FORMATION OF P-N JUNCTION IN ITO/P-Si STRUCTURE BY Nd:YAG LASER RADIATION FOR SOLAR CELLS APPLICATION

A.Medvid[1], P.Onufrievs[1], E.Dauksta[1], L.Blumbeka[1], J.Barloti[1], A.Ulyashin[2], I. Dmytruk[3], I. Pundyk[3]

[1] Riga Technical University, Latvia, [2]SINTEF, Oslo, Norway, [3]Kyiv National University, Ukraine

Abstract

The research report is devoted to the development of a new method of nanostructures formation in ITO/p-Si/Al structure with powerful laser radiation and study of its optical and electrical properties for solar cells applications. It was showed that after the structure irradiation by the second harmonic of Nd:YAG laser, dark current voltage characteristics become diode-like. Increase of ITO/p-Si/Al structure power after irradiation by laser, using photocurrent voltage characteristic method, was shown.

Key words: *ITO/p-Si/Al, nanostructures, solar cells*

Introduction

Indium–tin-oxide (ITO) thin films are widely used as transparent conductive oxide (TCO) in optoelectronics devices such as solar cells [1], liquid crystal displays (LCD) and plasma display panels. This material have high transmittance in the visible region of spectra [2], surface uniformity and process compatibility [3]. ITO is a perspective material for elaboration a new generation of solar cells using nanotechnology.

In this paper, ITO/p-Si/Al structure have been irradiated by Nd:YAG laser with the aim to form a p-n junction in structure and to grow of nanohills on a surface of Si in which Quantum confinement effect (QCE) takes place.

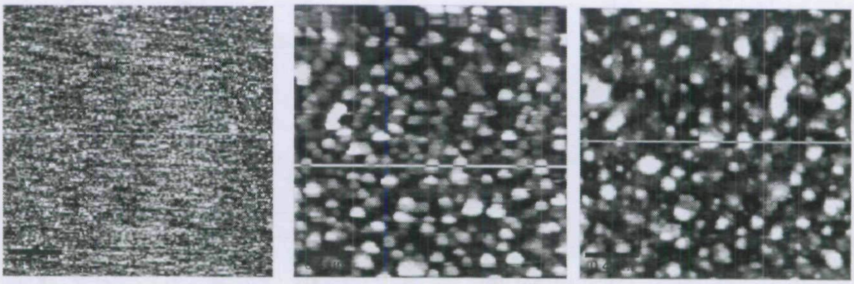
Experimental details

ITO/p-Si/Al structures, where ITO top layer was 70 nm thin, Si layer - 500μm and Al layer - 100 nm in the experiments were used. The surface of the structures from ITO side was irradiated by second harmonic of Nd:YAG laser radiation (LR) (λ = 512 nm, τ = 10 ns). The irradiated structures were studied by atomic force microscope (AFM), photoluminescence (PL) spectroscopy. The measurements of current - voltage (I-V) characteristic were done to observe the changes of electrical parameters for ITO/p-Si/Al structure after irradiation by laser.

Results and discussions

ITO/p-Si/Al structure have been irradiated by Nd:YAG laser with the aim to form a p-n junction ar the surface of Si and to grow of nanohills on a surface of Si in which QCE takes place [4]. On p-type Si, the n-type Si layer was formed as a result of interstitial Si atoms drift to towards the irradiated surface due to huge gradient of temperature induced by LR [5].

The three-dimensional surface morphology of ITO/p-Si structure was measured by AFM before and after irradiation by the Nd:YAG laser at intensities of 1.13 MW/cm^2 and 2.83 MW/cm^2 (Fig.1). Nanohills were observed of the average heights 12 nm and 26 nm formed by laser radiation at the intensity of 1.13 MW/cm^2, and 2.83 MW/cm^2, respectively.



a b c

Fig.1. 3D AFM images of ITO/p-Si structure: a- before, after irradiation by the Nd:YAG laser at intensities of b -1.13 MW/cm^2 and c -2.83 MW/cm^2

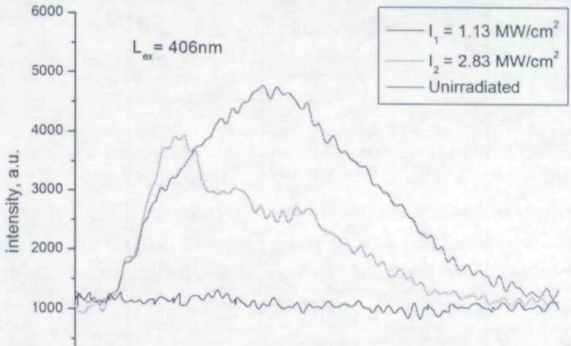


Fig.2. PL spectra of ITO/p-Si/Al structure: before and after irradiation by the Nd:YAG laser.

PL spectra of the ITO/p-Si structures with the maxima at 490 – 575 nm obtained after laser irradiation at intensities of 1.13 MW/cm^2 and 2.83 MW/cm^2

are shown in Fig.2. Position of the observed PL peak compared with the bulk Si shows a significant "blue shift". The maxima of the PL band at 490 – 575 nm are explained by presence of the QCE [6].

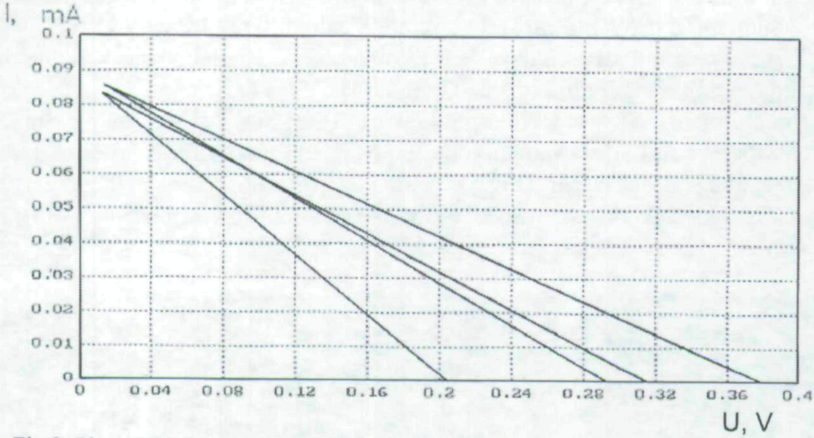


Fig.3. Photo I-V characteristics of ITO/p-Si/Al before and after irradiation by laser.

After irradiation of ITO/p-Si/Al structure by laser, photocurrent power increased by two times comparison to the nonirradiated structure. This effect is explained by QCE in nanohills. It means Si band gap is increased.
It is found that dark I-V characteristic becomes diode-like with rectification coefficient $K = 10^5$ at 5 V cause of laser irradiation with intensity I = 2.83 MW/cm^2. The improvements of ITO/p-Si/Al structure as solar cell can be explained by increase of potential barrier between ITO an p-Si layers.

Conclusion

1. The possibility of p-n junction and Si nanohills formation by laser irradiation in ITO/p-Si/Al structure is shown.
2. The photoluminescence spectra from irradiated ITO/Si/Al structure by laser irradiation have been found in visible range of spectra.
3. By I-V characteristic it is shown, that it becomes diode-like with rectification coefficient $K = 10^5$ at 5 V caused of laser irradiation with intensity I = 2.83 MW/cm^2.
4. After irradiation of ITO/p-Si/Al structure by laser, photocurrent power increased by two times comparison to the nonirradiated structure.

References

1. L. Bruk. V. Fedorov. D. Sherban. A. Simashkevich. I. Usatii. E. Bobeico and P. Morvillo. CURRENT TRANSPORT MECHANISMS IN ITO/nSI STRUCTURES. - Materials Science and Engineering: B,159-160, 2009, 282-285 p.

2. F.O. Adurodijaa. H. Izumia. T. Ishiharaa. H. Yoshiokaa. M. Motoyamaa. K. Muraib. - Effect of laser irradiation on the properties of indium tin oxide films deposited at room temperature by pulsed laser deposition. Vacuum, 67, 2002, 209-216 p.

3. R. Blasundaraprabhu, E.V. Monakhov, N. Muthukumarasamy, O.Nilsen, B.G. Svensson. - Effect of heat treatment on ITO film properties and ITO/p-Si interface Materials Chemistry and Physics, 114, 2009, 425-429. p.

4. A. Medvid', Y. Fukuda, A. Michko, P. Onufrijevs. Laser induced self–assembling formation of semiconductors nanohills for nanoelectronic and optoelectronic applications. - Appl. Surf. Sci. 244/1-4, 2005, 120 p.

5. A. Medvid'. Redistribution of the Point Defects in Crystalline Lattice of Semiconductor in Nonhomogeneous. - Temperature Field Defects and Diffusion, 210, 2002, 89 p.

6. L. E. Brus, Electron-electron and Electron-Hole Interactions in Small Semiconductor Crystallites: The Size Dependence of the Lowest Excited Electronic State. - J. Chem. Phys. 80, 1984, 4403-4409. p.