Controlled Nano Texturing in Silicon Wafer for Excellent Optical and Photovoltaic Properties

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Abstract : The crystalline silicon (Si) solar cells are highly renowned photovoltaic technology and well-established as the commercial solar technology. Most of the solar panels are globally installed with the crystalline Si solar modules. At the present scenario, the major photovoltaic (PV) market is shared by c-Si solar cells, but the cost of c-Si panels are still very high as compared with the other PV technology. In order to reduce the cost of Si solar panels, few necessary steps such as low-cost Si manufacturing, cheap antireflection coating materials, inexpensive solar panel manufacturing are to be considered. It is known that the antireflection (AR) layer in c-Si solar cell is an important component to reduce Fresnel reflection for improving the overall conversion efficiency. Generally, Si wafer exhibits the 30% reflection because it normally poses the two major intrinsic drawbacks such as; the spectral mismatch loss and the high Fresnel reflection loss due to the high contrast of refractive indices between air and silicon wafer. In recent years, researchers and scientists are highly devoted to a lot of researches in the field of searching effective and low-cost AR materials. Silicon nitride (SiNx) is well-known AR materials in commercial c-Si solar cells due to its good deposition and interaction with passivated Si surfaces. However, the deposition of SiNx AR is usually performed by expensive plasma enhanced chemical vapor deposition (PECVD) process which could have several demerits like difficult handling and damaging the Si substrate by plasma when secondary electrons collide with the wafer surface for AR coating. It is very important to explore new, low cost and effective AR deposition process to cut the manufacturing cost of c-Si solar cells. One can also be realized that a nano-texturing process like the growth of nanowires, nanorods, nanopyramids, nanopillars, etc. on Si wafer can provide a low reflection on the surface of Si wafer based solar cells. The above nanostructures might be enhanced the antireflection property which provides the larger surface area and effective light trapping. In this work, we report on the development of crystalline Si solar cells without using the AR layer. The Silicon wafer was modified by growing nanowires like Si nanostructures using the wet controlled etching method and directly used for the fabrication of Si solar cell without AR. The nanostructures over Si wafer were optimized in terms of sizes, lengths, and densities by changing the etching conditions. Well-defined and aligned wires like structures were achieved when the etching time is 20 to 30 min. The prepared Si nanostructured displayed the minimum reflectance ~1.64% at 850 nm with the average reflectance of ~2.25% in the wavelength range from 400-1000 nm. The nanostructured Si wafer based solar cells achieved the comparable power conversion efficiency in comparison with c-Si solar cells with SiNx AR layer. From this study, it is confirmed that the reported method (controlled wet etching) is an easy, facile method for preparation of nanostructured like wires on Si wafer with low reflectance in the whole visible region, which has greater prospects in developing c-Si solar cells without AR layer at low cost.

Keywords : chemical etching, conversion efficiency, silicon nanostructures, silicon solar cells, surface modification
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