

2-Dimensional Holographic Grating Formation in Chalcogenide Thin Films

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Amorphous chalcogenide thin films, especially a-(Se, S) based films, exhibit a number of photo-induced phenomena. In this study, we make the $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin film and then we measure the holographic diffraction efficiency according to thickness of Ag. And we form the two-dimensional holographic grating. At first, we formed one-dimensional grating and then we form two-dimensional grating by rotate the sample. We found out the most suitable thickness of Ag and in case of $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$, the diffraction efficiency was more higher than other samples. The holographic grating was formed by He-Ne laser ($\lambda=632.8\text{nm}$). The intensity of incident beam was 2.5mW and incident angle was 20° . We confirm the two-dimensional holographic grating by the pattern of diffracted beam and AFM(Atomic Force Microscope) image. We perform the etching process using by 0.26N NaOH in order to confirm clearly two-dimensional grating.

Keywords : $As_{40}Ge_{10}Se_{15}S_{35}/Ag$, Holographic grating, Diffraction efficiency, Etching process

1. INTRODUCTION

Over the past decade an increased interest in optical properties of multidimensional, periodic structure has arisen[1,2]. An especially interesting class of such structure, namely those in which electromagnetic field propagation for certain frequency ranges is prohibited, are often referred to as photonic crystal or photonic band gap structure. Because of their ability of controlling the propagation of light, photonic crystal will apply to many new optical devices[2].

In semiconductor, the lattice might introduce the concept of gap into energy band structure of crystal, so that electrons are forbidden to propagate with certain energies in certain direction. In the other side, while photonic crystal has the optical analogy, the periodic potential is due to a lattice of macroscopic dielectric media instead of atoms. So we can design and construct photonic band gap from the concept of propagating the light in certain direction with specified[3].

The chalcogenide glass generated photo-induced phenomena by structure flexibility. Also it have been known excellent characteristic of electric and optical properties[4-8].

In this study, we manufacture the thin film using by chalcogenide and Ag and we form 1-dimensional

holographic grating. After then we form 2-dimensional grating by rotate the sample. And we confirm 2-dimensional grating by etching.

2. EXPERIMENT

2.1 The manufacture of thin film

The amorphous As-Ge-Se-S systems exhibit a good photorefractive effect and especially the $As_{40}Ge_{10}Se_{15}S_{35}$ composition, selected in this work, shows the maximum change for reversible photo-structural transformation among $As_{40}Ge_{10}Se_{50-x}S_x$ ($x = 0, 25, 35$ at. %) thin films.

We manufacture $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin film. The thickness of $As_{40}Ge_{10}Se_{15}S_{35}$ was $2\mu\text{m}$ and thicknesses of Ag were 200, 400 and 600\AA . Figure 1 shows schematic view of thin films.

2.2 The formation of 2-dimensional grating

Figure 2 shows the schematic diagram of the experimental setup for grating formation and observing intensity of diffracted beam. A He-Ne laser beam is split using beamsplitter (BS). The two beams after reflection from mirror (M1, M2) are allowed to interfere at the sample to form the holographic grating. And two polarizer are used to control the polarization state of

incident beams. We formed one-dimensional holographic grating and then we formed two-dimensional holographic grating by rotate the sample. The pattern of diffracted beam was confirmed by camscope(ics-305A) and we confirm two-dimensional grating in thin film by AFM(Atomic Force Microscopy). We performed etching in order to confirm clearly two-dimensional grating by 0.26N NaOH solution based on previously result of one-dimensional etching.

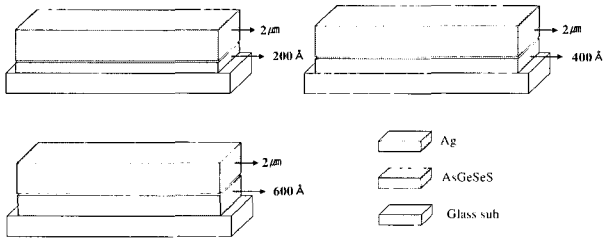


Fig. 1. Schematic views of the thin films.

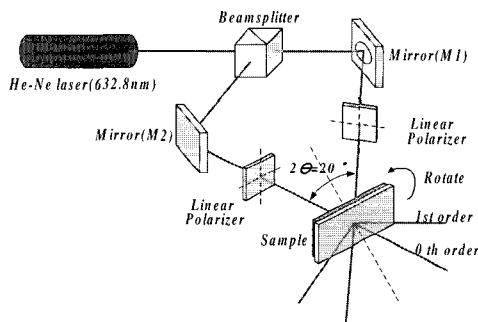


Fig. 2. Schematic views of experimental setup for two-dimensional grating.

2.3 The etching of holographic grating

The chalcogenide thin film generated different speed of developing in photo-exposed region and unexposed region by alkali solution[9]. We perform the etching on the basis of previous result[10] used 0.26N NaOH solution during 60 sec.

3. RESULTS AND DISCUSSIONS

We confirmed diffraction efficiency and grating according to thickness of Ag using photo-doping in $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin films. Table 1 show the diffraction efficiency according to thickness of Ag in (P:P) polarization state on $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin films. Figure 3 shows the diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$ thin film. In the Figure 3, the maximum diffraction efficiency was 2.8%. The diffraction efficiency was increased. And then the diffraction efficiency was decreased.

Table 1. The Diffraction efficiency according to thickness of Ag in $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin films.

| | Maximum diffraction efficiency (%) |
|-------------------------------------------------|------------------------------------|
| $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$ | 2.8 |
| $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$ | 3.2 |
| $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$ | 13 |

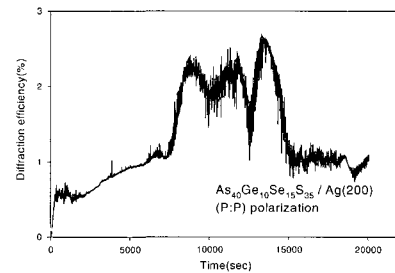


Fig. 3. The diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$.

Figure 4 shows the diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$ thin film. In the figure 4, the maximum diffraction efficiency was 3.2%. The diffraction efficiency was increased. And then the diffraction efficiency was decreased.

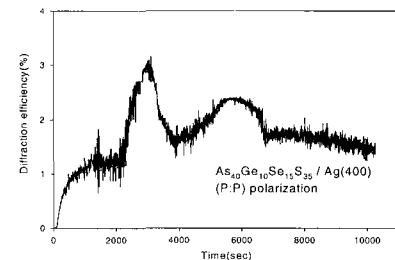


Fig. 4. The diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$.

Figure 5 shows the diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$ thin film. In the figure 5, the

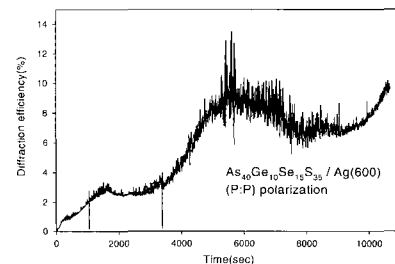


Fig. 5. The diffraction efficiency in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$.

maximum diffraction efficiency was 13%. The diffraction efficiency was increased. And then the diffraction efficiency was decreased. Finally the diffraction efficiency was increased.

Figure 6 shows surface of thin film which formed 2-dimensional grating on (P:P) polarization state in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$. In the Fig. 10, we could see diffracted beam by 2-dimensional grating but we could confirm only direction of one-axis grating. In above result, we thought that the one was formed in surface of thin film and another was formed the inside of thin film.

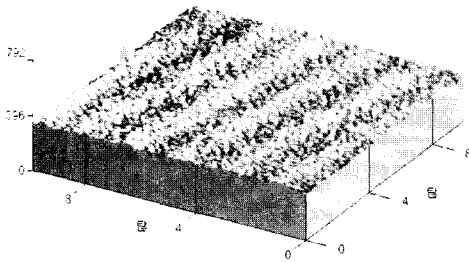


Fig. 6. The AFM image in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$ thin film.

Figure 7 shows surface of thin film which formed 2-dimensional grating on (P:P) polarization state in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$. As the same of the Fig. 5, the one was formed in surface of thin film and another was formed the inside of thin film

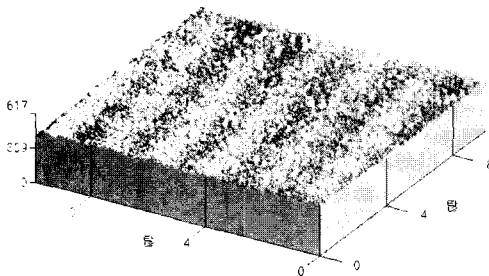


Fig. 7. The AFM image in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$ thin film.

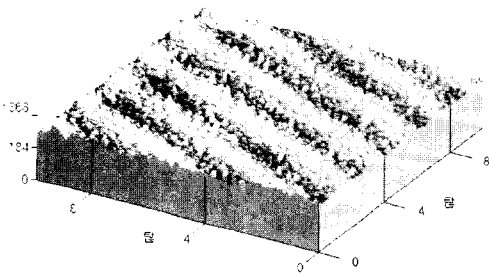


Fig. 8. The AFM image in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$ thin film.

Figure 8 shows surface of thin film which formed 2-dimensional grating on (P:P) polarization state in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$. In the Table 1, the diffraction efficiency of $As_{40}Ge_{10}Se_{15}S_{35}/Ag(600\text{\AA})$ thin film is more higher than other samples. Also the 2-dimensional grating was clearer than other samples.

Figure 9 shows that the pattern of diffracted beam in $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin film. We could see 0th order and 1st order of beam which diffracted by 2-dimensional holographic grating. In the figure 9, we found out that the patterns of diffracted beams were similar independent thickness of Ag.

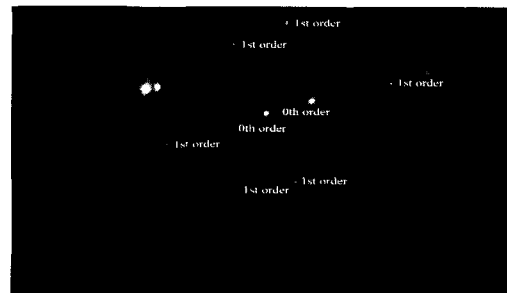


Fig. 9. The pattern of diffracted beam in $As_{40}Ge_{10}Se_{15}S_{35}/Ag$ thin film.

The chalcogenide thin film generated different speed of developing in photo-exposed region and unexposed region by alkali solution. And we etched the chalcogenide film in order to confirm the grating which formed inside of thin film by 0.26N NaOH solution.

Figure 10 shows the surface of thin film that etched by 0.26N NaOH solution during 60sec in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$. In the fig. 5, we could see the 2-dimensional grating because the grating was formed inside of thin film but we could confirm 2-dimensional grating by the etching.

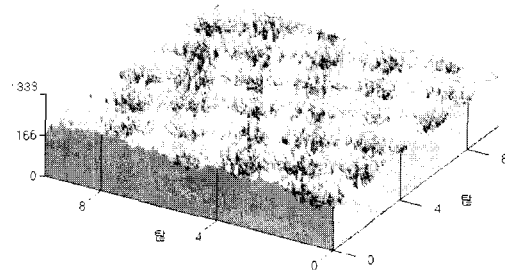


Fig. 10. The AFM image after the etching in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(200\text{\AA})$ thin film.

Figure 11 shows the surface of thin film that etched by 0.26N NaOH solution during 60sec in $As_{40}Ge_{10}Se_{15}S_{35}/Ag(400\text{\AA})$. As the same result of figure 10, we could confirm 2-dimensional grating by the etching.

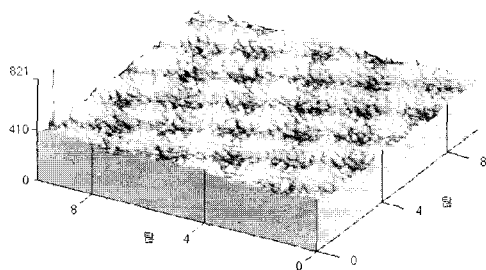


Fig. 11. The AFM image after the etching in $\text{As}_{40}\text{Ge}_{10}\text{Se}_{15}\text{S}_{35}/\text{Ag}(400\text{\AA})$ thin film.

Figure 12 shows the surface of thin film that etched by 0.26N NaOH solution during 60sec in $\text{As}_{40}\text{Ge}_{10}\text{Se}_{15}\text{S}_{35}/\text{Ag}(600\text{\AA})$. We could confirm that the 2-dimensional grating more clearer than Fig. 10 and Fig. 11.

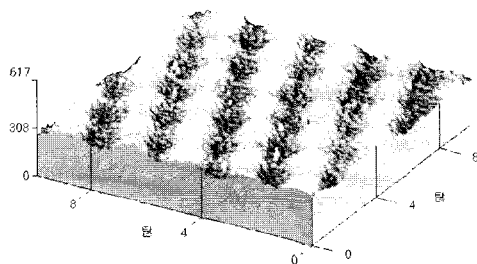


Fig. 12. The AFM image after the etching in $\text{As}_{40}\text{Ge}_{10}\text{Se}_{15}\text{S}_{35}/\text{Ag}(600\text{\AA})$ thin film.

4. CONCLUSION

In this paper, we formed 2-dimensional holographic grating in $\text{As}_{40}\text{Ge}_{10}\text{Se}_{15}\text{S}_{35}/\text{Ag}$ thin films. At first, we formed 1-dimensional holographic grating and then we formed 2-dimensional grating by rotate sample. Also we measured diffraction efficiency according to thickness of Ag. In case of $\text{As}_{40}\text{Ge}_{10}\text{Se}_{15}\text{S}_{35}/\text{Ag}(600\text{\AA})$, the diffraction efficiency was more higher than other samples and 2-dimensional grating was more clearer than other samples. And we confirm that characteristics of volume property by the etching.

On the basis of above results we found out the most suitable thickness of Ag and we confirmed the possible of manufacture application to 2-dimensional photonic crystal, diffract optical device and micro lens.

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