Top-down and bottom-up approaches to silicon nanowire solar cells

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Silicon nanowires are attracting increasing attention in the energy field for their light trapping potential in radial junction solar cells. Top down fabrication approaches based on etching crystalline silicon wafers through various mask schemes make it possible to obtain ordered arrays of crystalline silicon wires which provide a model system to study the optical and electronic properties of these novel structures. However, cost issues call for a bottom-up approach where similar wires can be obtained on cheap substrates using a VLS growth mode. In this approach, crystalline silicon wires are synthesised from gas particles through a liquid metal catalyst. To date, Au has been favoured as the catalyst of choice despite its negative effects on transport properties in crystalline silicon.

In this presentation we introduce a new approach to produce silicon nanowires and radial junction solar cells [1]. Our approach is based on the use of standard plasma enhanced CVD reactors to :

i) Reduce a metal oxide layer to produce metal catalyst drops (Sn, In,..) in a hydrogen plasma at ~250 °C.
ii) Grow silicon nanowires by switching from hydrogen to a silane plasma, to which PH_3 or B_2H_6 can be added to obtain p-type or n-type wires.
iii) Deposit intrinsic and doped hydrogenated amorphous silicon layers around the nanowires to obtain a radial junction.(Fig. 1)

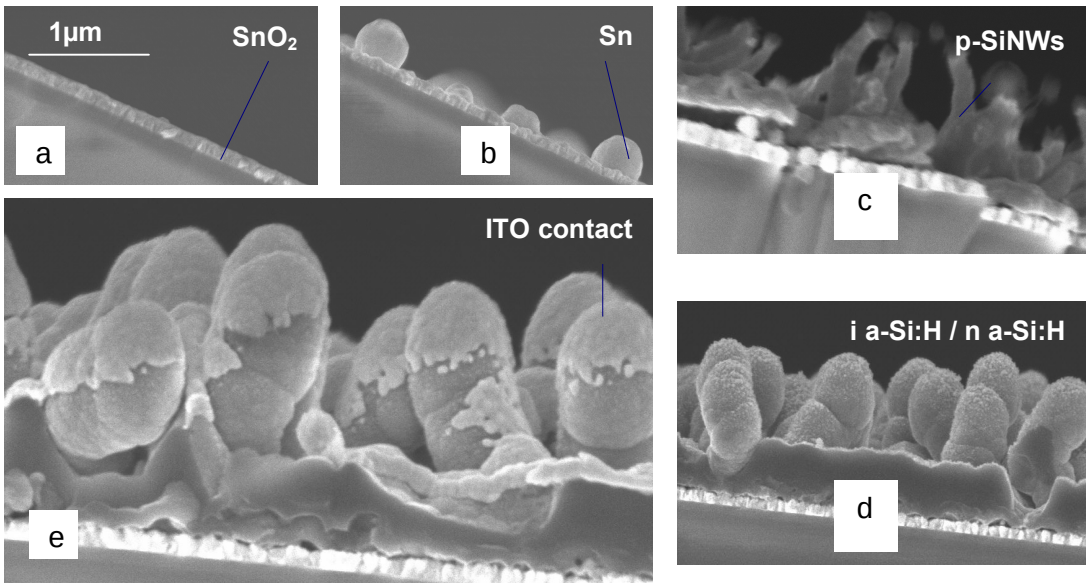

Figure 1: *Cross sectional SEM micrograph of SnO_2 layer on glass prior to nanowire growth (a). Substrate is exposed to a hydrogen plasma and heated to 300°, reducing the oxide and forming Sn droplets (b). These droplets catalyse the growth of p-doped nanowires when exposed to a silane and B_2H_6 plasma (c). The wires are covered with conformal layers of intrinsic and n-doped silicon (d) and a transparent conductive oxide layer to complete the*

Thus, in a single pump down process, the solar cell structure is ready for ITO deposition, which provides the contacts to the n+ a-Si:H layer of the solar cells [2]. Altough the wires grown in this process adopt disordered orientations, our efforts over the past few years have led to solar cells with efficiencies up to 6.8%, demonstrating that these systems can effectively trap light and collect the photogenerated carriers.

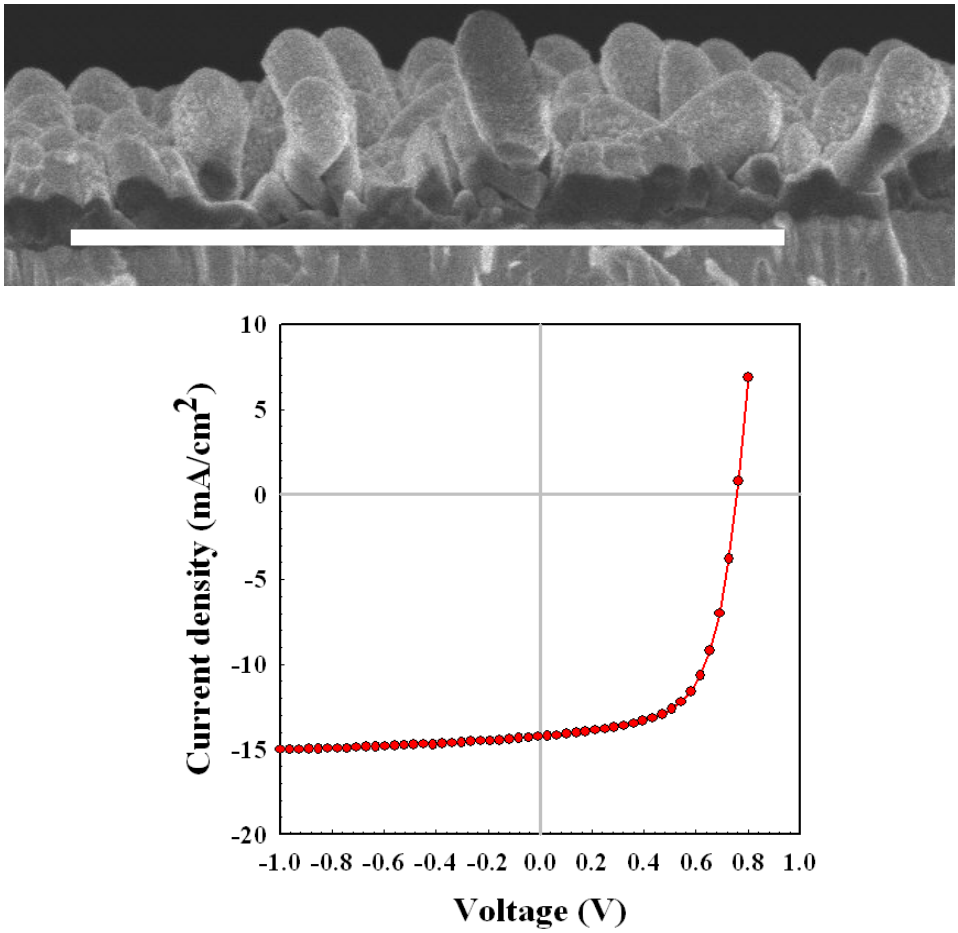

Figure 2: *Cross sectional SEM micrograph of an array of PIN radial junctions grown by Sn-catalysed VLS on a glass substrate (top). The energy conversion efficiency of this cell under AM1.5 is of 6.8% over a 3.14 mm² area (bottom).*

The fact that this standard PECVD process can be scaled to large areas (m^2) along with its simplicity when compared to top down approaches, opens new opportunities for high efficiency and low cost solar cells.

1. Pierre-Jean Alet et. al. Journal of Materials Chemistry (2008) 18, 5187
2. L. Yu, B. O'Donnell et.al. Solar Energy Materials and Solar Cells 94 (2010) 1855