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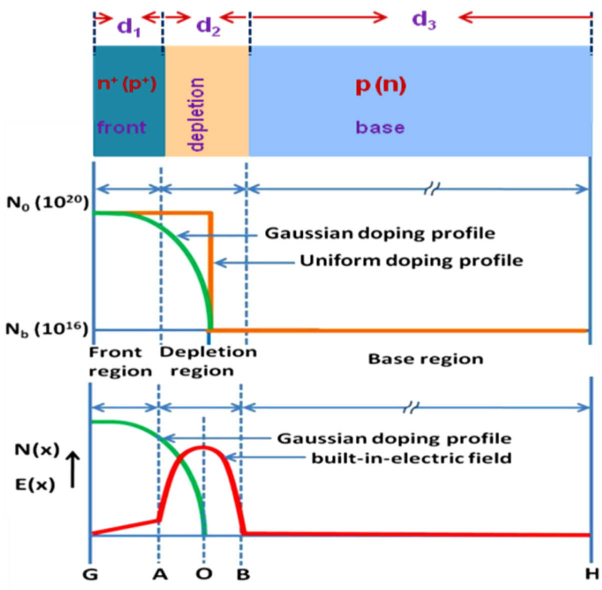
| **Title of Ph.D. Thesis** | : | Studies on enhancement in optical absorption and reduction in minority carrier recombination in silicon solar cells. |

## Abstract of PhD Thesis

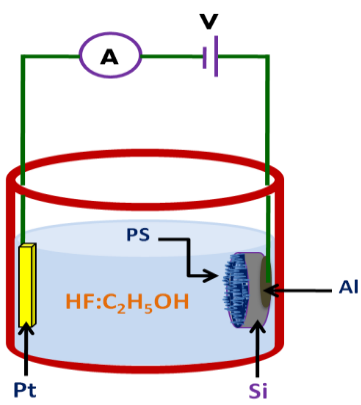

The research work carried out under the course work of this PhD thesis has focused on developing new methods and methodologies for measurement of important parameters of substrate material (c-Si) and the solar cell, such as, surface recombination velocity at the front and back of solar cell and diffusion length of minority carriers in the Si wafers, and the growth kinetics and optical confinement studies of low cost porous silicon antireflection coating for silicon solar cells.

I. The front heavily doped region of silicon solar cells generally has a dopant profile which is either Gaussian or Complementary error function in nature and is responsible for a linear or nearly linear built-in-electric field in the diffused region. A theoretical analysis has been carried out to determine the contribution of the front diffused region to $J_{sc}$ of the cell taking the effect of the presence of the built-in field into account. The analysis was then used to develop a new method for the determination of the front surface recombination velocity $S_f$ of minority carrier of the $n^+$-p (or $p^+$-n) structure based silicon solar cell in which $n^+$ (or $p^+$) front heavily doped region is made by diffusion of dopant impurity in the p(n) region and has a Gaussian dopant impurity profile.



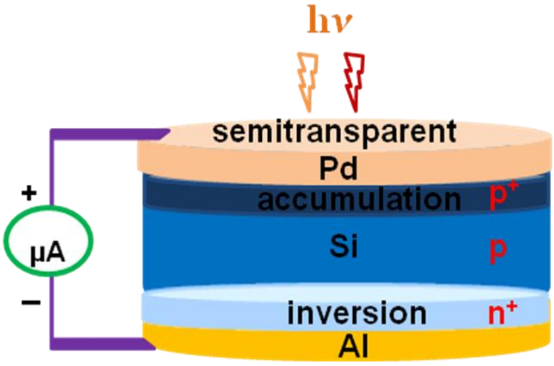

The analysis carried out, showed that the effect of built-in- field in the front heavily doped region reduces the minority carrier recombination in this region significantly and should not be ignored while determining the $S_f$ using the spectral response values for the short wavelength region. Simple assumption that the front heavily doped region is uniformly doped ignores the influence of built-in-field and leads to overestimation of the recombination in the front heavily doped region and thereby underestimates the value of $S_f$ of a diffused junction solar cell. The value of $S_f$ is a direct indication of the recombination at the front surface of a solar cell. **[*Solar Energy Materials & Solar Cells 91, (2007), 1515*]**

II. A study investigating the growth kinetics and optical properties of low cost porous silicon (PS) anti-reflection coating (ARC) for the enhancement in optical absorption in silicon solar cells has been carried out. The effect of orientation on the growth rate of porous Si grown on p-Si wafers was investigated. The PS layers were grown electrochemically on <100>, <110> & <111> oriented p-Si wafers for different time durations at a constant current density.



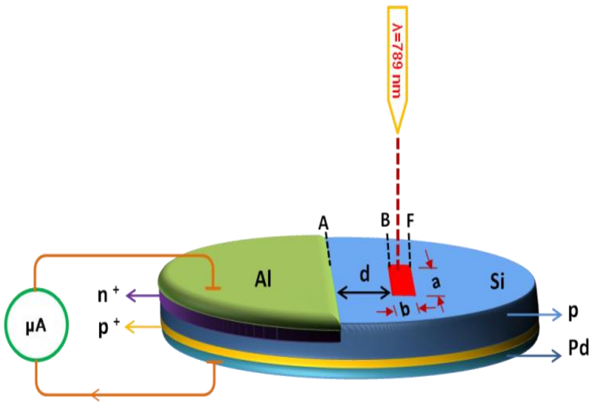
The growth was found practically independent of orientation of the wafer and also the diffusion limited. The orientation independent growth of porous silicon layer provides an attractive low cost option for use of PS as ARC for $n^+$ -p -$p^+$ multi-crystalline silicon solar cells. The PS ARC layer of 70 nm thickness showed 26% improvement in the $J_{sc}$ and 24% in cell efficiency η against the cell prepared without PS ARC. These studies showed that PS layers grown electrochemically on $n^+$ front surface could act as an effective low cost antireflection coating for $n^+$-p Si solar cells but have some adverse effect on $S_f$ which will need to be curbed by some other means. **[*Solar Energy Materials & Solar Cells, 91, (2007), 701]***

III. Photocurrent generation (PCG) method is used to determine diffusion length L of minority carriers in p-Si wafer by making an induced $n^+$ -p -$p^+$ structure by depositing semitransparent or suitably thick layers of low and high work function metals on the opposite sides of the wafer. In this method the short circuit photocurrent density $J_{sc}$ of the structure obtained under illumination with a monochromatic light from $p^+$ side varies linearly with the illumination intensity $P_i$ and the slope of $J_{sc}$ -$P_i$ curve is used to determine L. Higher the slope of $J_{sc}$ -$P_i$ curve higher is the value of L. The slope is found to decreases for aging in air.




In this work the effect of different ambient conditions on the $J_{sc}$ - $P_{in}$ characteristics of the $n^+$-p-$p^+$ structure was investigated. The investigations showed that the decrease in the slope of $J_{sc}$ - $P_i$ curve is owing to the increase in surface recombination velocity $S_b$ at the p-$p^+$ surface which results from the adsorption of moisture on the Pd coated surface and the degraded slope can be used to determine correct value of L with the PCG method if the effect of increase in $S_b$ is taken into account. Also, a methodology has been developed to determine the $S_b$ at p-$p^+$ interface of the solar cell or induced structure using the two monochromatic wavelength illuminations. ***[Solar Energy 85, (2011), 1137]***

IV. A new method for determination of L in p-Si wafer which is based on lateral collection of minority carriers generated under side-on illumination has been developed. In this method, a photocurrent $I_{sc}$ is generated when a rectangular area of a part of the bare front surface in the vicinity of the $n^+$-p interface is illuminated with a monochromatic light. The magnitude of $I_{sc}$ varies with the normal distance d between the electron collecting $n^+$-p interface and nearest edge of the illuminated region.




The slope Φ of the normalized $J_{scn}$ vs. d curve is used to determine a parameter $\sinh^{-1}\theta$ which depends on Φ. The reciprocal of the slope of $\sinh^{-1}\theta$ vs. d curve in the linear region gives the diffusion length L. The value of L are less susceptible to error due to the effect of $S_f$ of bare silicon surface if linear region of $\sinh^{-1}\theta$ vs. d curve lies in the region of smaller d values. Therefore, the developed method may be used as a tool to examine the effectiveness various surface passivation layers applied on the solar cell to reduce surface recombination. **[*Solar Energy Materials & Solar Cells, 100, (2012), 48]***