BAPVC Annual Project Report

Project Title: High efficiency a-Si:H /c-Si/a-Si:H dual heterojunction solar cells on exfoliated ~ 25 µm monocrystalline silicon substrates by improved surface treatment and passivation

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Summary:

Dual heterojunction (DHJ) solar cells consisted of a-Si:H/c-Si/a-Si:H architecture can obtain excellent passivation qualities at low deposition temperatures. Together with the low cost, kerf-less mechanical exfoliation method, 12.4 % efficient monocrystalline DHJ silicon solar cells of ~ 25 µm thickness are demonstrated. Improvements of the surface cleanness after front side texturing and passivation film quality were successfully conducted.

Key Accomplishments:

The Banerjee group at UT-Austin has demonstrated low cost, kerf-less mechanical exfoliation of 25 µm thick monocrystalline silicon foils, up to 8 inch in diameter, in which the parent wafer can be re-used for subsequent exfoliation. They have previously demonstrated a-Si:H/c-Si/a-Si:H dual heterojunction (DHJ) solar cells on thin silicon foils with 11 % efficiency. They have increased the overall efficiency of the cells by improving the surface cleanness after front side texturing. Auger Electron Spectroscopy (AES) measurement revealed that a combination of SC-15 solution (Surface Chemistry Discoveries, Inc) treatment followed by piranha clean resulted in the least amount of potassium and carbon contaminants at the textured surface as described in Table 1 and Fig 1.

Sample#	Treatment after KOH texturing	Carbon (Atomic %)	Potassium (Atomic %)
1	None	2.84	1.11
2	Piranha	2.32	0.88
3	SC-15	2.11	0.25
4	SC-15+Piranha	1.63	0.22

Table 1. Treatment splits after front side texturing of exfoliated samples and their calculated atomic percentage of C & K contaminants using AES

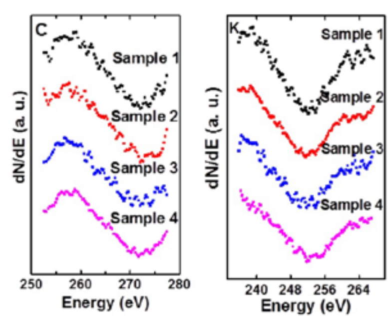


Fig 1. AES spectra with differentiated peaks of C & K

Along with the improved surface cleanness, they have also increased the a-Si:H passivation film quality. By increasing the deposition temperature of a-Si film from 150 ˚C to 200 ˚C followed by post deposition annealing (PDA) at 260 ˚C for 60 minutes, the minority carrier effective lifetime (τ_{eff}) increased from 16 µs to 1.5 ms as shown in Fig 2 (a).

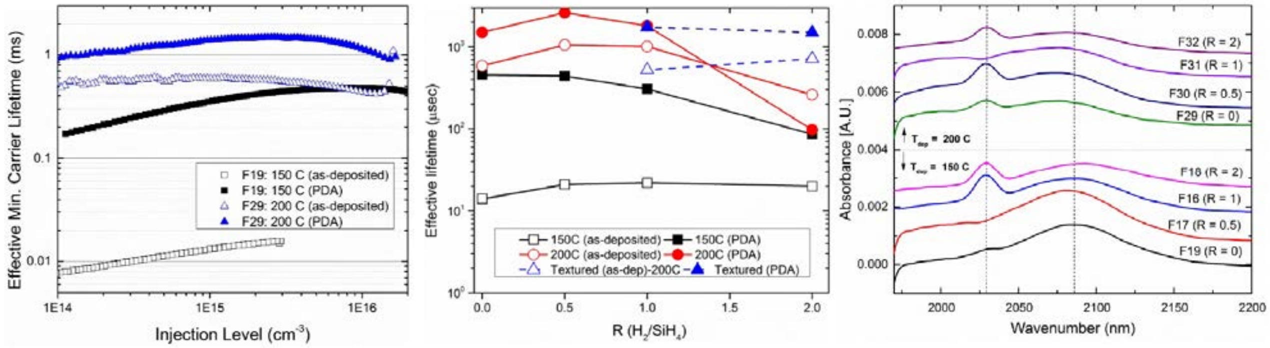
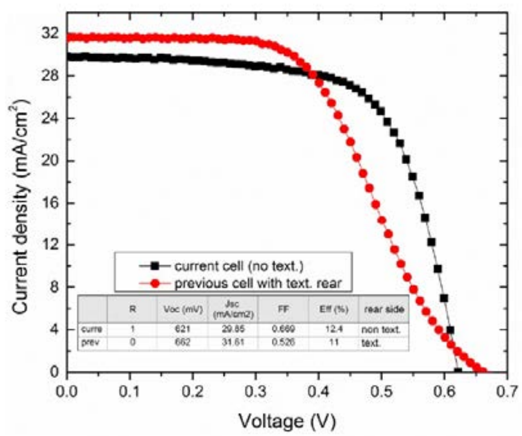


Fig 2. (a) τ_{eff} of a-Si passivated silicon substrate (FZ, n-type, <100>, 2 Ω·cm) for 150 ˚C and 200 ˚C deposition temperature with PDA

(b) τ_{eff} of a-Si:H passivated silicon substrate for different H_2/SiH_4 (R) ratio for textured and non-textured surfaces

(c) FTIR absorption spectra for various a-Si:H deposition conditions

Also, introducing hydrogen dilution during a-Si film deposition proved additional increase in τ_{eff} for both textured and non-textured surfaces which is presented in Fig 2 (b). Fig 2 (c) represents the fourier transform infrared spectroscopy (FTIR) measurement of various a-Si:H films with different deposition conditions. An optimal range of R exists for maximum τ_{eff} where both mono- and di-hydride bonding co-exist inside the film. Incorporating the improved surface cleaning method along with high quality a-Si:H passivation film deposition resulted in efficiency of 12.4 % as described in Fig 3.



	R	Voc (mV)	Jsc (mA/cm2)	FF	Eff (%)	rear side
curre	1	621	29.85	0.669	12.4	non text.
prev	0	662	31.61	0.526	11	text.

Fig 3. J-V characteristics of DHJ cells on exfoliated ~25 μm substrates

Future Work:

Future work will be focused on two major aspects; increasing the overall efficiency of a-Si:H based heterojunction solar cells and further reducing the cell thickness. The approach will be to optimize the n+/p+ doped a-Si:H and anti-reflective coating (ARC) layer as well as to explore helium based plasma deposition of a-Si:H. Mechanically exfoliated silicon films of < 15 μm will developed. Finally, metal-thin insulator-semiconductor (MIS) architecture solar cells on exfoliated substrate using large area 2-D materials such as graphene and h-BN will be studied for flexible photovoltaic applications.