ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Low temperature metal oxide/fluoride passivated contacts for crystalline silicon solar cells

James Bullock

Department of Electrical and Electronic Engineering, University of Melbourne, Melbourne, Victoria, Australia

E-mail: james.bullock@unimleb.edu.au

The fast-growing terrestrial solar cell industry is currently dominated by crystalline silicon cell architectures which employ heavy doping and direct metallization for electron/hole separation. Despite being commonplace, the use of heavy doping and direct metallization is known to incur fundamental and practical performance limitations. A strategy to address these shortcomings is to replace such regions with surface passivating heterocontacts. As shown in Figure 1, a range of passivating heterocontact technologies have been developed in recent years including those based on the silicon heterojunction (SHJ) and polysilicon contact technologies. These have resulted in a cluster of silicon solar cell efficiencies above 25% since 2014.[1] Another related passivated contact stream utilises materials like metal oxides, fluorides, sulphides and organic molecules to form passivated contacts, the best results of which are represented by green points in Figure 1. Although less mature, the use of such materials, deposited via low temperature techniques, introduces potential advantages related to transparency and cost. In this paper, I will discuss recent breakthroughs in this research area, which highlight the potential of this concept. To provide a comprehensive breakdown of progress in this area,

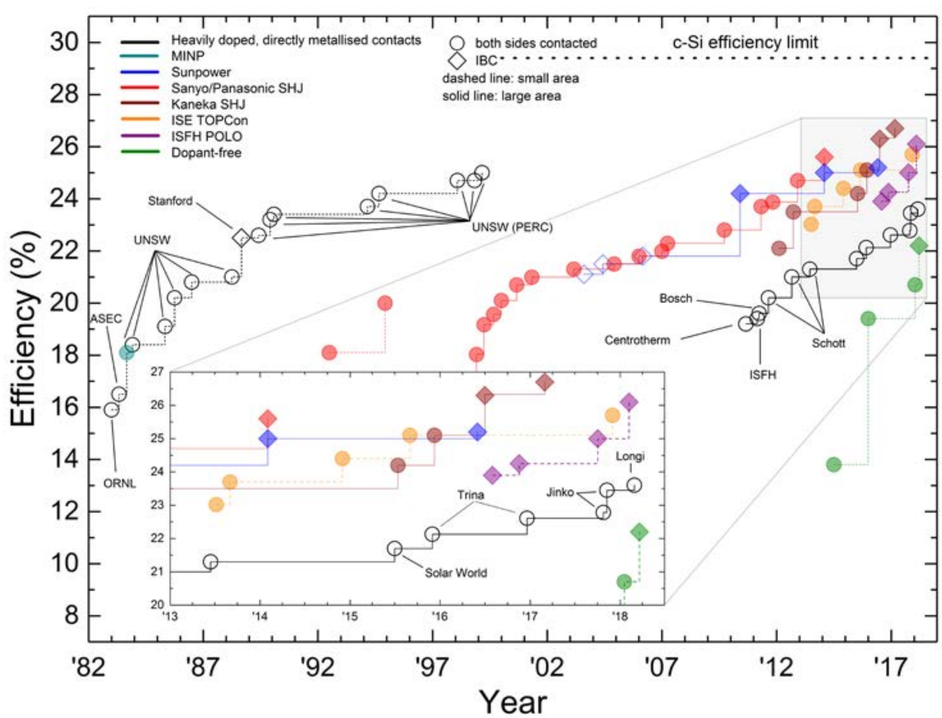

Figure 1. Progression in crystalline silicon solar cell efficiency verses year for several different cell technologies. Coloured points represent cells with passivated contacts. The green points represent recent progress in cells which feature contacts achieved via metal oxides and fluorides deposited at low temperatures. The black unfilled points are representative of homojunction architectures. Modified from Ref [1].

recently demonstrated solar cells featuring metal oxide/fluoride contacts for either one or both contacts will be discussed.

Architectures belonging to the former of these two categories, replace one contact in an otherwise conventional solar cell with a metal oxide/fluoride layer. Following a rapid improvement in efficiency over the last three years, separate studies released in 2019, have demonstrated efficiencies above 23% for cells featuring electron and hole metal oxide-based contacts. The first of these, shown in Figure 2a, introduced a TiO_x / LiF_x / Al partial rear contact to an n-type homojunction cell, attaining an efficiency of 23.1%.[2] The second study replaced the front a-Si:H(*p*) layer in a SHJ cell with a high work function MoO_x layer, demonstrating a certified 23.5% efficiency.[3]

The exploration of silicon solar cells which utilise metal oxide/fluoride layers for both contacts, sometimes referred to as dopant-free asymmetric heterocontact (DASH) cells, is also an active area of research. As it stands, the efficiency record for a both-sides-contacted cell is at 20.7% (Figure 2b), achieved in 2018 with a-Si:H/MoO_x and a-Si:H/TiO_x/LiF_x/Al, hole and electron contacts.[4] This efficiency was surpassed later that year by an interdigitated back contact DASH cell which achieved 22.2% utilising a-Si:H/MoO_x and a-Si:H/MgF_x hole and electron contacts.[5]

If selected, this presentation will explore both theory and emerging trends related to the use of metal oxide/fluoride contact layers in crystalline silicon photovoltaics. In addition, it will compile the latest cell results, such as those shown in Figure 2c, from various groups around the world.

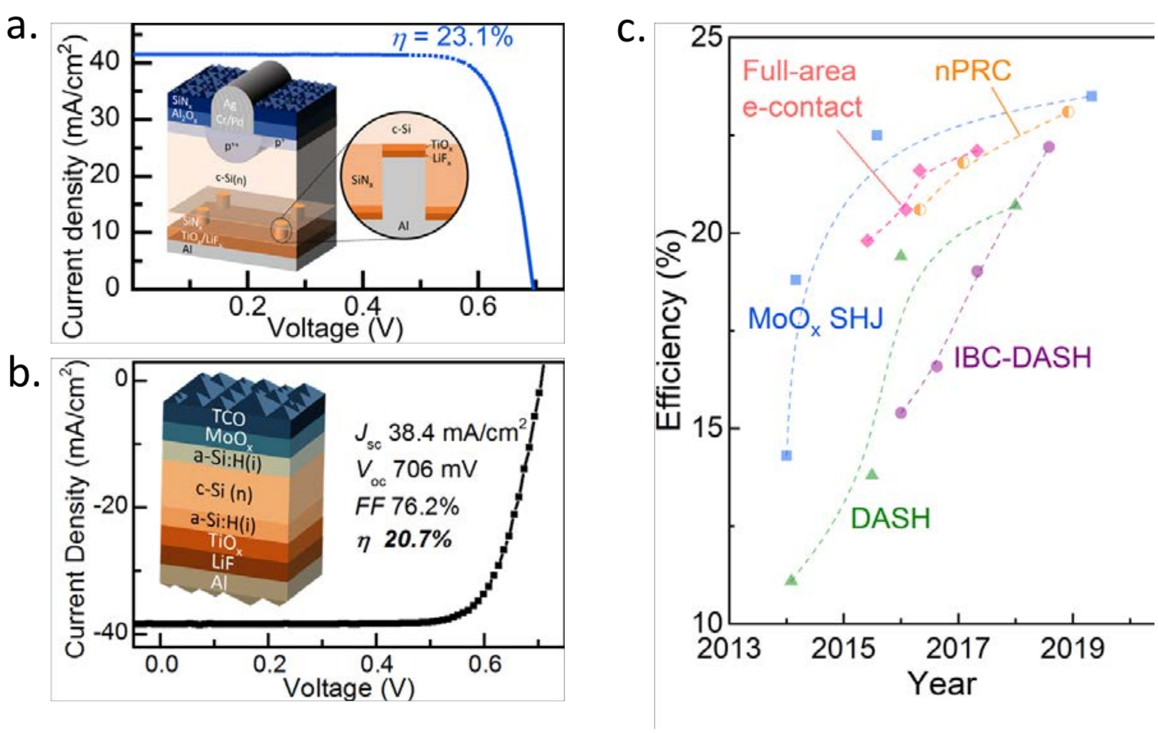

Figure 2. a. n-type partial rear contact cell featuring TiO_x based rear contact (modified from Ref [2]). b. n-type DASH cell featureing MoO_x and TiO_x based hole and electron contacts (modified from Ref [4]). c. Efficiency progression for a range of solar cells featuring one or two metal oxide/flouride based passivated contacts. DASH = dopant free asymmetric heterocontact, IBC-DASH = interdigitated back contact DASH, nPRC = passivated partial rear electron contact cell (most commonly featuring TiO_x), MoO_x SHJ = silicon heterojunction cell with a MoO_x layer in place of the a-Si:H(p), full area e-contact = n-type solar cell with a full area rear contact (most commonly TiO_x).

References

[1] T. Allen, J. Bullock, X. Yang, A. Javey, and S. De Wolf, 2019, “Passivating contacts unlock the full potential of silicon solar cells,” *Accepted*.

[2] J. Bullock *et al.*, 2019, “Dopant-Free Partial Rear Contacts Enabling 23% Silicon Solar Cells,” *Adv. Energy Mater.*, 1803367.

[3] J. Dréon, C. Ballif, and M. Boccard, 2019, “Influence of MoOx and (i)a-Si:H layer thickness on the properies and stability of c-Si heterojunction solar cells,” presented at the European Materials Research Society Spring meeting, Nice, France.

[4] J. Bullock *et al.*, 2018,“Stable Dopant-Free Asymmetric Heterocontact Silicon Solar Cells with Efficiencies above 20%,” *ACS Energy Lett.*, pp. 508–513

[5] W. Wu *et al.*, 2018, “22% efficient dopant-free interdigitated back contact silicon solar cells,” *AIP Conf. Proc.*, vol. 1999, no. 1, p. 040025,