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DIRECT LASER WRITING OF CONDUCTIVE STRUCTURES ON INDIUM TIN OXIDE

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Investigations on the laser-induced reduction of indium tin oxide (ITO) are presented. Here, the oxygen content of the material is locally decreased by CW YAG:Nd laser irradiation in hydrogen atmosphere. The dependences of resistance of metallized stripes versus laser beam power and beam scanning velocity are shown. Electrical conductivity of laser-written stripes was estimated 2–3 orders higher with respect to raw ITO film conductivity.

Keywords: laser processing, direct laser writing, laser-assisted reduction

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1. Introduction

Indium tin oxide (ITO) is one of the most widely used transparent conducting oxides for optoelectronic devices, flat panel displays and sensors, as it combines good electrical conductivity with high transparency in the visible range [1–3].

Laser processing, including direct laser writing, is based on the interaction of intense laser radiation with either the material surface or/and with the ambient medium surrounding this material [4]. The microscopic mechanism of excitation can be photothermal or photochemical in nature.

We had reported that oxygen content of advanced ceramic materials can be locally reduced by CW YAG:Nd laser irradiation in hydrogen atmosphere [5, 6]. Here a similar method has been presented to produce metallized stripes on to ITO surface.

2. Experimental procedure

Indium tin oxide thin films were obtained by reactive magnetron sputtering from metallic source. The target was a 20 cm diameter In (92%) and Sn (8% by weight). Alloy In–Sn was melt in argon atmosphere by using quartz crucible. Films (400 nm in thickness) were deposited on glass (K-8) substrates. The substrates were cleaned in an ultrasonic cleaner for 10 min with acetone and then methanol. All substrates were blown dry with nitrogen gas before they were introduced into the deposition system. The structure of a thin ITO film is microcrystallic, with small metallic (In) islands.

For laser processing the ITO samples were placed into a reaction chamber, which has been operated with constant pressure of hydrogen 1.5 bar. Laser-induced reduction and alloying was then achieved by focusing the irradiation of CW YAG:Nd (1064 nm wavelength) laser beam onto the sample surface. In the present experiments the diameter of the beam waist was $2\omega_0 = 20$ μm at $1/\mathrm{e}^2$ intensity. For direct laser writing the laser beam was translated perpendicularly to sample surface with PC programmable $x{-}y$ stage. The conducting stripes were characterized by optical microscope, the resistance per length of stripe was measured by using a standard four-probe technique at room temperature.

The conducting stripes were characterized by optical microscope, the resistance per length of stripe was measured by using a standard four-probe technique at room temperature. We have used ITO samples with medium range conductivity ($\approx$10 kΩ·cm) 100–1000 times lower compared to laser metallized stripes. It allows one to use in the first approximation the four-probe method for resistance measurements.

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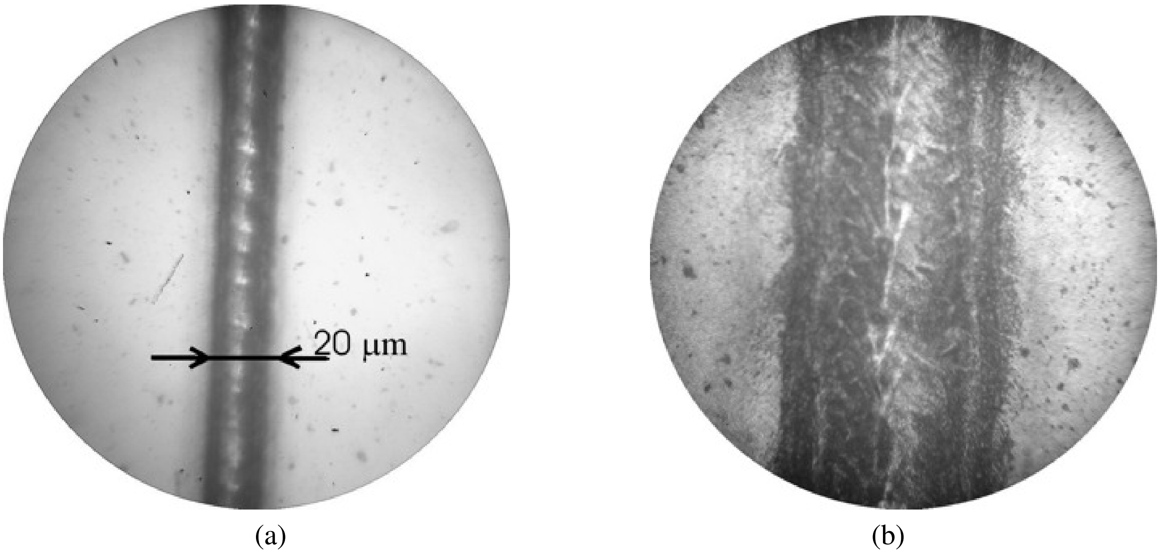


Fig. 1. Metallized stripes on ITO. The ambient atmosphere was 1.5 bar H_2, laser power ≈6.5 W, and scanning velocity 51 μm/s.

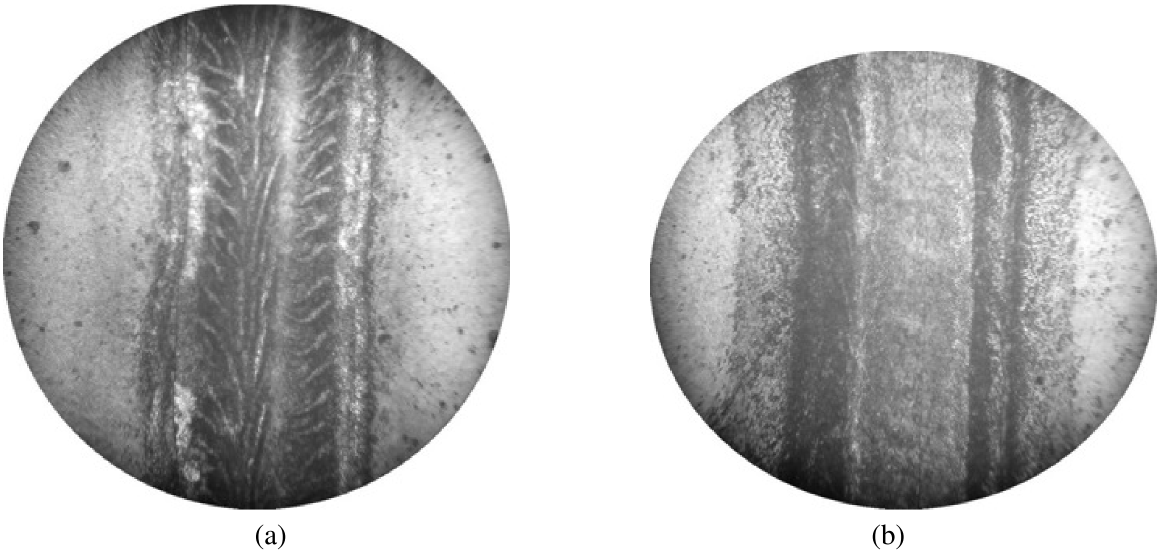


Fig. 2. Metallized stripes on ITO. The ambient atmosphere was 1.5 bar H_2, laser power ≈6.5 W, and scanning velocity (a) 84 μm/s and (b) 244 μm/s.

3. Results

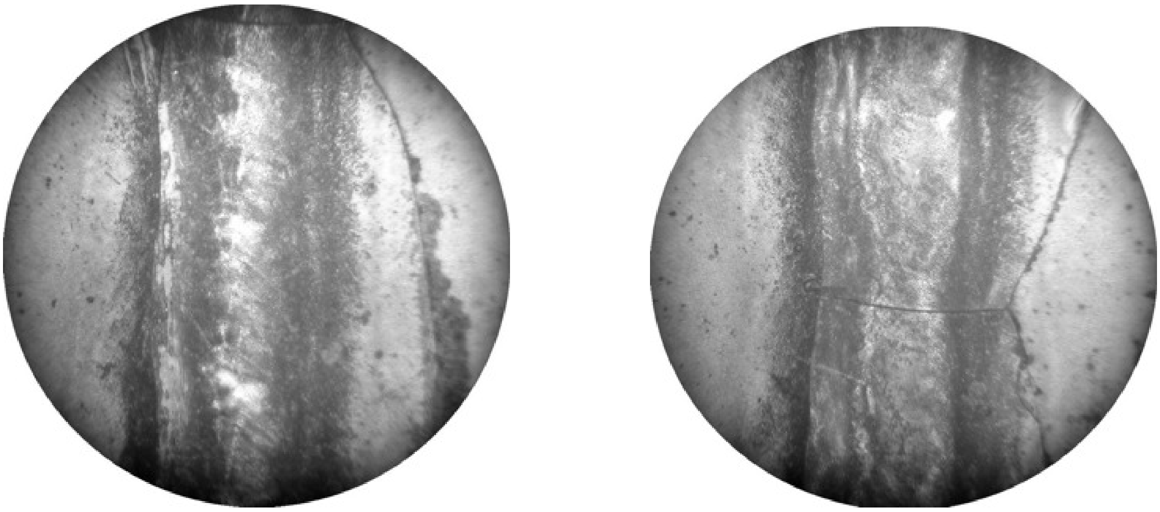
We have demonstrated laser-induced metallization of ITO (Figs. 1–3). The dependence of resistance of stripes from laser beam power and beam scanning velocity are shown in Fig. 4. The electrical conductivity of laser-written stripes due to reduction in hydrogen ambient was estimated 2–3 orders higher with respect to raw ITO film conductivity.

Here, the hydrogen pressure is 1.5 bar, different laser power and scanning velocity has been used. With low and medium laser powers (1–7 W) strong surface reduction of material takes place. When the laser power is further increased, destruction of the sample surface was observed (Fig. 3), which evidently leads to conductivity decrease.

Experimental data show that the resistance of the conducting stripes depends strongly upon from processing parameters: laser beam power and scanning velocity. For higher conductivity of stripes it is necessary to use higher light power and longer reaction time with respect to diffusion processes and melting of reduced ITO.

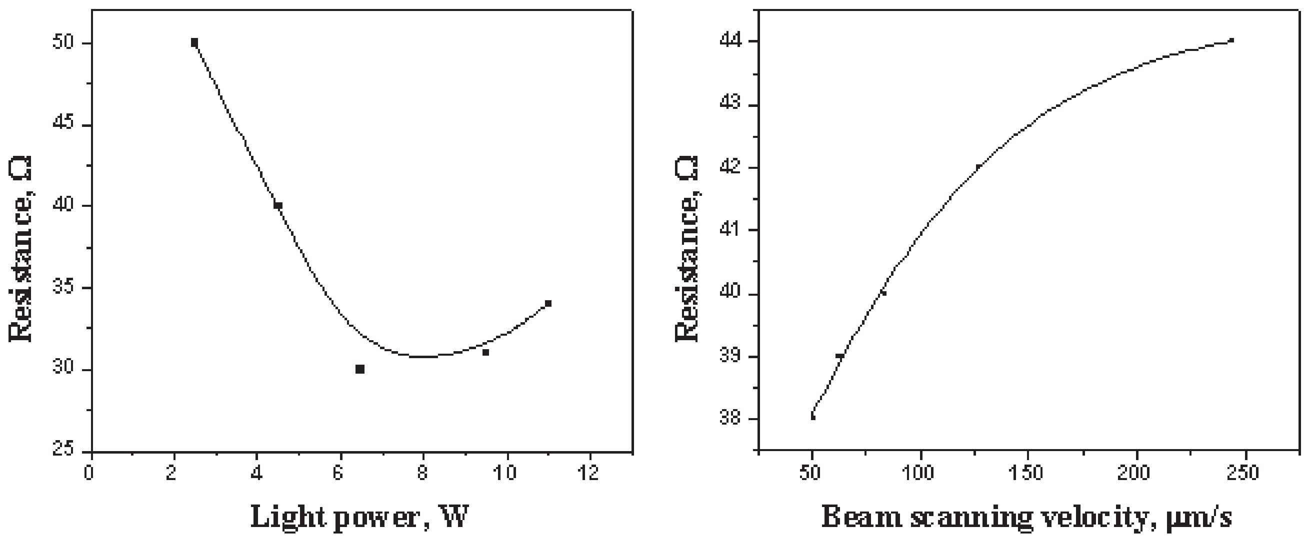
4. Conclusions

We have presented single-step direct laser writing of electrically conducting patterns onto indium tin oxide



(a) (b)

Fig. 3. Metallized stripes on ITO. The ambient atmosphere was 1.5 bar H_2, laser power ≈9.5 W, and scanning velocity (a) 51 μm/s and (b) 127 μm/s.



(a) (b)

Fig. 4. Resistance of metallized stripes versus (a) laser beam power and (b) beam scanning velocity.

surface. The process is believed to be based on photothermally activated diffusion and removal of oxygen from the sample surface. Because of strong influence of oxygen content on the resistance of ITO, this technique permits one to draw conducting electrode structures.

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TIESIOGINIS LAIDŽIŲJŲ SANDARŲ IŠDEGINIMAS LAZERIU ANT INDŽIO ALAVO OKSIDO

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Santrauka

Tirta indžio alavo oksido redukcija švitinant lazerio spinduliu. Deguonies koncentraciją pavyksta lokaliai sumažinti švitinant YAG:Nd lazeriu vandenilio atmosferoje. Gauta metalizuotų juostelių varžos priklausomybė nuo lazerio spinduliuotės galios ir spindulio slinkties greičio. Rasta, kad lazeriu išdegintų juostelių laidumas yra 2–3 eilėmis didesnis, nei pradinės nešvitintos plėvelės.