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Microstructure and interface of indium–tin–oxide contacts on hydrogenated amorphous silicon

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ABSTRACT: Evaporated and sputtered indium-tin-oxide (ITO) contacts on hydrogenated amorphous silicon (a-Si:H) devices were examined by cross sectional transmission electron microscopy (TEM). Evaporated ITO films were found to show high porosity whereas sputtered films were compact. The thickness of the interfacial oxide (SiO_x) between ITO and a-Si:H agrees well with electrical properties.

Metallization is an important topic of research in the development of semiconductor devices. For electro-optical applications a transparent electrode with good electrical properties is required. This can be achieved by use of indium-tin-oxide (ITO) contacts. In the case of large-area image-sensor devices based on hydrogenated amorphous silicon (a-Si:H) [1] a reverse-biased Schottky contact turned out to be advantageous because of a low dark current and a saturated photocurrent with fast response behaviour [2,3]. This Schottky diode characteristic can be achieved by fabricating a well-defined interfacial oxide layer (SiO_x) between ITO and a-Si:H [4]. In this contribution the microstructure of evaporated and sputtered ITO films and the interfacial oxide layers were studied by cross sectional TEM. The results will be correlated to electronic properties.

The interfacial oxide was formed immediately after the a-Si:H deposition in the same reactor by plasma oxidation. In a next step the ITO was deposited by electron gun evaporation or by sputtering from an ITO target. Then the films were annealed at 200°C in oxygen atmosphere normally for 1 hour. In order to study the whole film structure, consisting of a-Si:H, SiO_x and ITO, thin cross sections were investigated at 200 kV beam voltage.

The typical film thickness of ITO is about 100 nm. Figure 1 shows evaporated layers. The lower part of the ITO consists of nearly compact amorphous material, whereas the upper part shows a columnar and porous structure. Within the ITO film isolated crystallites (~10 nm size) are visible as dark dots. Despite an interface roughness of about 8 nm (peak to peak) in both samples, plasma oxidation of the a-Si:H provides a thin SiO_x layer with uniform thickness. Different SiO_x thicknesses of 2 nm and 7 nm for the two specimens shown in figure 1 a and b correlate well with different barrier heights of the ITO/a-Si:H junction.

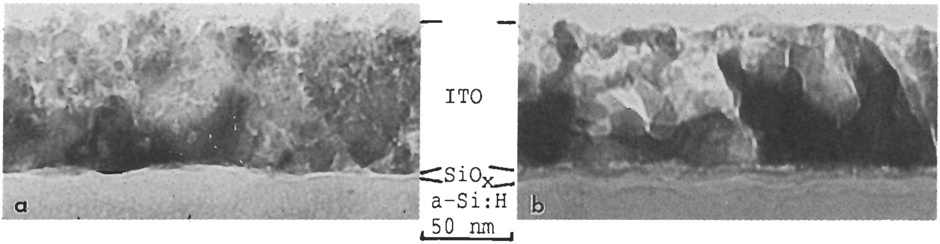
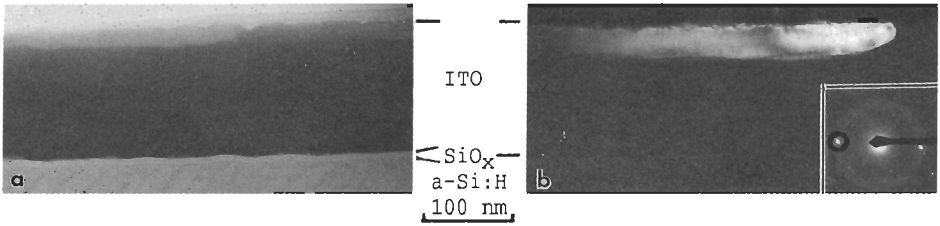


Fig. 1 :
Evaporated ITO with interfacial SiO$_x$ layers of different thicknesses.

Images of sputtered ITO (fig. 2) indicate a homogeneous amorphous phase without any porosity. Isolated, approximately 30 nm thick crystallites with a large lateral extension (~ 500 nm) were found below the top surface of these layers. In figure 2 c the effect of irradiation damage caused by electron beam is imaged. Due to the high dose of the order of 50 As·cm^{-2}, which is about 100 times higher than the dose needed for a standard TEM image exposure, the ITO layer has crystallized. Wave-like structures within the a-Si:H are decoration artefacts induced by argon etching used for preparation of the TEM specimens. Change of microstructure during annealing of the sputtered ITO films will be presented.



c

100 nm

Fig. 2 :
(a) Sputtered ITO with crystallites below the surface of the layer, which is clearly visible in the dark field micrograph (b). (c) crystallization of amorphous ITO caused by electron beam irradiation.

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