured the BLS signal is not large enough due to its physical origin, and the small signal to nose ratio make it difficult to determine iDMI in the moderate interface quality samples. Therefore, improvement of the BLS signal can be helpful in the study of not only iDMI, but also spin wave related physics.

It is well-known that the underlying physics of BLS is nothing but the light scattering by the MOKE from fluctuated spin waves. The fluctuated spin waves in the wave vector space act as a kind of magneto-optical grating. Therefore, the better magneto-optical signal, the better gratings. It is also well-known that the additional optical anti-reflection (AR) layer can noticeably enhance the MOKE signal [5,6,7]. Therefore, we introduced additional AR layer in the typical heavy metal/ferromagnet layer structures, and we found that there is strong correlations between MOKE and BLS signals. By employing this method, we can more precisely determine spin wave excitation energies, and it is useful in the spin dynamics studies.

2. Enhancement of MOKE signal

In order to investigate the correlations between the MOKE and BLS signals, we prepared Ta(4 nm)/Pt(4 nm)/Co(2 nm)/MgO(t_{MgO} = 5~100 nm)/Ta (4 nm) structures on Si/SiO_2 substrate by using dc magnetron sputtering system. t_{MgO} is varied from 5 to 100 nm with 10 nm step. The depositions were carried out a base pressure of 3×10^{-8} Torr or lower and typical sample structures are shown in Fig. 1.

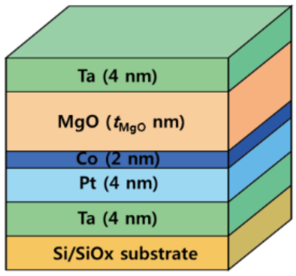

Fig. 1 The Schematic of sample structure. Si/SiO_2/Ta(4 nm)/Pt(4 nm)/Co(2 nm)/MgO(t_{MgO} = 5~100 nm)/Ta (4 nm) are depicted, and t_{MgO} is varied from 5 to 100 nm with 10 nm step.

Before investigating MOKE and BLS signals, we performed medium boundary and propagation matrices calculations for simple ferromagnet/MgO bilayer system with varying MgO capping layer thickness [8]. The results are shown in Fig. 2 for the incident angle of 45°. The Kerr rotation angle and ellipticity are defined as follows:

$$\theta_K + i\varepsilon_K = \frac{\Delta R}{R}$$

where, θ_K is the Kerr rotation angle, ε_K is the ellipticity, and $\Delta R/R$ is ratio of reflection change due to MOKE.

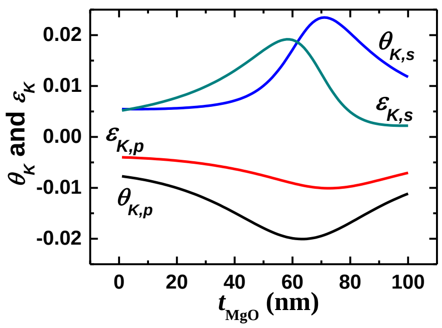

Fig. 2. Numerical calculation results for Kerr rotation angle and ellipticity in ferromagnet/MgO bilayer system as a function of MgO layer thickness for each *s*- and *p*-polarization light with incident angle of 45°.

The oscillation of the MOKE signal as a function of the MgO layer can be understand by simple multiple reflection with additional dielectric layer. Multiple reflection gives more chance to interaction with magnetic media, the source of MOKE, so the MOKE signal can be improved.

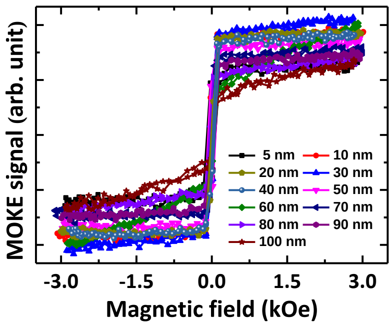

Fig. 3 Results of MOKE hysteresis loops measurement dependent on MgO layer thickness. All samples have in-plane magnetic anisotropy.

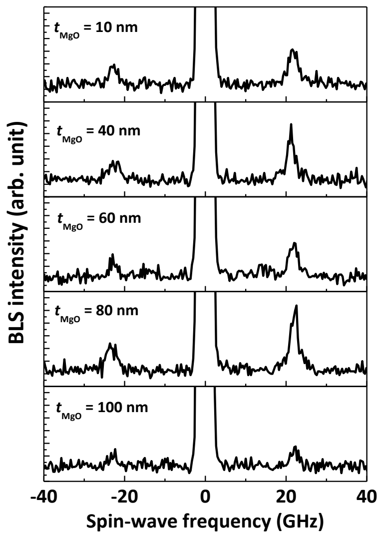

Fig. 4. BLS spectra for several MgO capping layer thickness. BLS signal has a maximum at MgO thickness at 80 nm.

Figure 4 shows BLS measurement for various MgO layer thickness, and it is clearly shown that the peak intensity is change with the MgO layer thickness even though the magnetic layers nominally identical. For example, 40 and 80-nm thick MgO samples show much better signals compared with others.

Finally, we plotted MOKE signal and BLS intensity together as a function of MgO thickness in Fig. 5 for the nominally identical Pt/Co structures. As we expected the MOKE signal oscillated with the MgO thickness, and the BLS signal is strongly correlated with the MOKE one. Since there are many other unclear factors contributed to the BLS single strength, the correlations are not perfectly matched, however, we can claim that the better MOKE signal can be improve the BLS signal also.

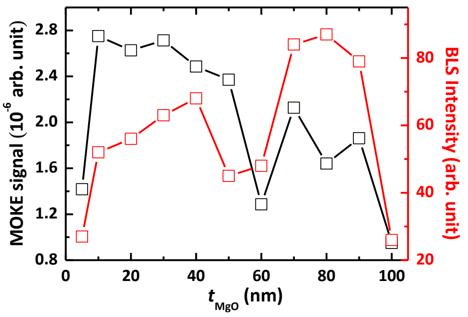

Fig. 5. Result of MOKE (black squares) and BLS spectrum (red squares) signals.

3. Conclusions

We introduced additional anti-reflection layer in order to improve BLS signals in the magnetic layers. Since the underlying physics of BLS is the same with MOKE, the MOKE improved condition can help to enhance BLS signal. We confirmed our expectations by measuring MOKE and BLS for various MgO anti-reflection layer thickness with nominally identical magnetic structures. We found that BLS signal can be improved several times when the MOKE is enhanced by the anti-reflection conditions. With this approach, we can more precisely determine the spin wave excitation energy, and it will be helpful in the study of spin dynamics.

Acknowledgements

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