# MORPHOLOGICAL STRUCTURE OF SOLAR CELLS BASED ON SILICON AND GALLIUM ARSENIDE AFTER ION ETCHING

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**Abstract**: Study deals with the investigation of the surface after ion etching on two types of solar cells – based on widely available polycrystalline silicon and on durable gallium arsenide for use in more demanding environments. Solar cell morphology was compared using an electron microscope together with an Energy Dispersive X-ray detector to show distribution ratios of elements. Atomic force microscopy was used to accurately describe the heights and roughness structure. Raman spectroscopy to study of vibrational properties and the stress investigations.

**Keywords**: RIE, GaAs, Si, ion bombardment, EDX, SEM, AFM

## 1 INTRODUCTION

Silicon-based solar cells are generally known as the most widely used type of cells with excellent efficiency in price-performance ratio. Also, arsenide gallium solar cells excel in their efficiency, but their purchase price are already considerably higher, mainly because of the material used. This GaAs material has excellent durability in difficult environments and, unlike silicon, is highly resistant to extreme temperatures or irradiation, it is also very light and thin. Thanks to such properties, these solar cells find use in specialized areas in demanding environments.

This study finds its application especially in understanding the changes in the morphological structure of these two types of solar cells. It has been shown that at some stage of surface treatment by ion bombardment the solar cell reduces the reflectanc, thus increasing efficiency, therefore, it is not always a degradation process [1, 3]. However, this study is mainly focused on topology and surface structure and compares these two solar cells before and after reactive ion etching (RIE) in the field of morphological properties.

## 2 MATERIALS AND METHODS

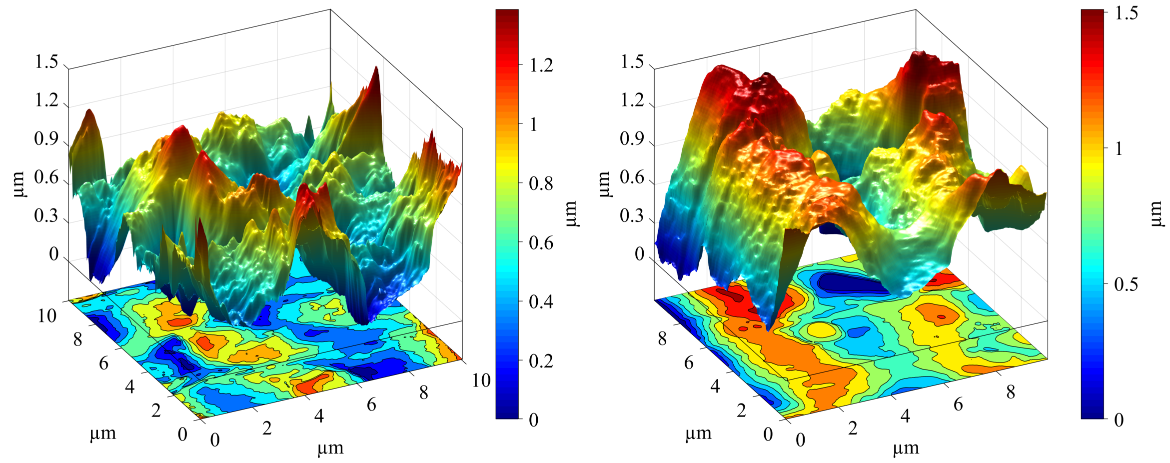
Selected specimens did not require any special preparation and were subjected by ultrasonic cleaning in isopropyl alcohol for seamless surface analysis, which is required for the measurement of the instruments we have chosen. Using all of the following methods, the samples were examined and compared before and after the etching. Polycrystalline c-Si cells and single-junction GaAs cells with Ge substrate and doped Al were selected. Gallium arsenide solar cell is a III-V semiconductor compound obtained by combining group III elements with group V elements. Crystalline silicon cell belongs to the group IV of semiconductor materials [4].

Ion bombardment was carried out using chemically reactive plasma, one of the types of dry etching. For processing, the PlasmaPro 100 Cobra ICP Etch system was used with RF power of 200 W and pressure of 40 mTorr. Reactant gases of sulfur hexafluoride ($SF_6$ = 8.5 SCCM), oxygen ($O_2$ = 12.5 SCCM)) and chlorine ($Cl_2$ = 2 SCCM)) were injected [2].

The X-Max 50 EDS detector (EDX) from Oxford Instruments and the Tescan's LYRA3 electron microscope were used to determine the element concentration. For scanning the surface structure by the NTEGRA Prima microscope (AFM), we also investigated the $S$ parameters, which are the parameters indicating the average material roughness $S_{\mathrm{a}}$, root mean square $S_{\mathrm{q}}$, skewness $S_{\mathrm{sk}}$ and kurtosis $S_{\mathrm{ku}}$ of the features. Renishaw inVia was used as a Raman microscope.

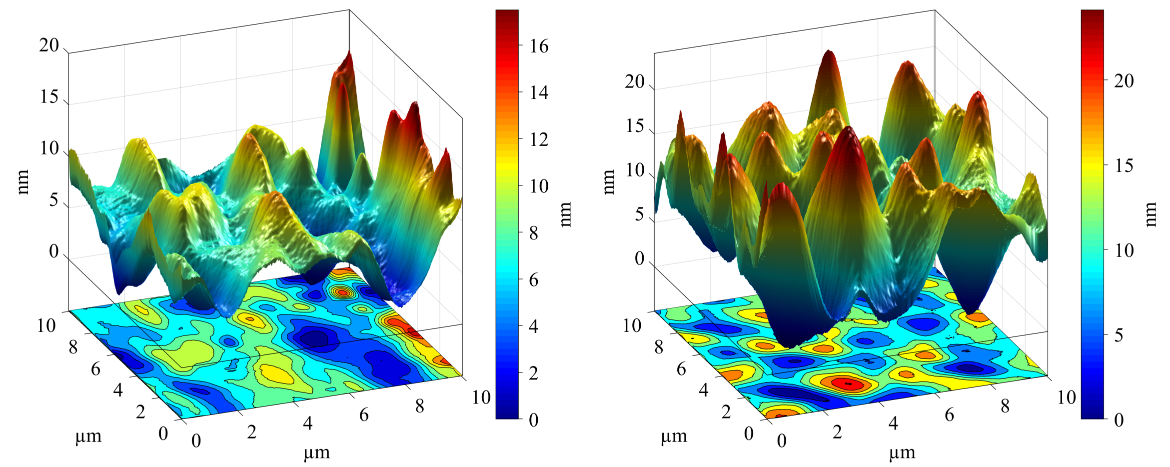
## 3 RESULTS

From the images in Figures 1 and 2 it is noticeable that the two types of solar cell have a very different structure. The main difference is at altitude – while the Si based solar cell sample has heights of up to 1.5 µm, the GaAs cell heights are only within 20 nm.




a) b)

**Figure 1:** The surface of Si solar cell under the AFM microscope a) before and b) after RIE etching.




a) b)

**Figure 2:** The surface of GaAs solar cell under the AFM microscope a) before and b) after RIE etching.

A relatively distinct difference in morphology is seen in Figure 1b for the Si cell, where RIE etching decreased the occurence and frequency of the height point of features, whereas Figure 2b in the GaAs sample are multiplied the number of these features. These findings can also be confirmed from Table 1 and 2 for $S_{ku}$ parameters, where this coefficient for each material is the opposite. In both cases, the roughness and root mean square of material also increased after the etching, while the skewness coefficient decreased [5, 6].

| | $S_a$ [nm] | $S_q$ [nm] | $S_{sk}$ [–] | $S_{ku}$ [–] |
|---|---|---|---|---|
| Before etching | 186.6 | 228.9 | 0.139 | −0.386 |
| After etching | 233.2 | 292.9 | −0.514 | 0.189 |

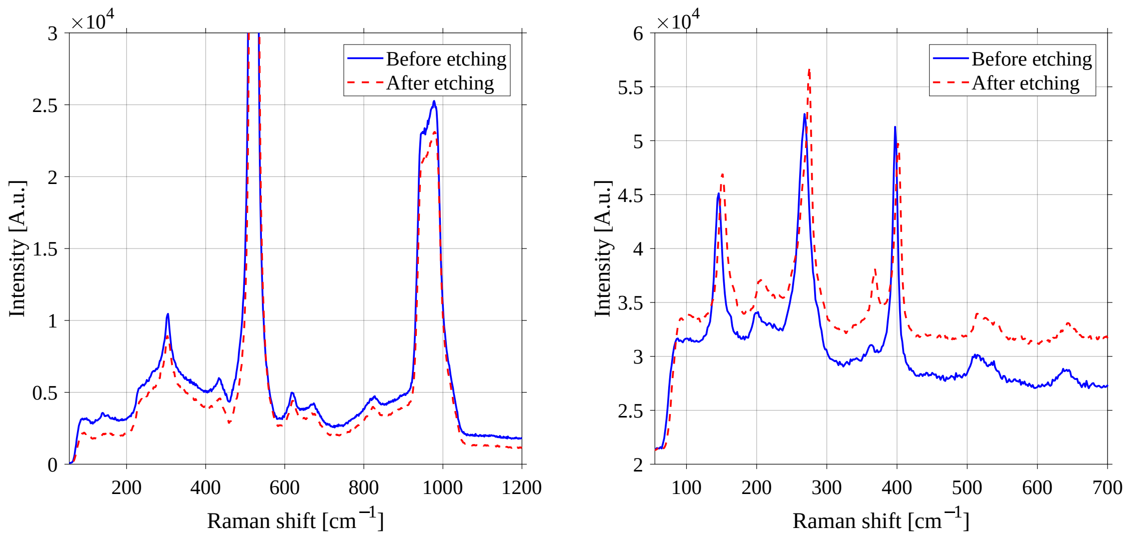
**Table 1:** Surface $S$ parameters for Si samples.

| | $S_a$ [nm] | $S_q$ [nm] | $S_{sk}$ [–] | $S_{ku}$ [–] |
|---|---|---|---|---|
| Before etching | 2.133 | 2.716 | 0.133 | 0.085 |
| After etching | 3.327 | 4.111 | 0.056 | −0.280 |

**Table 2:** Surface $S$ parameters for GaAs samples.

Below the measured samples in Figure 3a using Raman spectroscopy show several observed Raman spectral bands that correspond to the silicon at 305, 435 and 520 $cm^{-1}$. The overtones of the optical transverse mode of silicon are located in the range of 930 to 1000 $cm^{-1}$. The difference over the etched sample is mainly in the intensity of the spectrum, which averages 1000 $cm^{-1}$.

For the GaAs sample in Figure 3b, the mode at 270 $cm^{-1}$ corresponds to arsenide gallium and at 400 $cm^{-1}$ to doped aluminium. There is also a difference in the intensity of the spectrum, which increases with the Raman shift. Peak after etching at 400 $cm^{-1}$ is then reflected by a significant drop in intensity. This drop determine the amount of the proper material that has slightly decreased, however, the intensity of vibrational spectra is the least understood area of vibrational spectroscopy at this point.




a) b)

**Figure 3:** The spectrum of the solar cell based on a) Si and b) GaAs observed by using Raman method.

Using electron dispersive spectroscopy, it is noticeable in Figure 4b for the GaAs that the weight and ratio of all elements is almost unchanged, and the curves before and after etching nearly overlap. Slight changes in intensity can only be observed in some parts of the peaks. Thus, it can be stated that the GaAs sample surface was modified less than the sample of Si cell, where a particular increase in silicon intensity at 1.75 keV was detected after etching. On the contrary, the peak of Ag decreased at 3 keV, and new peak of fluoride formation was observed at 0.68 keV, which may be the result from highly reactive $SF_6$ gas from RIE.

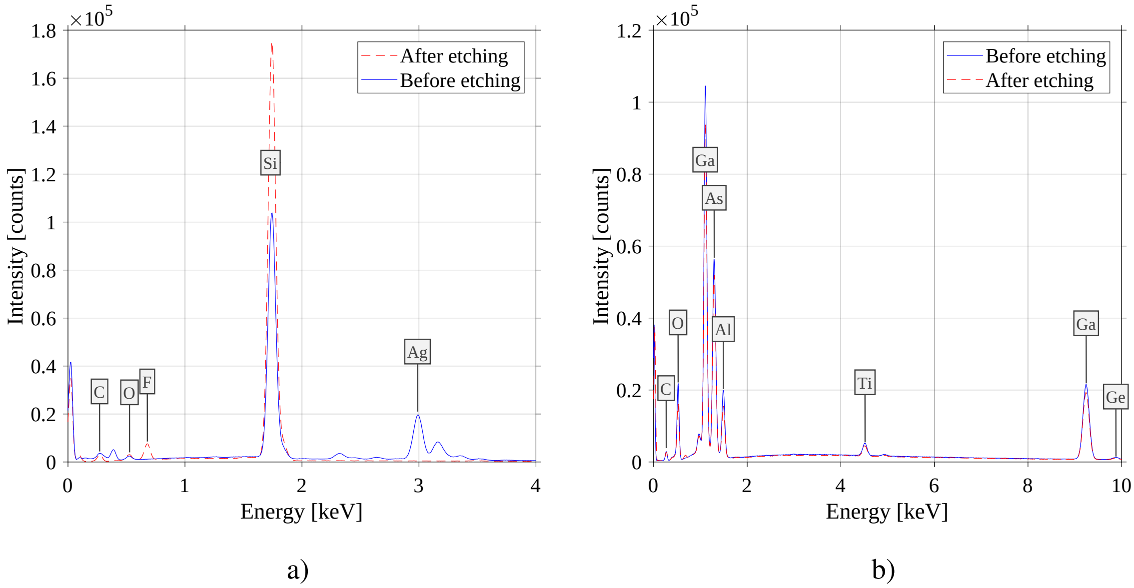



**Figure 4:** The spectrum of the solar cell based on a) Si and b) GaAs observed by using Energy-dispersive X-ray spectroscopy.

## 4 CONCLUSION

Solar cells of silicon and gallium arsenide before and after etching were measured and compared in this work. The surface of the cells after the treatment was under investigation by AFM microscope rougher in the case of both types of specimen, which could also lead to a increase in features height.

For silicon specimen after processing the kurtosis coefficient $S_{ku}$ increased, for a sample of gallium arsenide, on the contrary decreased. Using the Raman spectroscopic method is an observable change for both types of samples but for silicon significantly larger.

Other notable changes were measured using EDX detector, especially for silicon cell, where it was probably reflected portion of reactive gas of sulfur hexafluoride, and was observed after etching peak of chlorine. On the other hand, GaAs cell did not show this change and there was only a slight decline in the current peaks. From the above, it can be confirmed that the surface of silicon solar cells is more susceptible to RIE etching than GaAs cells, which, in particular in Energy Dispersive X-ray spectroscopy, excel in their material stability.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