Area: Crystalline and Thin Film Silicon PV

CARRIERT SELECTIVE TRANSPORT PATH IN A MOLYBDENUM OXIDE/TUNNEL INSULATOR/N-CSI CELL

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[Introduction] The molybdenum oxide (MoOx)/(tunnel)-insulator/n-cSi cell [2] is an n/n-iso-type heterojunction cell. That is, exactly speaking, the molybdenum oxide electrode is not a p-type “hole” contact. In the forward bias region, electrons in the n-cSi substrate are injected into the MoOx electrode over a built-in surface potential, both in dark and under illumination. Photo-generated holes in the n-cSi substrate, stored in a surface depletion-or-inversion layer, are injected into MoOx electrode. However, without band alignment for direct tunneling of the holes [2] or without enough carrier recombination sites in the insulator or at the MoOx/insulator interface in case of band misalignment, the holes will be impeded to transport into the MoOx electrode. Then the s-letter like distortion appears in the IV curve. In this paper, to see the electrical nature for the hole transport from the surface depletion-or-inversion layer to the MoOx electrode, IV characteristics of an electron transport path and that of a hole transport path are separately extracted in experimental cells.

[Experiment] The experimental cells were fabricated by thermal vacuum evaporation of 30 nm thick MoOx on chemically (1.2 nm thick by hot nitric acid) oxidized n-type 1-5 Ω cm (100) face 300 μm thick cSi substrates. Further, 50 nm thick indium tin oxide (ITO) was deposited on MoOx by the remote plasma deposition (RPD). After RPD of ITO, post-deposition forming-gas-annealing (PDFGA) was performed at 200, 250, 300 and 400°C, respectively. As electron selective back contacts, Al was deposited on the chemical oxide on back surfaces of the substrates. Shown in Fig. 1 is IV characteristics of an experimental cell with PDFGA at 250°C, an IV curve in dark and an IV curve under the illumination of AM 1.5, respectively. A large s-letter like distortion in the illuminated IV curve is observed. The s-letter like distortion was negligibly small for the cells with 200°C PDFGA and without PDFGA (as depo).

[Analysis] If the cell is of a conventional p’n homo-junction structure, an illuminated IV curve would be a curve obtained by adding the constant photocurrent at a reverse bias, Iph to dark IV curve, as labeled “Iph + Idark” in the figure, where, strictly speaking, the effects of a series resistance and increase of Idark by the increase in number of electrons under the illumination should be considered. However, big differences were observed between the experimental IV curve under illumination and the hypothetical “Iph + Idark” curve for p’n homo-junction. To see an IV curve for the hole transport from the depletion-or-inversion layer to the MoOx electrode, hole current component was extracted by deducing the electron current (approximated by Idark) from IV curve under illumination. Then, using a model of series connection of the constant current Iph and the above stated hole current component, an IV curve for hole transport was obtained.

[Discussion and Conclusion] Thus extracted IV curves for hole transport path before and after PDFGA at various temperatures are shown in Fig2. The voltage range of the IV curves becomes larger, as the temperature of PDFGA increases more than 200°C. This suggests the band misalignment due to the decrease of the interface workfunction with PDFGA at more than 200°C [3] and reduction of number of the carrier recombination sites at the interface or increase in the tunneling insulator thickness.

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[References]

Figure 1: IV curves under illumination AM1.5 and in dark of an experimental ITO/MoOx/chemical oxide/n-cSi cell with PDFGA at 250°C

Figure 2: extracted IV curves for the photo-generated hole transport with PDFGA temperature as a parameter