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Influence of femtosecond surface modification of TiO_2 layer to features of organic solar cell

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Abstract: In this research 300 fs pulses of Yb:KGW laser has been applied to form electron transport layer TiO_2 of Grätzel type organic solar cells (OSC) with different surface roughness. Profiler, AFM, SEM has been used to define surfaces. Scattering of 532 nm wavelength light from ablated regions has been measured. OSC have been formed onto TiO_2 and I-V characteristics have been measured. Investigation results demonstrated that laser treatment of TiO_2 has impact to the I-V dependencies of OSC.

1. Motivation

In 1991 dye – sensitized solar cells based on TiO_2 were discovered [1]. Since then different approaches has been made to enhance external efficiency coefficient [2–4]. Enhancement of energy conversion efficiency and better long term stability has been observed when freestanding scattering film was used in dye–sensitized solar cells [5]. It was demonstrated that not only optical and electronic properties but also surface morphology of layers of solar cell influence effectiveness of OSC [6]. In present work we have used femtosecond laser pulses to create different surface morphologies of TiO_2, and light scattering measurement results showed that scattering depends on surface morphology.

2. Experiment

TiO_2 layers were prepared from commercially available paste 13 nm, Ti-nano-oxide. TiO_2 layers were formed on glass substrates with ITO layer. Third harmonics (λ=343 nm) of femtosecond Yb:KGW laser (pulse duration τ= 300 fs) have been used to create different TiO_2 surface roughness. The surfaces have been characterized using profiler, SEM and AFM. Scattering of λ=532 nm beam going through different laser treated substrates were mapped. Integrating sphere, translation stages and photo coupler were used to characterize scattering of 532 nm light of substrates with different TiO_2 surface roughness. The dye and 2,2-diphenylethenyl substituted triphenylamine (hole transport materials - 10^{-3} cm^2/Vs mobility of holes) organic layers have been vacuum deposited or spin coated from solution on TiO_2 layers. Finally, the metal electrodes have been vacuum deposited onto the top of structures and the OSC structures on unaffected and laser ablated TiO_2 regions were formed (figure 1).

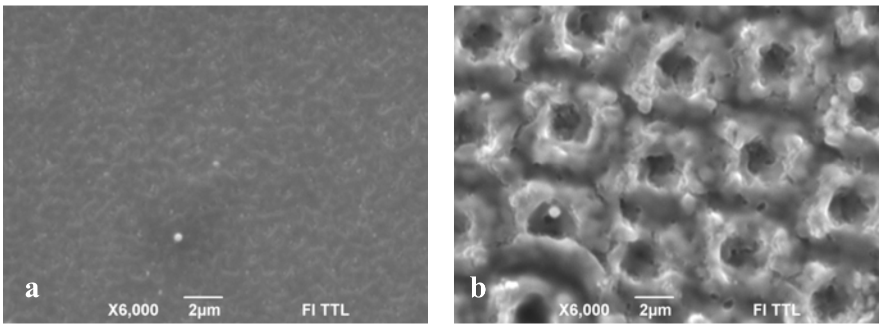

Fig. 1. a) Metal (Au) electrode in area where TiO_2 is unaffected. b) Metal (Au) electrode in area where TiO_2 is laser ablated.

The photoelectric features of so formed OSC structures have been investigated by measuring I-V characteristics in the dark and under illumination by AM1.5 light source.

3. Results

Figure 2a shows that changing laser ablation conditions may lead to enhancement of scattered light in TiO_2 layer. Currently in figure 2a distances between centers of areas ablated by single pulse are kept 40 µm. Light scattering maps are shown where pulse energies are 2.49 µJ; 3.32 µJ; 4.15 µJ. Figure 2b shows I-V characteristics of a same sample. Each sample has few electrodes on top of laser ablated TiO_2 area and few on non-ablated. This helps to evaluate laser treatment impact with identical conditions. OSC with laser ablated zone gives short circuit current Isc = 0,3 µA, i.e. higher if compare to non-ablated region.

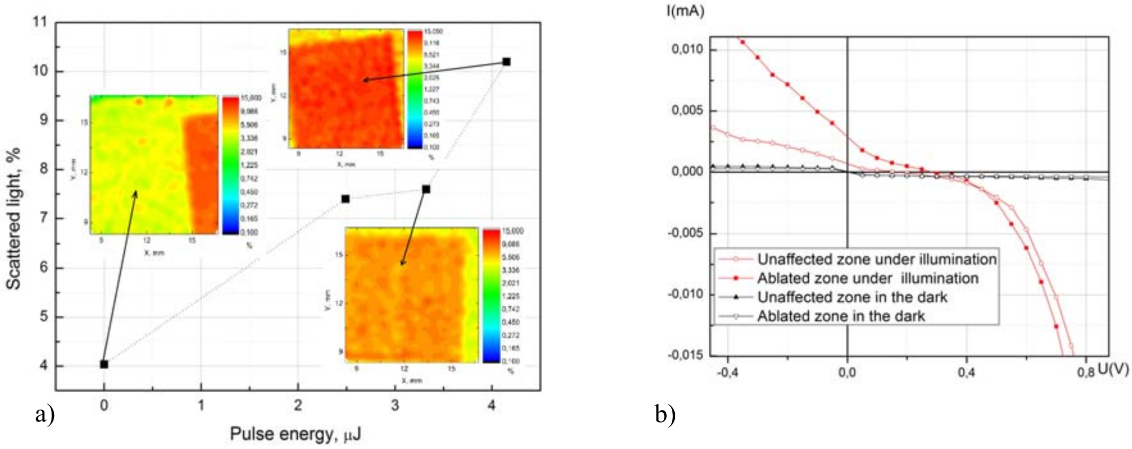

Fig. 2. a) Scattered light in TiO_2 layer dependency on pulse energy. b) I-V characteristics of the same sample, ablated and non-ablated regions under illumination and in the dark.

4. Conclusions

Areas of TiO_2 that were ablated by femtosecond pulses of light demonstrated higher surface root-mean-square roughness (R_a). These regions also scatter more light comparing to non-ablated areas. Proper combination of R_a of TiO_2 layer and, consequently, amount of scattered light may lead to higher external efficiency coefficient of OSC.

4. References

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