Si Nanowires for Antireflective Coatings of Photovoltaic Cells

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Abstract – **The paper deals with investigation of CVD grown silicon nanowires fabrication for antireflective coatings of photovoltaic cells.**
Keywords – **nanowire, photovoltaic cell, antireflective coating.**

I. INTRODUCTION

Recently the prospects of submicron one-dimensional semiconductor structures (whiskers and nanowires) for use in alternative energy sources with different operation principles, in particular, for photovoltaic cells (PV), have been shown [1-3]. The idea of nanowires (NW) incorporation into photovoltaics concerns the creation of antireflective coatings for PV cells in order to increase the photons absorption and to increase the efficiency of electricity generation. As of now, the most common PV material is silicon, thus, the formation of such coatings on the basis of silicon nanowires would be desirable, which is also advantageous from the economic point of view because of cheap and relatively simple methods of their production compared to other technological approaches to the improvement of PV efficiency. Since the unique transport, electrical, optical and other characteristics of Si micro- and nanowires are determined by their dimensions and morphology, the study and optimization of technological conditions for fabrication of these structures and the study of their formation kinetics and properties are of great importance.

In this paper we present the results of experiments on the optimization of Si NW arrays growth for use as an antireflective coating for PV cells.

II. RESULTS AND DISCUSSION

Silicon nanowires were grown by chemical vapor deposition (CVD) technique in the open-flow system described elsewhere [4-5]. For the initiation of NW growth by vapor-liquid-solid mechanism the gold films of various thicknesses (4 to 10 nm) were deposited onto the Si (111) substrates. A thermal treatment at 600 °C has been utilized in order to coagulate the gold into nanoscale drops (Fig. 1). The obtained samples of Si substrates covered with gold nanodrops layers were placed into reactor and the $SiCl_4$ + H_2 gaseous mixture was passed through the chamber. The nanowire growth occured at T = 580 °C and pressure of gaseous mixture circa 100 mmHg. The growth duration was 5 min.

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With the use of described technique disordered arrays of randomly oriented Si NWs with significant length scattering have been obtained (Fig. 2). In principle, such a morphology of substrate surface should absorb the light quite efficiently and may be used as an antireflective coating for PV cell [6-7]. However, due to a high density and irregularity of NWs the surface remains partially unpassivated with extended charge-trapping centers.

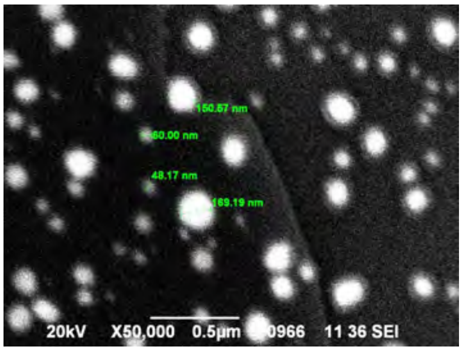

Fig. 1. SEM-photograph of Si-Au nanodrops distribution.

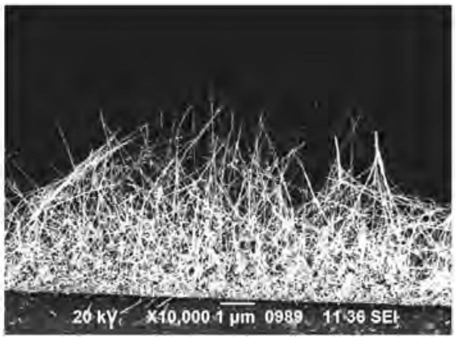

Fig. 2. SEM-photograph of the grown Si NW array.

In order to reduce the effects related to the insufficient passivation of the substrate surface the creation of regular Si nanowire arrays by formation of Si-Au melt cells on the substrate applying the preliminary deposited template was suggested (Fig. 3, a) [8]. This allowed the obtaining of regular NW arrays utilizing the above described technological conditions (Fig. 3, b).

As it has been reported in one of the pioneer articles dedicated to the use of whiskers with p-n junction in PV cells [1], the antireflective coatings on the basis of NWs provide a substantial increase of light absorption in the spectral range of 300 – 1100 nm compared to that of other PV structures (Fig. 4). Such structures provide the photoelectric current of 1,2 mA/cm^2 and the efficiency of light-conversion of approximately 2–3 %, which is due to the unpassivated surface states caused by the high density of nanowires per surface unity. In addition, extended surface leads to significant charge carriers recombination causing the decreased efficiency of photovoltaic energy conversion.

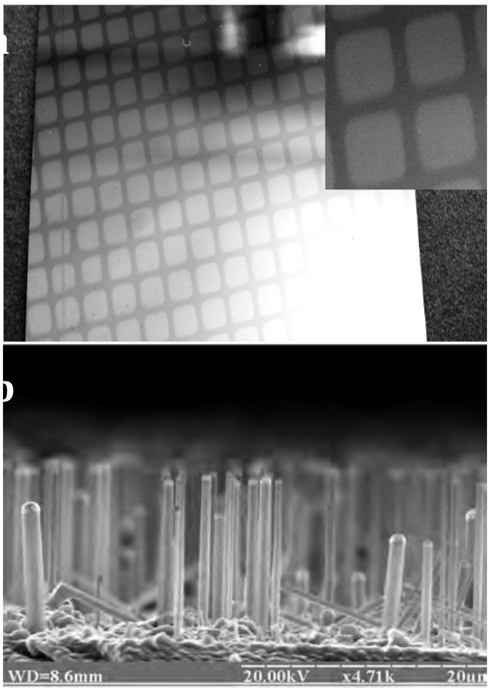

Fig. 3. The Si(111) substrate with the formed Au-Si melt cells (a) and a SEM-photograph of the regular Si nanowire array (b).

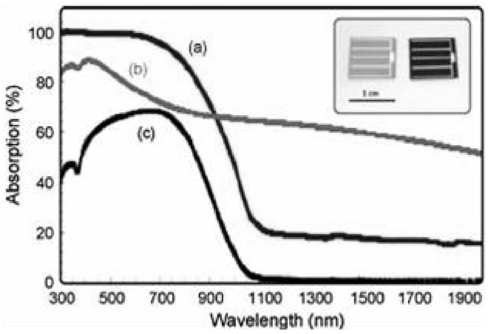

Fig. 4. Absorption spectre of PV structures [1]:
a –Si NWs fabrigated by wet etching; b – CVD-grown Si nanowires; c – Si thin films.

Even though the efficiency of PV conversion in solar cells based on Si NW yields only 2% as of now, while in those based on multicrystalline silicon is gained at a level of even 22–24%, there are plenty of technological approaches for improvement of PV efficiency of the former, in particular, by passivation of the nanowire arrays surface of the antireflective coating.

The suggested technological process for creation of Si photovoltaics with the use of nanostructures on the front surface includes the following steps: 1) formation of diffusive p-n junction by doping of p-Si substrates from the solid phosphorus sources at 950 °C, which provides the dopant profile of about 1 μm; 2) the deposition of thin (d = 4 nm) gold film onto the created planar p-n junction followed by the thermal treatment of the substrate under vacuum up to the coagulation of gold drops and the formation of NW seeds; 3) the growth of Si NWs in the open-flow hydrogen system with introduction of $SiCl_4$ as a source of a grown material; 4) creation of contacts to the p-region of photovoltaic cell by the deposition of Al film followed by the annealing at 380 °C; 5) formation of golden current-collective contact rods in the n-region of p–n junction.

III. Conclusions

The technology optimization for CVD growth of Si nanowires in the open-flow system, in particular, using the template formation of golden cells atop the substrate surface, has been suggested. This allowed to fabricate vertically oriented regular nanowire arrays. It has been shown, that such structures possess a wider optical absorption spectre compared to other PV structures, which is prospective for their use as an antireflective coatings for photovoltaic cells.

IV. References

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