CHARACTERISTICS OF GALLIUM ARSENIDE SOLAR CELLS AT HIGH TEMPERATURE

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Abstract: This article reviews a work on processing of gallium arsenide (GaAs) solar cells. The performance of the cells before and after 300 °C thermal processing was correlated with topography identified by optical camera, atomic force microscope (AFM) and scanning electron microscope (SEM). Experiment indicates insignificant changes in topography of GaAs solar cells, but electrical characteristics show an excellent resistance of the samples to processing temperature.

Keywords: GaAs, solar cells, processing, topography, SEM, AFM

1 INTRODUCTION

Solar cell is an optoelectronic device that can directly convert solar energy into electrical. The examination of the behavior of solar cells with temperature is important in terrestrial or even in space applications. They are commonly exposed to temperatures up to 50 °C and higher values so their durability is very important.

Solar cells on the basis of gallium arsenide (GaAs) were developed in the early 1970s. Their unique advantages are great robust to UV radiation and moisture with direct band gap to allow efficient photon absorption. For single junction devices it has extreme energy efficiency close to 30 % [1], because of their good toughness to UV radiation and high temperatures they're commonly used in outer space applications such as satellites or robotic rovers [2]. Disadvantage of these solar cells is the higher production price.

Potential-induced degradation (PID) has attracted much attention in recent days since drastic reduction in output power occurs within relatively short period, for example, several months or a few years. Result of this phenomenon is always the cell degradation and lower power efficiency and has a significant impact on the solar cell life. Amount of this degradation depends on the type of irradiation and material of solar cells [3]. PID phenomena have been sometimes reported in mega-watt scale photovoltaic (PV) power plant and much effort has been devoted to clarifying the mechanism of PID and also to developing the PID-resistant PV modules.

Thermal processing is one of the methods for solar cells stability testing by heating of the sample to a certain temperature to investigation of its influence on the sample. This operation can simulate a various real working conditions and also accelerate the aging process of the specimen. It is a core experimental method in this study [4].

2 MATERIALS AND METHODS

All of the following measurements were performed with two samples of GaAs before and after thermal processing. Duration of this processing did not exceed 10 minutes at 300 °C. Specimens have

been measured by several microscopic methods which are mentioned in this chapter bellow and specific results before and after processing are discussed at the end of the study.

Sollar cells for this study are identical to those which are used in real satellite constellation. They are single-junction gallium arsenide on germanium substrate (figure 1) obtained via the metalorganic chemical vapor deposition (MOCVD) process. Before this measurement cells were tested for open circuit voltage, for fill factor and efficiency in conversion sunlight into electricity >16% at Am0 condition, which means that cells was used for space power applications with zero atmospheres.

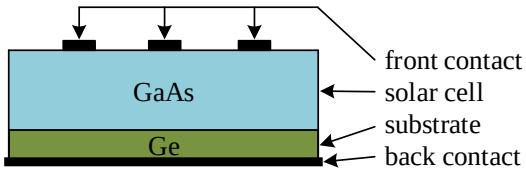
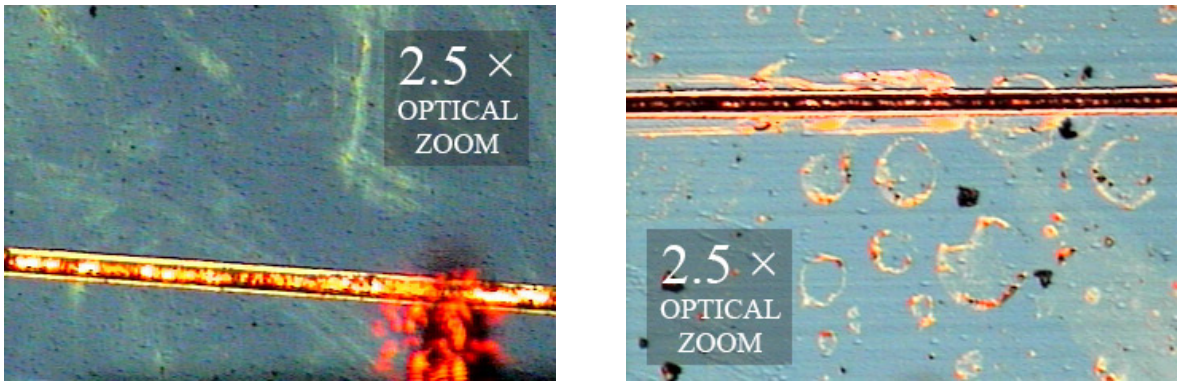


Figure 1: Cross-section of the sample.

2.1 Atomic Force Microscopy

Atomic force microscope is type of scanning probe microscopy (SPM). Information is collected by "touching" the specimen surface with a mechanical tip. Deflection of the probe is detected by laser. This tip is a sharp 3-6 µm tall pyramid tip with radius about 10 nm. Tip is moving in raster over a surface using a moving stage and feedback loop. Method is commonly used to achieve an image of the precisely three-dimensional topography. Image could be processed for better observation. There is no need to special sample preparation [5].

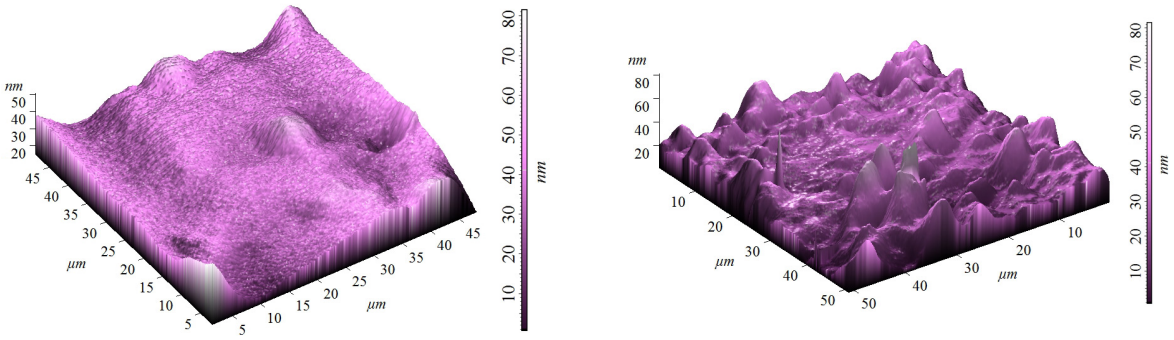
AFM has attached a light microscope which was also used for detection of surface changes and specimen position. Figure 2 bellow shows a surface with a contact at the same location of solar cell.



a) b)

Figure 2: Contact on the surface of GaAs solar cell under the light microscope a) before and b) after thermal processing.

Results obtained from the AFM are presented in figure 3 in three-dimensional images with structured surfaces. They are colored for better area highlighting. The measured surface area is about 50 µm.

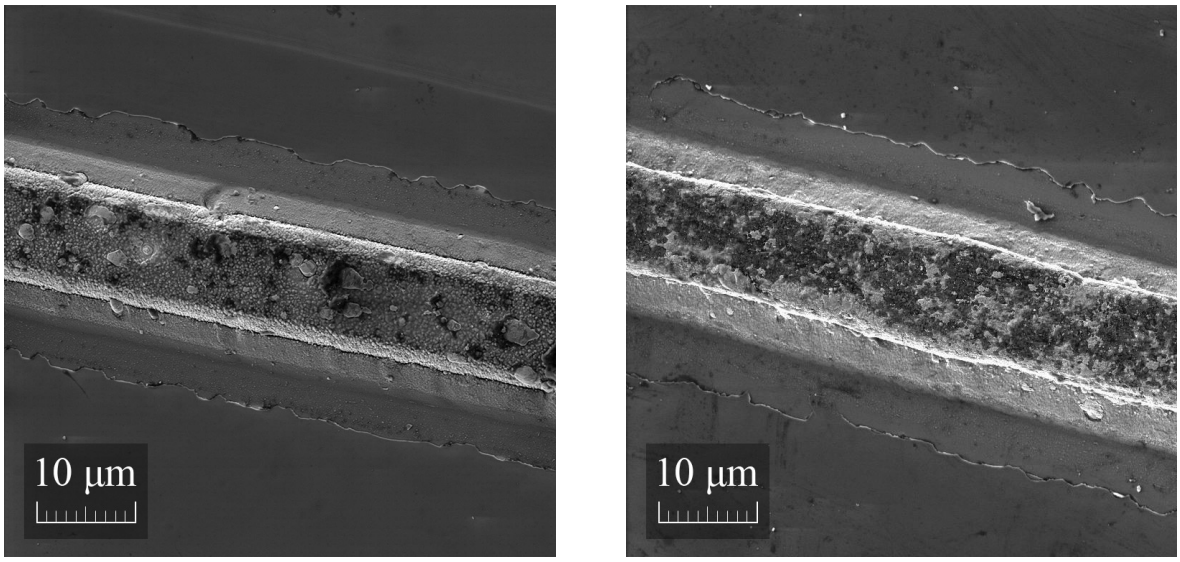


a) b)

Figure 3: Surface of GaAs solar cell in three-dimensional representation under the AFM a) before and b) after thermal processing.

2.2 Scanning Electron Microscopy

Scanning electron microscope is an instrument for high-resolution imaging of specimens surface that utilizes a beam of electrons instead of light. It works in vacuum condition and good conductivity of the sample is preferred. Non-conductive material should be covered by a thin-film of metal. It is desirable that specimen is electrically conducting and solid [6].

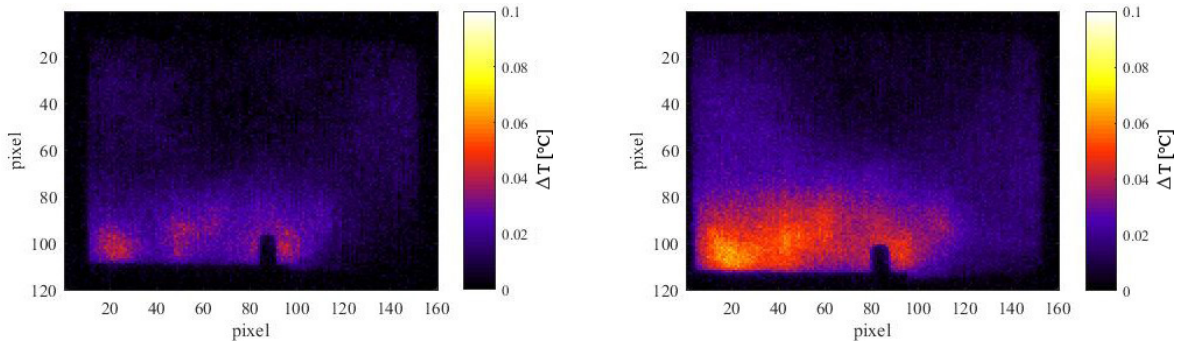


a) b)

Figure 4: Surface of GaAs solar cell under the SEM a) before and b) after thermal processing.

2.3 Infrared camera

Camera was used to determine the thermal radiating defected areas under reverse-bias condition. To reduce a noise the resulting images were averaged. For sample listed below it was 580 elemental pictures with current 20 mA. Diferential temperature changes are observed.

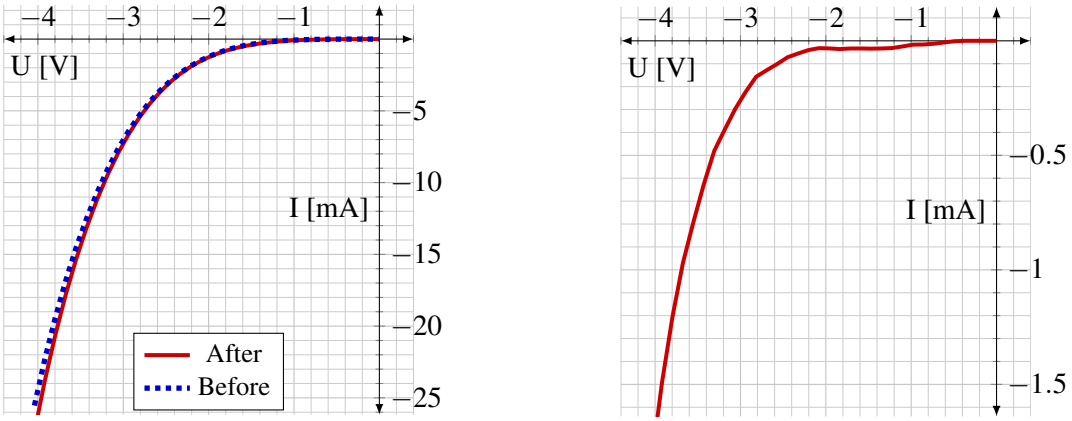


a) b)

Figure 5: Heating process of GaAs solar cell under the constant bias-conditions a) before and b) after thermal processing.

2.4 CURRENT-VOLTAGE CHARACTERISTICS

I-V characteristics was measured in a conductive box between two metal plates that serve as probes for the samples. Figure 6 ilustrate solar cell in a reverse current direction. Dotted line represents the sample before thermal processing and continuous line means that sample wasn't processed yet. As can be seen characteristics was measured in a reverse current.



I-V characteristics after and before processing. Relative changes after the thermal processing.

Figure 6: Current-voltage curves in a reverse direction.

3 CONCLUSION

After ten minutes of processing at 300 °C it was possible to observe the following events: In figure 2 under a light microscope which is attached at AFM we can see newly created crater formations. Processing also caused a shape elevation and increased rate of surface features in figure 3b. Likewise it has occurred metal degradation on the top of contacts of solar cell (figure 4). In measurment with infrared camera has deteriorated degraded areas and began to radiate more heat. Surprisingly pn-junction has remained unaffected in same effectivity level. This was verified by measuring the solar cell and its current-voltage characteristics are shown in figures 6a and 6b. In this case it can be concluded that during extended periods and higher temperatures, solar cells began to lose their effectiveness.

It was subjected to the test several gallium arsenide solar cells in this study . After aging at temper-

atures at 300 °C it was confirmed a high operational and electrical properties of this cells. Even if pn-junction was not aparently degraded, there was revealed a deterioration in surface characteristics.

ACKNOWLEDGEMENT

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