Inversion layer solar cells; from MOS to conducting polymer/inorganic hybrids

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With conducting and semiconducting polymers such as PEDOT:PSS and P3HT a new type of polymer/Si heterostructure solar cell is emerging. With a conducting polymer (a degenerate semiconductor) as emitter such organic /inorganic hybrid heterojunction is likely to achieve high conversion efficiencies only if the inorganic semiconductor is pushed into strong inversion, to reduce dramatically the space-charge recombination, and to mitigate the poor lateral conductance of the polymeric layer. We explain this notion through a review of the types of solar cells based on an inversion layer, induced in the semiconductor absorber by a metal, by a dielectric material with fixed charges, or by another semiconductor. In these types, which include the MIS, SIS and MIS-IL solar cells, interfaces play a crucial role, even more so than in other forms of solid state photovoltaics. At sufficiently low interface state density Si type-inversion can be achieved, for example by using Al_2O_3, layers with fixed charge on n-Si (and SiOx, Si_3N_4 or HfO_2 on p-Si). This type of device takes advantage of charged interface states to generate depletion or inversion in the underlying Si by electrostatic repulsion, if the majority carriers of the Si substrate are of the same sign as the charge at the interface. Inversion becomes possible in this case thanks to the passivating properties of the Si-dielectric interface. However, the oxides are dielectrics and, therefore, ways need to be found to extract the charges without paying a high price in voltage to overcome the resistance of the dielectric film.

We demonstrate a novel cell utilizing the high density of negative fixed charge states at the interface between Si and Al_2O_3 to generate strong inversion in n-Si, where the maximum processing temperature reached is only 425 °C for 30 minutes. Charges are then extracted via an inversion layer (IL), generated at PEDOT:PSS contacts, where the Si surface contacting the PEDOT:PSS is both electrically passivated and inverted by a monolayer of polar molecules with a suitable dipole.

Inversion layer solar cells show promise for reducing the cost of solar electricity by eliminating the need for the energy-intensive dopant diffusion step, required to make a conventional p-n junction, when wafers are typically heated to over 900 °C for hours. Initial results with multi-crystalline n-Si show this approach can be extended to low cost Si, where the presently used high temperature step

uses an even higher fraction of the energy, needed to make the cell (estimated at 10% of the total cell fabrication energy or 7% of the panel fabrication energy).