3P1-4

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 405-406
3-5 December, 2014

Brillouin scattering measurement using induced phonon from ScAlN piezoelectric thin film

ScAlN 圧電薄膜による高周波励起フォノンを用いた高速 Brillouin 散乱測定

Masahiko Kawabe[1†], Takahiko Yanagitani[2], Hayato Ichihashi[1], Shinji Takayanagi[1], Masashi Suzuki[2] and Mami Matsukawa[1] ([1] Doshisha Univ.; [2] Nagoya Inst. Tech.)
川部昌彦[1†]，柳谷隆彦[2]，市橋隼人[1]，高柳真司[1]，鈴木雅視[2]，松川真美[1]([1] 同志社大, [2] 名工大)

1. Introduction

Brillouin scattering is a nondestructive technique to measure the velocity of acoustic waves propagating in thin materials using a focused laser beam. This technique enables the simultaneous measurement of longitudinal and shear wave velocities in a microscopic region at hypersonic frequencies. However, the measurement accuracy of wave velocities was lower than those of other methods, such as ultrasonic pulse–echo techniques. The accuracy strongly depends on the measurement conditions and specimen transparency, because Brillouin scattering from thermal phonons is usually weak.

Therefore, we attempted to overcome this problem by making use of the induced shear acoustic phonons excited by a c-axis tilted ZnO piezoelectric film transducer.[1] In this study, we tried to improve the intensity of induced phonon by using ScAlN films which possess higher piezolectricity than ZnO.

2. Experiment system

Brillouin scattering measurements were carried out with a six-pass tandem Fabry–Perot interferometer (JRS scientific instruments) using an Argon ion laser with wavelength of 514.5 nm. The laser power near the specimen was 60 mW. The actual diameter of the focused laser beam spot on the specimen was approximately 50 μm.

The wavelength of the observed phonons is determined by the scattering geometry, which specifies the directions of the incident and scattered light. The Reflection Induced ΘA (RIΘA) scattering geometry is shown in Fig.1.[2] This geometry is attained by attaching a flat metal to the reverse side of the specimen films as a reflector. The interaction of incident and scattered lights enables the measurement of the phonons that propagate in the direction of wave vector of $\boldsymbol{q}^{\Theta A}$. From observed spectra, we can obtain the frequency shifts of $f^{\Theta A}$, which give us the wave velocity as

$$v^{\Theta A} = f^{\Theta A}\lambda_0 / [2 \cdot \sin(\Theta/2)]. \qquad (1)$$

Here, λ_0 is the wavelength of the incident laser, equation (1) shows that the shift frequency $f^{\Theta A}$ changes due to the incident angel $\Theta/2$.

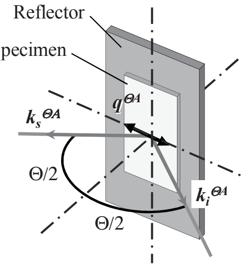


Fig. 1 RIΘA scattering geometry

3. Specimen and measurements

Fig. 2 shows the specimen configuration. We attempted to observe longitudinal phonons induced by a $Sc_{0.41}Al_{0.59}N$ piezoelectric film. The film was grown by an RF magnetron sputtering on DC sputter-deposited Ti metal film(150 nm)/ silica glass specimen (5 × 5 × 25 mm, ED-H, Tosoh Corp.). The crystalline c-axis of the film was aligned with the substrate normal, allowing the effective excitation of longitudinal wave in the gigahertz range. The film (with apploximately 4 μm thick) was deposited on one side of a silica glass specimen. On the reverse side of the specimen, an Al film (apploximately 300 nm) was deposited as a light reflector for the RIΘA scattering geometry.

In this study, we used a signal generator (E8257D, Agilent technologies) and the coaxial resonator (AET, Inc.) to induce phonons. We applied an electric field to the ScAlN film using the electromagnetic evanescent wave at 1.989 GHz that leaked from a small orifice of the resonator.

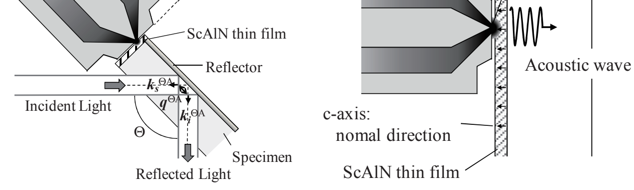


Fig. 2 Specimen configuration

4. Result and discussion

Figure 3(a) shows a Brillouin scattering spectrum from the silica glass specimen without the induced wave. Here, the incident angle of the laser beam was adjusted to $\Theta/2 = 5^\circ 05'$, which matched the shift frequency $f^{\Theta A}$ resulting from the longitudinal acoustic wave and the fundamental resonance frequency of the coaxial resonator.

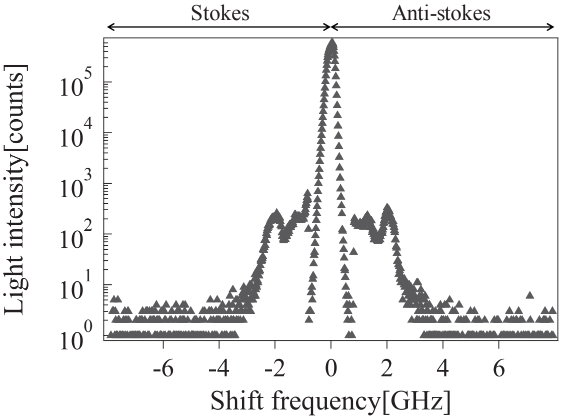
Figure 3(b) shows a Brillouin spectrum from the specimen with the induced wave. Only the Stokes peak was strongly amplified by the excitation longitudinal wave, because the induced wave propagated in only one direction. The Stokes peak intensity was found to be approximately 227995 counts (the power Psw applied to the coaxial resonator was 0 dBm). In contrast, the Anti-stokes peak caused by thermal phonons was approximately 263 counts. The shift frequency was the same with the frequency from the generator.

Figure 4(a) shows the light intensity distribution in the silica glass specimen. The origin indicates the center of the coaxial resonator. The half width at half maximum (HWHM) of the intensity distribution near the thin film was approximately 0.1 mm.

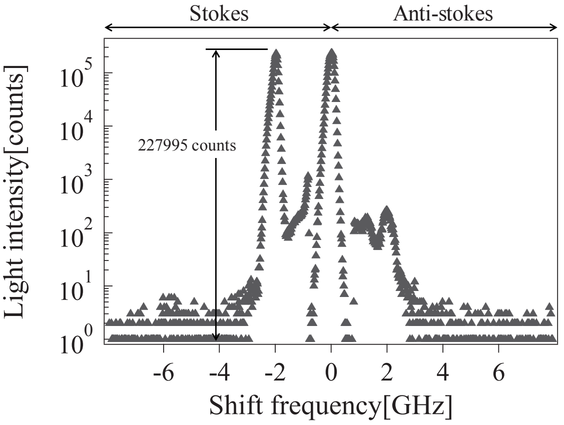
The light intensity decresed as a function of distance from the ScAlN film (Fig.4(b)). Curved lines represent estimated values of attenuation in the silica glass specimen. The curved lines for 38 dB/cm were obtained from the estimated value of propagation loss at 2 GHz.[3][4] The distribution of the light intensity is almost in agreement with the estimated values.

5. Conclusion

We have succeeded in the Brillouin scattering measurement of longitudinal acoustic waves induced by ScAlN thin film. The Brillouin peak was much stronger than the peak excited by the ZnO films. Moreover, the sound wave was able to be induced easily by using a coaxial resonator without electrodes. This technique can improve the measurement accuracy and shorten the measurement time of Brillouin scattering.

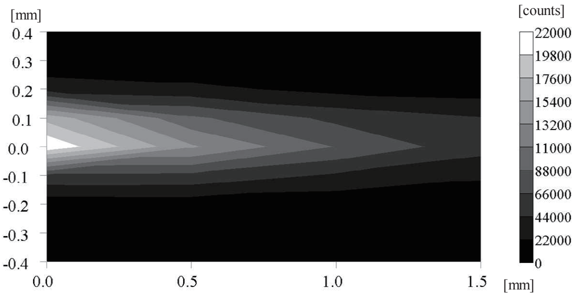


(a)Without the induced longitudinal wave.

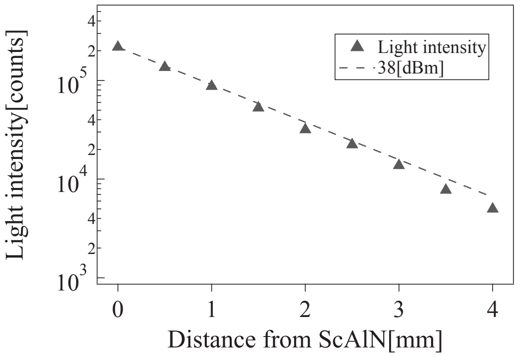


(b)With the induced longitudinal wave.
($\Theta/2 = 5^\circ 05'$, f_{sw}=1.989 GHz)

Fig. 3 Brillouin spectrum in the silica glass.



(a) Two-dimensional distribution



(b) Attenuation characteristics.

Fig. 4 Distribution of light intensity.

References

1. H. Sano: IEEE Trans Ultrason Ferroelectr Freq Control. vol. 60, no. 5, May (2013) 873
2. J. K. Krüger, J.Embs, J. Brierley, and R. Jiménez:J. Phys. D 31, 1913 (1998).
3. J. Kushibiki, M. Arakawa: IEICE Tech. Rep. 72, 37 (2004).
4. D. B. Fraser, J. T. Krause and A. H. Meitzler: Appl. Phys. Lett. 11, 308 (1967).