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Hydrogen Effect in Surface Free Technology by Laser Annealing / Ablation (SUFTLA TM)

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We have developed a new technology that we have named SUFTLA TM [1], for "surface free technology by laser annealing / ablation." This technology enables the transfer of thin film devices from an original substrate to another substrate using laser irradiation. Using this technology, we succeeded in transferring TFT backplanes for LCDs and PLEDs, thus realizing the world's first all-plastic substrate TFT-LCDs [2] and TFT-PLEDs [3]. In this paper, we will discuss the transfer mechanism on SUFTLA TM technology [4].

1. SUFTLA TM Process

Figure 1 shows the SUFTLA TM process sequence. First, a 100-nm a-Si film is deposited as an exfoliation layer by chemical vapor deposition (CVD) on a glass substrate, termed the "original substrate" herein. After that, the CMOS poly-Si TFTs are fabricated on the exfoliation layer by using a low-temperature process. The original substrate with the CMOS poly-Si TFTs is glued onto a glass substrate, termed the "first transfer substrate," using a water-soluble temporary adhesive. This adhesive is stiffened by UV light. Next, an XeCl excimer laser irradiation is performed to the original substrate from the back side. At this time, the exfoliation layer is melted and hydrogen is released. Because a-Si film deposited by CVD contains hydrogen in several %. This phenomenon reduces the adhesion between the exfoliation layer and the original substrate, and TFTs can be detached from the original substrate.

A second transfer substrate is then glued onto the back side of the TFTs using a permanent adhesive. The non-water-soluble adhesive also stiffens in UV light. We used plastic film for the second transfer substrate. The TFTs sandwiched between the first transfer substrate and the second transfer substrate are then cut and soaked in water. Since the water-soluble adhesive dissolves in water, the TFTs are peeled off from the first transfer substrate while remaining on the second substrate. In this way, TFTs and TFT-devices can be transferred from the glass substrate to plastic film.

2. Transfer Mechanism of SUFTLA TM

As mentioned above, the transfer is accomplished by ablating the exfoliation layer with laser irradiation. The minimum laser energy density that causes the ablation in the exfoliation layer is influenced by the concentration of hydrogen in the exfoliation layer.

In order to clarify the relationship between the hydrogen concentration in the exfoliation layer and the minimum laser energy density that causes the ablation, we performed the experiments described below. The 100-nm a-Si films were deposited on the quartz substrates by PE-CVD. Some of the samples were then annealed for two hours at different temperatures. The annealing temperatures varied from 300°C to 450°C. After that, the concentrations of hydrogen were measured by thermal desorption spectroscopy (TDS). As a result, it was confirmed that as-deposited a-Si film contains hydrogen of 3.49×10^{21} molecules in a cubic centimeter; that is, about 7%. The hydrogen concentration declined as the annealing temperature increased, and the number of molecules of hydrogen in a cubic centimeter decreased to 1.05×10^{20} — or about 2.1% — in the case of a-Si film annealed at 450°C.

An XeCl excimer laser was then used to irradiate these a-Si films from the back side of the substrate, after which each sample was evaluated to find the minimum laser energy density at which ablation occurred. The minimum laser energy density was found to be about 180 mJ/cm^2 at a hydrogen concentration of 2.1%. The minimum laser energy density declines as the hydrogen concentration rises, reaching 130 mJ/cm^2 at a hydrogen concentration of 7%.

3. Conclusion

We have investigated the relationship between hydrogen concentration in the exfoliation layer and the minimum laser energy density that causes the ablation. It was confirmed that the optimum laser energy density in the SUFTLA TM process is strongly dependent on the hydrogen concentration in the exfoliation layer and declines as the hydrogen concentration increases.

4. References

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[3] S. Utsunomiya, et al., SID '03 Digest, p. 864, 2003.
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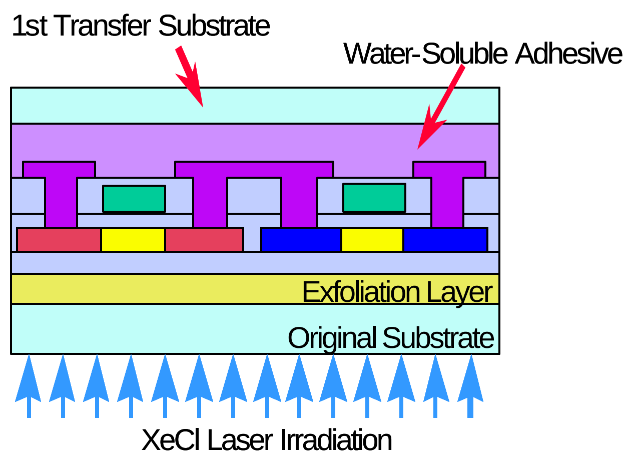

Fig. 1. Process sequence of SUFTLA TM.

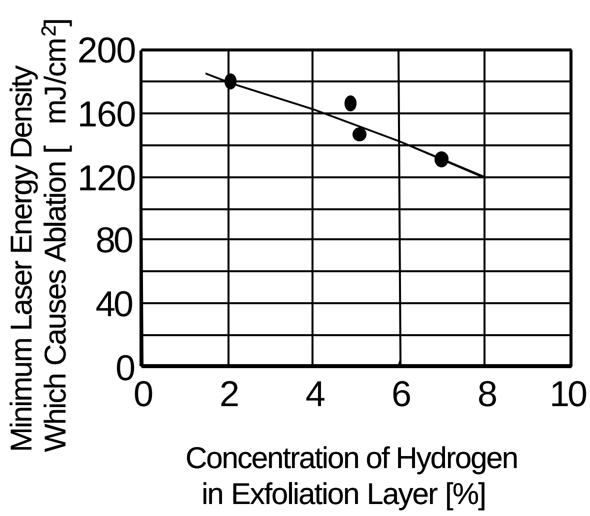

Fig. 2. Relationship between hydrogen concentration in the exfoliation layer and the minimum laser energy density which causes the ablation.