Towards Dopant-Free Solar Cells on Crystalline Si using Metal Oxide Carrier Selective Layers

RAŞIT TURAN[1,2] AND HISHAM NASSER[1]

[1] Center for Solar Energy Research and Applications (GÜNAM),
Middle East Technical University (METU)
Ankara 06800, TURKEY

[2] Physics Department, Middle East Technical University (METU)
Ankara 06800, TURKEY

ABSTRACT

Recently, there has been a substantial increase in the performance of crystalline silicon (c-Si) solar cells featuring dopant-free carrier selective passivating contacts. These contacts can simultaneously passivate the Si surface while selectively extract only type of photogenerated charge carriers (i.e., either holes or electrons). The dopant-free Si solar cells are less fundamentally limited by parasitic light absorption and carrier recombination with the potential for lower costs compared to widely used state-of-the-art heavily doped, directly metallized counterparts. In this work, a comprehensive study on three emerging hole-selective transition metal oxides (TMOs), molybdenum oxide (MoOx), vanadium oxide (V2Ox), and tungsten oxide (WOx) on n-type and p-type c-Si solar cell is reported. Owing to their high work-function (above 5 eV) compared to c-Si, these oxides are able to extract hole, and thus repel electrons. Their wide energy band gaps make them excellent candidate to serve as front side hole-selective contacts. The studied TMOs were deposited on n- and p-type c-Si substrates by thermal evaporation technique at room temperature. The corresponding optical, electrical, and structural properties are investigated using spectroscopic ellipsometry, AFM, and IV measurements. After optimizing the materials properties, the passivation quality of these TMOswere investigated on n- and p-type wafers coated with different passivation interlayers. A comparative study on the photovoltaic behavior of p and n-type c-Si solar cells with these hole-selective layers (thickness less than 15 nm) will be presented. Photovoltaic conversion efficiency exceeding 17.6% was obtained from industrial-scale p-type solar cells featuring full-area MoOx/Ag rear contacts. Efficiency values of 19.42% and 18.38% were achieved from large area p-type c-Si solar cells with MoOx/Ag and WOx/Ag local rear contacts, respectively. An impressive efficiency of 14% (12.1%, and 11.5%) was achieved from ultra-thin (c-Si substrate thickness of 22.5 µm) p-type c-Si solar cells with MoOx/Ag (WOx/Ag, and V2Ox/Ag) full-area rear contacts. A record efficiency, from low temperature processes, of 18% was obtained from wet-chemically passivated n-type c-Si heterojunction enabled by MoOx at the front side coupled with electron-selective LiFx/Al rear contact. The aforementioned materials properties and solar cells efficiency results infer that these TMOscan be utilized in other light-emitting diode or photovoltaic devices.

BRIEF BIOGRAPHY

Raşit Turan completed B. Sc. and M. Sc. degrees at the Physics Department of Middle East Technical University (METU), Turkey. He received his Ph.D degree from University of Oslo, Norway in 1990. He worked as Post. Doc. at Linköping University, Sweden. He joined METU Physics Department as faculty member in 1991. He worked as a visiting scientist at the Material Science Department of Toronto University, Canada in 1996. His main research interests have been physics and technology of semiconductor materials and devices including solar cells. He has published more than 220 scientific papers in this field in the internationally recognized journals.

Rasit Turan initiated the foundation of a national research center called Center for Solar Energy Research and Applications (GUNAM) on METU campus in 2009. Since then, he is serving as the director of GÜNAM.