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Atmospheric Plasma Effect on Structural Properties of Silicon

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***Abstract*— Micro and nanostructures were synthesized on silicon substrate using atmospheric plasma generated by corona discharge in the air and at ambient temperature. The morphology of microstructures grown on the surface during the treatment of the samples depends on the processing time and the discharge voltage. The grown structures had tapered and nanowires forms as observed from microscope analysis. Integral sphere analysis of a p-type silicon sample exposed to the plasma for two hours, showed a reduction of silicon surface reflectance to 10% in the visible range, and to 20% in the infrared range.**

***Keywords*— Texturization, Silicon nanowires, Atmospheric plasma**

I. Introduction

The cold plasma generated at atmospheric pressure and low temperature have been extensively studied both experimentally and theoretically [1] because of their wide application areas like; ozone generation, surface modification and thin films deposition (SiOx, SiNx....) [2-3]. Because of the ability of plasma to make a change on surface morphology, plasma-surface interaction is becoming more attractive to researchers specially modification of silicon surface [4].

Silicon surface has high naturel reflectivity (35%-40%) with strong spectral dependence, which limits the the power conversion efficiency of silicon based solar cells [5-6]. One of the most important means of improving the efficiency of crystalline silicon solar cells is to decrease the velocity by removing contamination and enhancing passivation effectiveness [7-8]. Several methods have been proposed to reduce the reflectance of silicon surface. Single layer anti reflection coating with texture surface is used routinely in industriel production but it requires system like PECVD. Micro and nanostructures such as Silicon nanowires, Silicon nanotips were developed to reduce surface reflectance losses [9-12].

In this work, we present study of simple process to develop micro and nanostructures on silicon surface with using plasma generated at atmospheric pressure by corona discharge.

II. Experiment Method

In order to study the effect of an atmospheric plasma on the silicon surface properties, p-type and n-type silicon wafers with (100) orientation and resistivity of “1, 5 Ω.cm”, “100 Ω.cm” respectively, were used. These wafers were cut into small pieces of “1cm×1cm”, then the silicon samples were exposed to the plasma generated in corona discharge system on point to plane configuration. This system consists of two inhomogeneous electrodes; point and plane. DC high voltage was applied between these electrodes, and then a very strong electrical field was created in the inter electrode space. This process generates cold plasma inside the electrode with small radius of curvature (point).

The experimental setup is illustrated in Fig1.

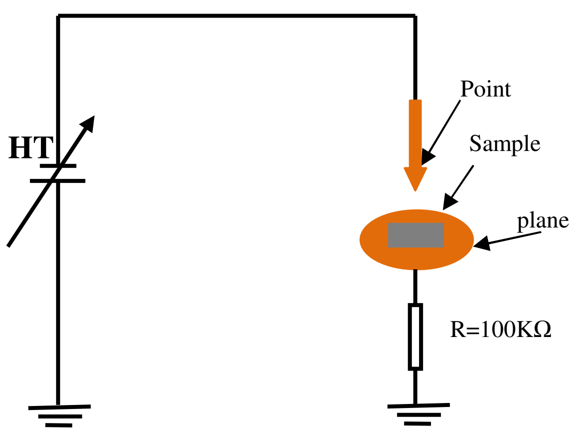

Fig. 1 Schematic of the system process

III. Results and Discussions

Applying cold plasma generated at atmospheric pressure at the surface of a silicon substrate produces a change in the

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silicon surface morphology. This modification resulted in the grown of microstructures.

P-type silicon sample is exposed to the discharge plasma for two hours. The plasma is generated for the voltage of “20KV” applied between the point and the plane. The morphology of the sample is analyzed using scanning electron microscope is shown in Fig 2.

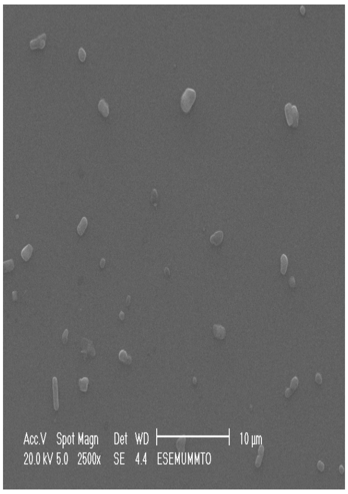

Fig. 1 Surface morphology of p-type silicon treated for 2 hours

It could be observed that there is grown of clusters with different size and distributions. The nature of this clusters deposited on the silicon surface was determinate using analyze EDX (Energy Dispersive X-Ray) (Fig 3).

The analysis indicates two peaks as observed in Fig 2, one of silicon and another of oxygen. The presence of oxygen is explained by the fact that the experiment is done under air at ambient temperature. This explains the formation of SiO2 microstructures.

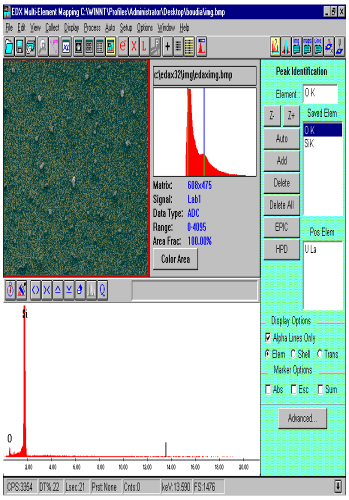

Fig. 2 EDX spectral of p-type silicon surface

The optical characteristics were studied to evaluate the SiO2 microstructures formed as anti-reflection for optical devices like solar cells.

The polished silicon usually shows a reflectance of more than 35% (Fig 4 (a)), which greatly modified by the micro particles grown on p-type silicon sample. The analysis showed a reduction of surface reflectance to 10% in visible range (Fig 4(b)), and to 20% in infrared (Fig 4 (c)).

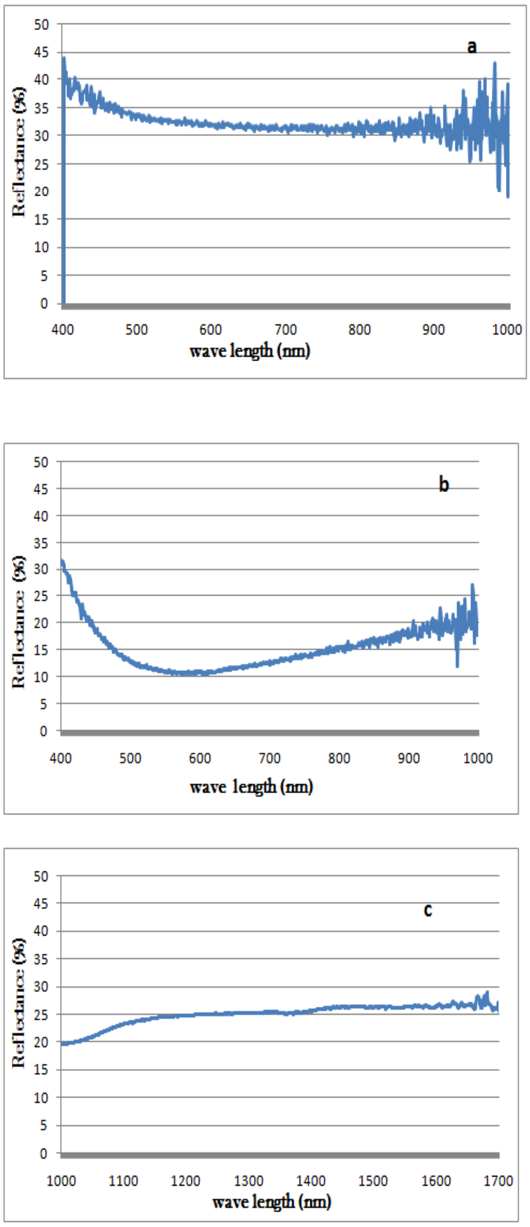

Fig. 4 Reflectance spectral of; (a) polished silicon, (b) p-type silicon spectral in visible range, (c) spectral in infrared range

Another time we perform surface treatement for the n-type silicon samples for “12 hours” by the discharge plasma. The plasma is generated for the voltage of “30kV” applied between the interelectrode space, the distance between the point and the silicon sample is "d=2cm". The morphology of the microstructures grown is shown in the fellowing SEM pictures.

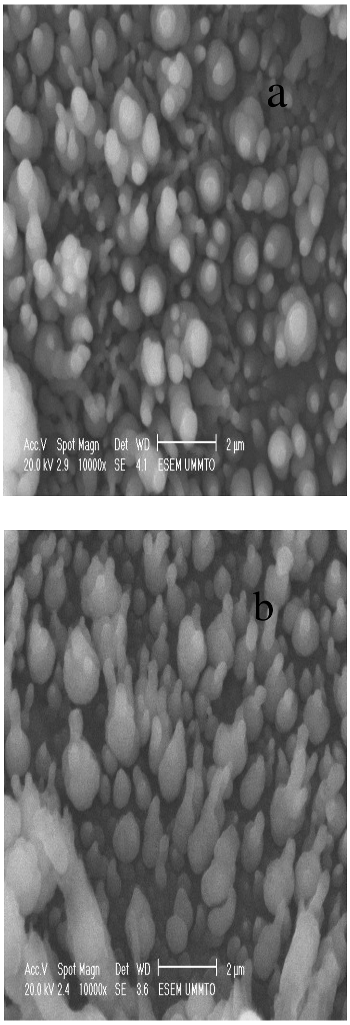

Fig.5. SEM picture of n-type silicon surface treated for 12 hours for d=2cm

As observed in Fig 5, the grown microstructures had tapered forms with uniform distribution and size varying between "400nm" to "1µm ".

With increasing the voltage discharge, the microstructures formed on the surface tend to have the shape of nanowires as shown in Fig 6.

The diameter of the nano particles grown was estimated in the range of 200-500nm by SEM investigations. The nanowires length increased from few nanometers to several micrometers, as illustrated in SEM picture.

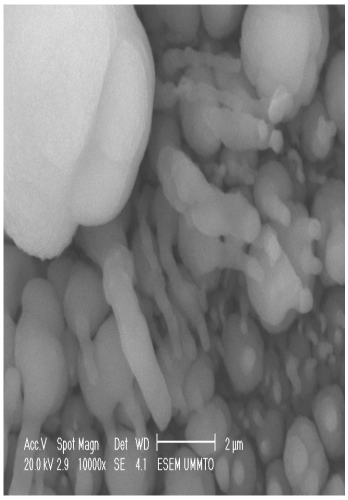

Fig.6. SEM picture of n-type silicon surface treated for 12 hours with increasing discharge voltage to 32K

IV. CONCLUSIONS

In this paper we studied the effect of cold plasma generated at atmospheric pressure and ambient temperature by corona discharge system, on the silicon surface morphology. We observed with using microscope analysis the growth of micro and nanostructures with tapered and nanowires forms. The optical characteristics of the silicon samples show reduction of reflectance from 35% for polished silicon to 10%. SEM analysis shows that with increasing the discharge voltage, nanowires with diameter of 200-500nm were synthesized. We can deduce that, with simple process without precursor and catalyst, we can obtain a texturization of micro and nanostructures on silicon surface which can be used as anti reflection for solar cells devices.

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