MASKLESS LASER PATTERNINTG OF METAL LINES FROM METAL POWDERS

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ABSTRACT

In this paper, a new, simple, high-speed method of selective metal deposition on glass substrates is proposed. The method is as follows: metal powder is placed on a glass substrate, then an argon ion laser is irradiated through the glass from the other side. Soda glass, Pyrex glass and silica glass were used as substrates, aluminum and copper powders, with grain sizes of 7.0μm and 4.6μm, respectively, were chosen. The beam of an argon ion laser (Coherent, DBW20) was used at 488nm wavelength, because the glasses have high transparency of visible light. Both aluminum and copper can be deposited on all the glasses. Aluminum deposited on the soda glass were 80μm - 800μm in width and 10μm - 120μm in height. The deposited aluminum and copper had high conductivity and resistances of 0.017Ω/mm - 0.64Ω/mm and 0.0014Ω/mm - 0.2Ω/mm, respectively.

INTRODUCTION

There is a growing need for the deposition of metal films on insulators that are used in devices such as SOIs (silicon on insulators), and TFT-LCDs (thin film transistor liquid crystal displays). These applications have three important requirements: high speed, fine quality and low cost.

In particular, the use of focused lasers for direct writing or maskless patterned depositions have been extensively described in the literatures, for instance: LCVD (laser-induced chemical vapor deposition) [1], LIFT (laser-assisted forward transfer)[2], laser-assisted deposition from organo-metallic solutions[3], laser enhanced electro- [4] or electroless [5] plating, and photothermal decomposition of metal-doped polymer films[6].

In this paper, a new, simple, high-speed method of selective metal deposition on glass substrates is proposed, in which metal powders placed on a glass substrate are irradiated by a laser through the glass from the other side.

The thickness and width of the deposited metal were observed as functions of scanning speed and laser power. The conductivity of deposited metal was estimated.

EXPERIMENTAL

Soda glass, Pyrex glass and silica glass were used as substrates, because they are popular materials and their thermal properties were varied as shown in Table 1. Aluminum and copper powders, with grain sizes of 7.0μm and 4.6μm, respectively, were chosen.

In the experiments, the beam of an argon ion laser (Coherent, DBW20) was used at 488nm wavelength, because the glasses have high transparency of visible light. The laser beam was focused by a convex lens, with a focal length of 170mm, down to a spot size of about 120μm. Glass substrates

Table 1 Properties of glass substrates

	Softening point ℃	Thermal expansion coefficient* *$10^{-7}K^{-1}$	Transmission rate %
Soda glass	735	99	Approximately 90
Pyrex glass	820	32	90-95
Silica glass	1600	5.5	90-95

* at 5 – 300 ℃

and metal powder were placed on an electronically controlled X-Y-Z stage, as shown in fig. 1.

Table 2 shows experimental conditions. The thickness of the metal powder layer was approximately 2mm and the power was compressed with a roller.

After irradiation, excessive or loosely adhered powder was brushed off, then the substrate was cleaned by ultrasonication.

RESULTS AND DISCUSSION

Laser irradiation of the glasses

The laser beam was focused on glass substrates, hence the glass substrates could be damaged, even when metal powder was not placed on the glass substrates. The laser beam (laser power: 7W maximum, exposure time: 60s, no scanning) was irradiated on each glass without metal powder. As a result, we found that there were no changes, except for the soda glass which became slightly warmer. Therefore, absorption of the glasses is considered to be negligible in this paper.

Irradiation of the metal powder on the glass

Glass substrates, metal powders, laser power and scanning speed were varied in deposition experiments. Both aluminum and copper were deposited on all the glasses under certain irradiation conditions. Fig. 2 shows scanning electron micrographs of the deposited metal lines at a laser power of 7W and scanning speed of 1mm/s.

These micrographs show that metal powders are deposited well. Fig.2 (a) shows aluminum deposited on soda glass. Each individual powder grain remains and cracks are observed on the glass due to rapid heating by laser irradiation and cooling. Aluminum deposited on Pyrex glass did not differ from that on soda glass. On the other hand, aluminum powder on silica glass was different from the others. In some parts of the deposited aluminum, grain shape could not be recognized. There were no cracks on the glass because silica glass has good

Table 2 Experimental conditions

Laser	Ar ion laser
Wavelength	488nm
Power	0 - 7.0 W
Beam mode	TEM_{00}
Scanning speed of moving stage	0.1 - 5.0mm/s
Substrate	Soda, Pyrex, silica glass
Thickness of substrate	2mm
Metal Powder (grain size)	Al (7μm), Cu (4.6μm)
Powder layer thickness	2mm

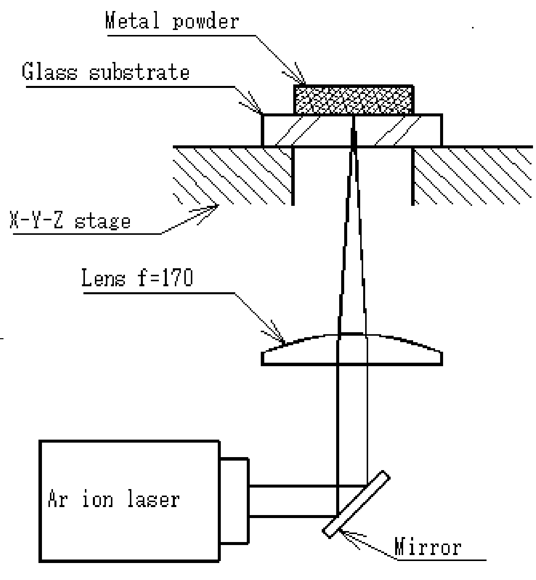
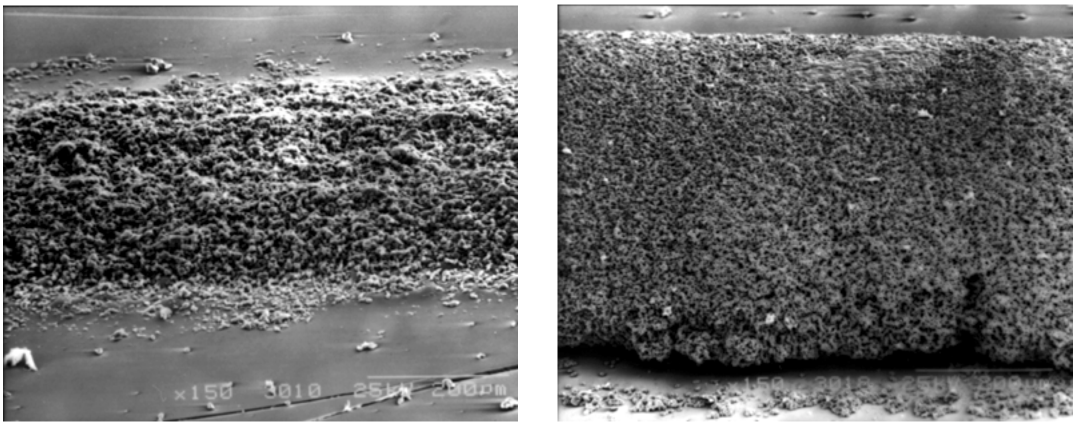
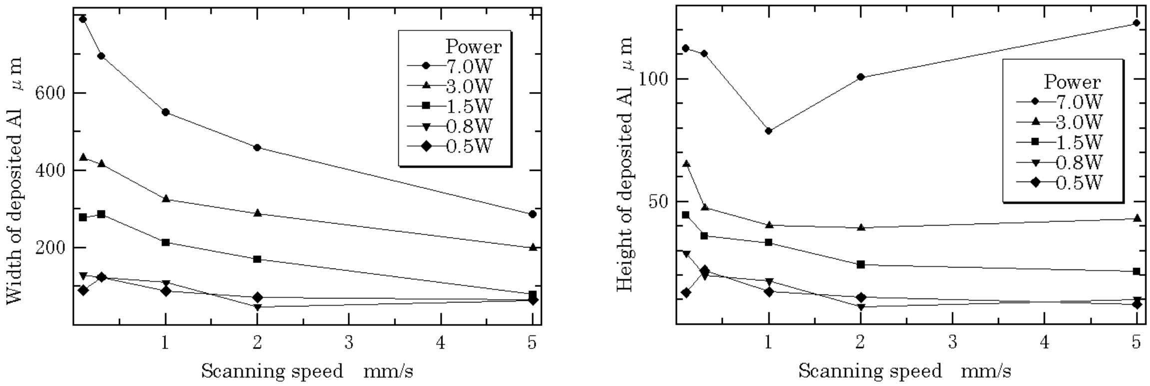


Fig.1. Illustration of the experimental setup



(a) aluminum on soda 200μm (b) copper on soda glass 200μm

Fig. 2. SEM micrographs of the deposited metals on glasses: laser power 7W,scanning speed 1.0mm/s.



(a) (b)

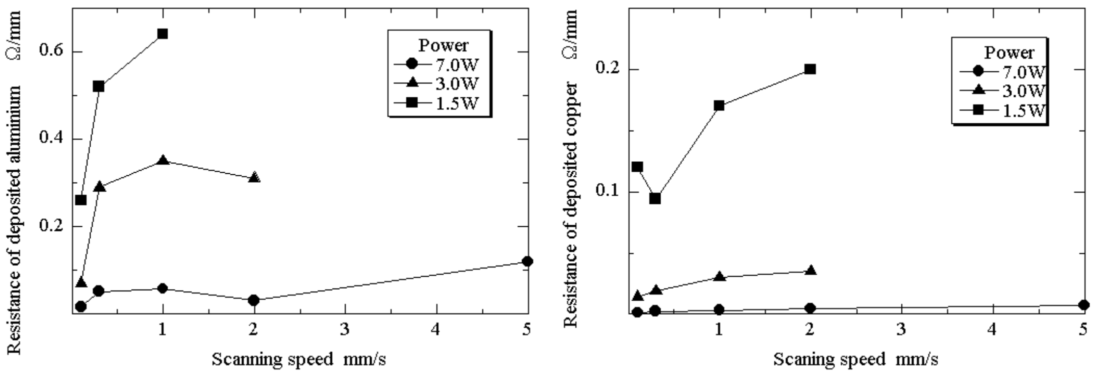
Fig. 3. Scanning speed dependence of the thickness and width of the deposited line

thermal protection. Copper deposited on soda glass is shown in fig.2 (b). Detachment is recognized at the interface of the glass substrate and the deposited copper.

Influence of the laser power and scanning speed was investigated in each glass and powder. Metal powder deposited on glasses better with increasing laser power and decreasing scanning speed. Aluminum was conductive on any glass. Copper was also deposited on all three types of glass, but adhesion strength on silica glass was poor, so the deposited copper was easily detached during brushing or washing in an ultrasonic bath. Copper deposited on soda glass and Pyrex glass was conductive, but on silica glass it was not conductive under any condition. Both metals adhered strongest to the soda glass and poorest to the silica glass. This result was due to a difference in the softening point.

Width and height of the deposited aluminum on the soda glass were measured using an optical microscope, and results are shown in fig.3. As scanning speed became slower and laser power became larger, both width and height became larger. However, width was not smaller than 80μm because the diameter of the laser spot was approximately 120μm.

Resistance values of the deposited metal were measured by the double bridge method. They



(a) aluminum on soda glass (b) copper on soda glass

Fig. 4. Resistance of metal lines as a function of scanning speed and laser power

could be divided into good conductor (<1Ω/mm) and poor conductor(>1MΩ/mm). When the deposited metals were poor conductors, there were gaps in the deposited metals. For the deposited aluminum and copper having good conductivity, resistance values are shown in fig. 4. That of aluminum was 0.017Ω/mm - 0.64Ω/mm, and that of copper was 0.0014Ω/mm - 0.2Ω/mm. In both cases, resistance values decreased with increasing laser power and decreasing scanning speed.

CONCLUSIONS

A novel method of metal deposition on glass substrates is proposed. The method is as follows: metal powder is placed on a glass substrate, then an argon ion laser is irradiated through the glass from the other side. Aluminum and copper can be deposited on soda, Pyrex and silica glass. The deposited aluminum and copper had high conductivity and resistances of 0.017Ω/mm - 0.64Ω/mm and 0.0014Ω/mm - 0.2Ω/mm, respectively.

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