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Laser-Induced Backward Transfer Technique for Maskless Patterning of Poly-Si Thin Films

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1. Introduction

Laser-induced forward transfer (LIFT) has been investigated by many researchers due to the ability to fabricate microstructure without photolithography process and to achieve low cost of ownership. LIFT has been applied to various materials, such as metals, semiconductor, oxides and polymer[1-9]. However, there is problem that many particles are scattered around transferred region by laser ablation.

We have proposed laser-induced backward transfer (LIBT) method to solve these problems. LIBT process consists of the sequence of the three events. First, an optical transparent substrate (receiving substrate) is contiguously placed on source thin film which is formed on support substrate. Second, laser is irradiated to the source thin film through the receiving substrate. Finally, the thin film is transferred to the receiving substrate.

In this paper, transfer characteristic and crystallinity of poly-Si thin film transferred by LIBT method is reported. We evaluated the shape and the surface roughness of transferred poly-Si films by optical microscope and atomic force microscopy (AFM), respectively. The crystallinity of the poly-Si films was observed by AFM after Secco-etching of the poly-Si film.

2. Experiments

LIBT set-up is shown in Figure 1. Amorphous Si (a-Si) thin film of 50 nm thickness was deposited on t-SiO_2 (1 um)/Si substrates (support substrate) by Ar^+ sputtering method. A quartz substrate (receiving substrate) and the a-Si film were strongly contacted by pressing from backside of the Si substrate with a metal needle. Single pulse laser was irradiated to the a-Si film through the quartz substrate. There is a possibility that the Si film can be transferred to the quartz substrate placed backward and phase transition from a-Si to poly-Si can be achieved at the same time as Si film transfer. Q-switch Nd:YAG SHG laser was used in this experiment. Wave length of the laser was 532 nm and pulse duration was about 4 nsec. Laser energy density and laser beam diameter on the a-Si film were from 1 J/cm^2 to 7 J/cm^2 and ϕ 70 um, respectively. The laser irradiation was performed in air at room temperature.

Shape of transferred Si film was observed by optical microscope and surface roughness of the film was measured by AFM. The crystallinity of the transferred Si films after Secco-etching was also observed by AFM.

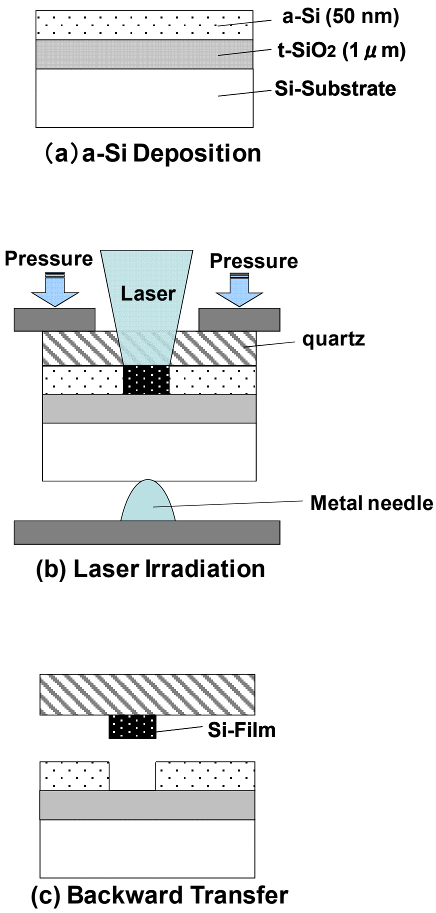

Fig.1 Schematics of laser-induced backward transfer.

3. Results and Discussion

Figure 2 shows optical microscope images of transferred Si films on quartz substrates. The laser energy density was 1 J/cm^2 and irradiation number was 1 pulse. As shown in fig.2, the Si films are transferred to the quartz substrate without scattering the Si film around the transfer region. Average diameter of the transferred films is about 30 μm. In the high irradiation energy up to 7 J/cm^2, Si film transfer could be also achieved without scattering the Si film.

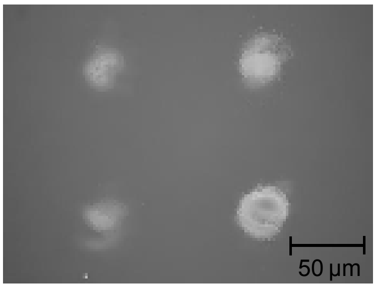

Fig.2 Optical microscope images of Si films transferred on quartz substrates by laser-induced backward transfer. The laser energy density: 1 J/cm^2.

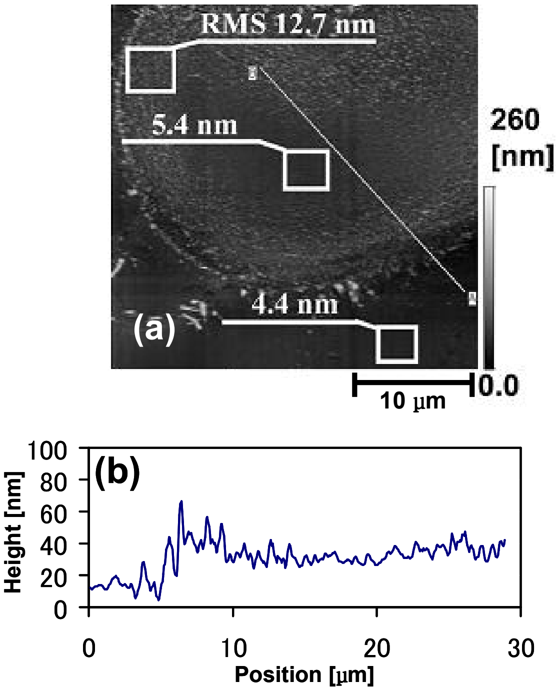

Fig.3 (a) An AFM image of the transferred Si film by LIBT method. (b) A cross sectional profile of the transferred Si film. Laser energy density of 1 J/cm^2.

Figure 3 shows (a) an AFM image and (b) a cross sectional profile of the transferred Si film at irradiation energy density of 1 J/cm^2. Root-mean-squar (rms) surface roughness calculated by the AFM image is inserted in the fig.3 (a). Rms surface roughness in the vicinity of the center of the transferred Si film is about 5 nm, which is almost equal to rms surface roughness at region of the quartz substrate without Si deposition. This result indicates that degradation of surface roughness is small at least in the vicinity of the center of the transferred film. Rms surface roughness at the edge of the transferred film is about 12.7 nm which is much larger than the rms surface roughness of the quartz substrate. In addition, the film thickness at the center of the transferred film is about 35 nm which is smaller than the a-Si film thickness of 50 nm before laser irradiation. Therefore, it is thought that the deposited film flows toward the edge from the center immediately after laser irradiation, and the film thickness thins in the vicinity of the center and projections are produced at the edge of the transferred film.

After etching by HF solution due to removal oxide film from the transferred Si film, average film thickness in the vicinity of the center was about 35 nm and rms surface roughness calculated from AFM image was about 5 nm, which values hardly changed as compared with that before HF etching. This result indicates that the oxidation of the Si film is hardly caused by Si transfer using LIBT method in air.

After Secco-etching due to removal of a-Si film from the transferred film, average film thickness and rms surface roughness hardly changed. In the AFM image of the transferred Si film after Secco-etching, grain boundaries of poly-Si are clearly observed. Average grain size calculated from the AFM image was about 100 nm. These results indicate that crystalline phase transition from a-Si to poly-Si is induced at the same time as transferring Si film.

4. Conclusions

We have successfully achieved direct patterning of poly-Si thin film on quartz substrate using laser-induced backward transfer. Q-switch Nd:YAG SHG laser irradiated to the a-Si film through the quartz substrate. The laser density of energy was from1 J/cm^2 to 7 J/cm^2. In results, Si thin film can be transferred to the quartz substrate without scattering the Si film. The transferred Si film thickness at the center of the transferred film is about 35 nm. Rms surface roughness in the vicinity of the center of the transferred Si film is equal to rms surface roughness at region of the quartz substrate without Si deposition. In addition, the transferred Si film was crystallization phase transition from a-Si to poly-Si. Grain size of the poly-Si thin film was about 100 nm.

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