Production of ultra-thin (100)Si substrates by MeV hydrogen implantation for photovoltaic applications

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MeV energy hydrogen implantation in silicon followed by a thermal annealing has been reported to be a kerf-free approach that can be used to produce high quality ultra-thin silicon substrates with thicknesses compatible to PV applications. First results reported with this approach were performed by Assaf et al [1]. They reported delamination of ultra-thin silicon substrates with thicknesses in the range of 10 to 50 µm for energies up to 2MeV. Recently, major groups including Twin Creeks Company used it to produce Si-based solar cells with thicknesses up to 20 µm [2]. They claimed that such approach help decreasing solar cells prices down to $ 0.40/W thanks to the implementation of Hyperion implantor able to produce beam current as high as 100 mA. Another major private group SiGen used this same process to produce solar cells with thicknesses up to 150 µm [3]. They reported an efficiency of 13%.

However, if SiGen and Twin Creeks depicted it as a revolutionary approach for PV industry, only (111)Si wafers were used. They were not able to produce (100)Si thin substrates, although most silicon wafers used in solar cells are (100)Si. In this work, we target the production of (100)Si thin substrates.

Recently, results reported by C. Braley et al [4] after MeV hydrogen implantation in (100)Si showed that unlike (111)Si, thin substrates obtained with (100)Si break in small pieces. Our work focuses on the effects of both hydrogen dose and implantation energy/stiffener thickness on (100)Si delamination efficiency. Hydrogen was implanted by using doses ranging from $5x10^{16}$ H/cm² to $2x10^{17}$ H/cm² with energies from 1 MeV to 2.5 MeV. After thermal annealing, TEM results revealed that fracture precursor defects (platelets) have an unfavorable orientation to generate fracture propagation in (100)Si. Nevertheless, we showed that a delamination optimization with larger surfaces sizes of thin substrates is possible by increasing both hydrogen fluence and stiffener thickness (or implantation energy).

[1] H. Assaf et al, Nucl. Instrum. and Methods Phys. Res. B 240, 183 (2005)
[2] G. Ryding et al, Twin Creeks White Paper, (2012)
[3] F. Henley et al, 34th IEEE PVSC, June (2009)
[4] C. Braley et al., Nucl. Instrum. and Meth. Phys. Res., B 277, 93 (2012)