INVESTIGATION OF DEGRADATION MECHANISMS ORIGINATING NEAR OHMIC ELECTRODES

Jonathon Mitchell

1The National Institute of Advanced Industrial Science and Technology, Japan

Hydrogen has been extensively studied for its use in passivating electrically active defects which occur, for instance, at the crystalline silicon surface. Conversely, the mechanisms in hydrogen-related degradation near ohmic electrodes for the solar cell have been overlooked. Key questions remain concerning the role of extrinsic factors, including oxidation or the presence of moisture, and that of intrinsic factors including inherent structural and electronic disorder present in semiconductor and dielectric films. In most photovoltaic devices, trapping of charge carriers in localised states occurs at the interface between two layers (e.g. c-Si/dielectric), however, the molecular level nature of these defects in terms of intrinsic structural defects and extrinsic chemical impurities, or a combination thereof is not well understood. This paper examines the H$_2$ sensitivity of ohmic contact regions by applying the MESH-PTS simulation in combination with experimental analysis of threshold voltage, duty-cycle, and dielectric-electrode resistance using the Single-Line-Area Resistance (SLAR-k) setup for a range of environmentally induced conditions.

Three sets of c-Si devices with passivating materials (SiO$_x$, SiN$_x$, a-Si:H) are examined. Hydrogen-related device degradation manifested as a shift in the expected threshold voltage, the sub-threshold slope, reductions of field-effect mobility for hydrogenated materials (SiNx, a-Si:H), and hysteresis between subsequent measurements of the transfer characteristics with changing bias voltage (Fig. 1). For SiO$_x$ and SiN$_x$, the threshold voltage was found to shift in the direction of the applied bias voltage. This degradation was reversible with extended annealing in N$_2$, however, only temporary. Pre-treatment of SiO$_x$ and SiN$_x$ by hydrogen through degradation, and restoration exhibited improvements in the conductivity surrounding the ohmic contact, however, this also induced higher electron migration providing additional limitations on device performance. Bonding angle shifts were observed for a-Si:H reducing the susceptibility of the thin passivating layer to hydrogen-related degradation near the electrode.

This work indicates that compressive voltage stress increases the susceptibility to specified, homoepitaxial hydrogen-terminated within the region of the ohmic electrodes were observed (Fig. 2).

Simulations by PTS-MESH of the hydrogen desorption in electrode region, indicate that the ohmic electrodes may act as a catalyst, in an oxygen environment, to ionise hydrogen. This then recombines with ionised silicon donors, depleting charge carriers, leading to current loss. Here, one possible cause of the degradation can be associated with mobile charge carriers becoming trapped in pre-existing or stress-generated deep localised states in the semiconductor or dielectric material surrounding the electrode, which can extend to the interface inducing further shifts in the threshold voltage. Once trapped, the charge carriers continue as part of the electrostatic charge near the electrode and interface, however, no longer contribute to the current.

In this work, it was observed that the anti-reflection coating and dielectric material surrounding the ohmic electrode may also contribute to reductions in device performance. Here we propose that hydrogen-related degradation demonstrates a mechanism for reduced performance and reliability of photovoltaics.