Application of grading Se alloys for high efficiency CdTe solar cells

Chuang Li[1], Wei Fu[2], Hamidou TANGARA[2], Chuanqi Li[1], Jingquan Zhang[1*], Takeaki Sakurai[2*]
[1]College of Materials Science and Engineering, Sichuan University, Chengdu 610065, China
[2]Institute of Applied Physics, University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan
E-mail: scucreateli@163.com

Improving the efficiency of CdTe solar cells will further promote the cost-reduction of photovoltaics. For devices with CdS as the buffer layer, very thin CdS layer can greatly deteriorate the performance, on the account of the deficit open circuit voltage (Voc) and fill factor (FF). However, the CdS layer is always considered as “dead” layer, which indicated that the photons absorbed by the CdS layer cannot be converted into photocurrent. Thick CdS layer will significantly reduce the current collection at the short wavelength region (300-520nm)[1)]. In this work, for optimal cell performance, 70nm CdSe was composited with very thin CdS layer (40nm) as buffer layer with the same application of CdTe deposition, post annealing process, back contact (ZnTe:Cu) and back electrode (Au). The highest efficiency reached 17.38%, with Voc 823mV, Jsc 28.67mA/cm^2 and FF 73.68% without the antireflection layer. which is the highest among CdTe solar cells with the CdS/CdSe composited window layer.

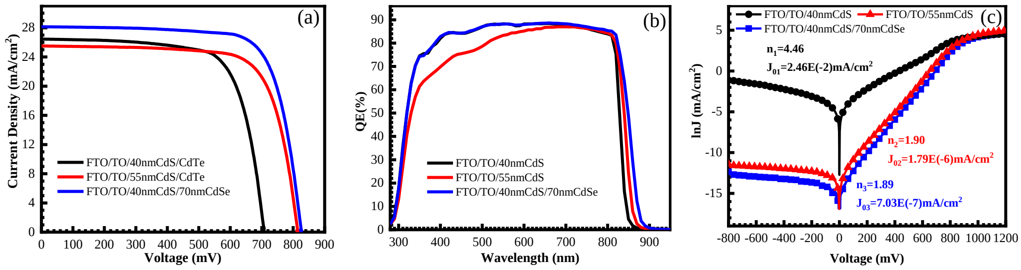

Figure 1 (a) Current density (J)-Voltage (V) under AM1.5 illumination; (b) External quantum efficiency (QE) (c) J-V measurement under dark condition of devices with varied buffer layer.

Increasing the thickness of CdS layer can enhance the energy harvest due to the improvement of the Voc and FF, as shown in figure 1 (a). But the current collection at the short wavelength region was significantly reduced as shown in Figure 1 (b). Introducing the CdSe layer into the device, higher Voc and FF than devices with thick CdS device and higher Jsc than devices with thin CdS layer can be maintained simultaneously. The Se alloys, formed in the high temperature CdTe deposition process and post annealing process, not only have no influence on the photon harvest in the short wavelength region but also extend the spectral response at long wavelengths region as shown in the Figure 1(b), which result in higher Jsc. The reduced dark saturation current may be the main contribution to the Voc and FF improvement of the devices with composited buffer layers. Defect distribution revealed by admittance spectroscopy was used to analyze the recombination in the devices. A total of three distinct trap signatures were detected in every cell. The shallowest defect with activation energy about 0.07eV is consistent with the singly ionized cadmium vacancy V_{Cd}^{-} accepter defect, as well as the chorine A center $V_{Cd}^{2-}Cl_{Te}^{+}$ complex[2)] The defect with activation energy about 0.25eV, which may be related to V_{Cd}^{2-} or Cu_{Cd}^{-}, has very small capture cross section, therefore should not contribute to recombination[3)]. Introducing the Se alloys would reduce the density of the deep defect with activation energy about 0.50eV, which may relate to the $(Cd_{Cu}Cl_i)^{2+}$ complex[4)]. The reduced deep defect may be the reason for efficiency enhancement. The device with Se alloys also exhibits higher photo luminescence intensity in the buffer/absorber interface with peak redshift, indicating less nonradiative recombination and the formation of the Se alloys. The less defective Se alloys in the vicinity of the interface may be the reason for the efficiency enhancement.

Reference

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