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AMBIENT-INDUCED DEFECT STATES AT a-Si:H/ITO INTERFACES

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The stability of image sensors made from a-Si:H was studied. If sensors are light-soaked in moist ambient, the reverse dark current rises by orders of magnitude. Contrary to the Staebler-Wronski effect, this increase disappears at room temperature between 1 minute and several days. We suggest: Ambient-induced defect states emerge at the interface a-Si:H/ITO in presence of H_2O. They act as hole traps 1.0 ... 1.4 eV above E_V. Thermal emission governs the relaxation of the dark current.

1. INTRODUCTION

Easy reading of A4-size documents calls for large-area scanners that can operate without optical reduction. Our sensors are built from amorphous silicon (a-Si:H) in the sequence Cr/ a-Si:H/ITO. Their elements meet the most important requirements for image sensors: high photocurrent, low dark current, and fast photoresponse behavior[1]. In this paper we study the stability of the sensor. As the elements are reverse-biased, the performance is governed by the a-Si:H/ITO junction. An intermediate oxide layer is introduced for a lower dark current and an enhanced chemical stability. Thus the contact is an MIS junction. It can be described by the Schottky theory, but as interface states play a major role, the Bardeen theory should also be applied. We will thus call it a Schottky-Bardeen-MIS (SBMIS) junction[2].

The reverse current of the diode is determined by the barrier height. It is evaluated by internal photoemission and from temperature-dependent current-voltage characteristics[3]. For simplicity we use the dark current at -5 V bias as a measure for the barrier height.

The barrier height is altered when electronic states in the a-Si:H bulk or at the interface to the ITO electrode are created or if they change their charge state. A detailed consideration[2] leads to the following conclusions: a lower barrier can be caused by (1) the creation of interface states with a neutrality level E_n above the Fermi level E_F, (2) negative charging of bulk states, or (3) positive charging of interface states.

2. EXPERIMENTAL

The samples were produced on glass with the sequence: chromium, undoped a-Si:H, deposited 1 μm thick by PECVD, and ITO. Details have been described elsewhere[5]. On the a-Si:H surface an about 3 nm thick oxide layer was developed by an oxygen plasma[4]. The samples are n-type with E_C-E_F typically 0.8 eV. The barrier height is 0.86 eV[6].

We took current-voltage characteris-

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tics in the dark and under illumination (10^{14} phot./cm^{2}s, 550 nm). Photocurrent transients were measured after switching off steady-state illumination by a Bragg cell[7].

Our investigations were performed either under vacuum or in N_2, O_2, air under atmospheric pressure or in saturated water vapour.

3. RESULTS

Current-voltage characteristics of our SBMIS junctions are shown in Fig.1. The annealed sample (curve A) exhibits a dark current density at reverse bias of only $5 \cdot 10^{-10}$ A/cm^2. The photocurrent is independent of applied voltage in the negative bias regime (primary photocurrent, unity quantum efficiency).

The diodes were light-soaked (-5 V bias, 12 h, white light, 100 mW/cm^2) in air. This causes the dark current at negative bias to increase strongly (curve B). Resting the sample in the dark for several days at room temperature leads to a recovery. The dark current approaches its low value in the annealed state (A). The current under forward bias is subject to the normal Staebler-Wronski degradation, which remains stable at room temperature.

The relaxation of the dark current under reverse bias was investigated at different temperatures. The samples were light-soaked at room temperature. Then they were heated quickly to the desired temperature and the dark current was recorded from 1 min up to 270 h (Fig.2). If we assume that trapped carriers are thermally emitted from localized states, we can convert

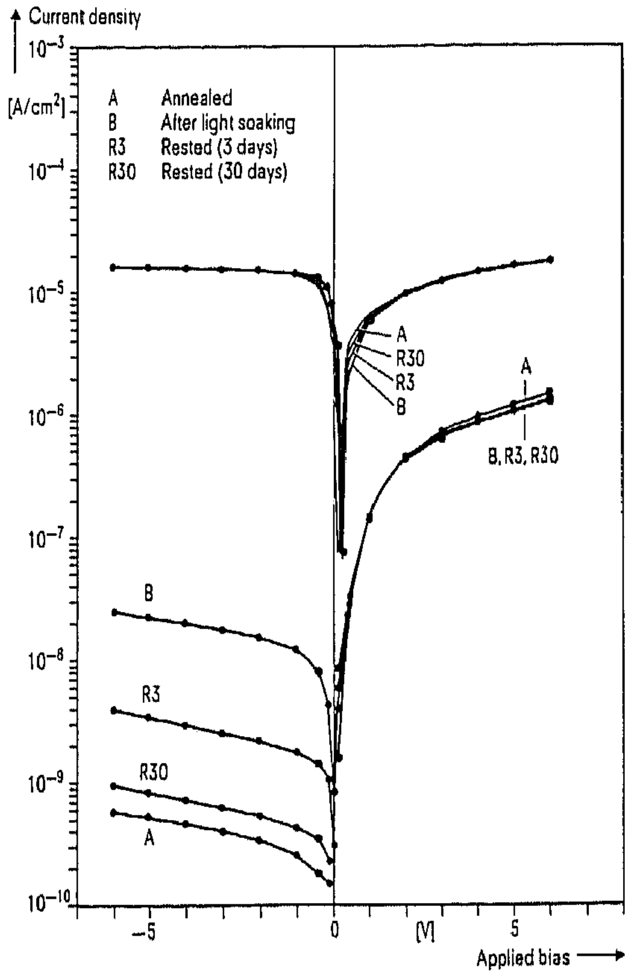

FIGURE 1: Current-voltage characteristics in the dark and under illumination. A = annealed, B = light-soaked (12 h, 100 mW/cm^2), R3 = rested 3 days at room temperature, R30 = rested 30 days at room temperature.

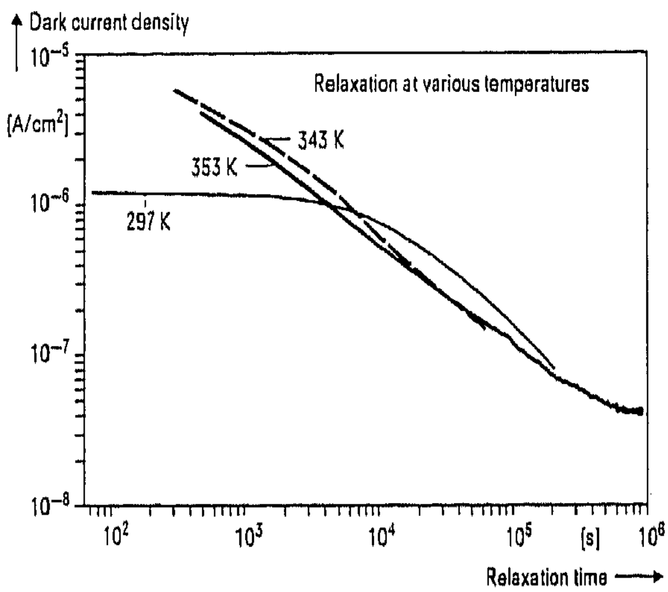

FIGURE 2: Relaxation of the dark current at different temperatures.

the time scale to an energy scale which spans a range of 0.93 eV to 1.4 eV. In Fig.3 the transients are replotted with the curves shifted relative to each other to yield a continuous trend.

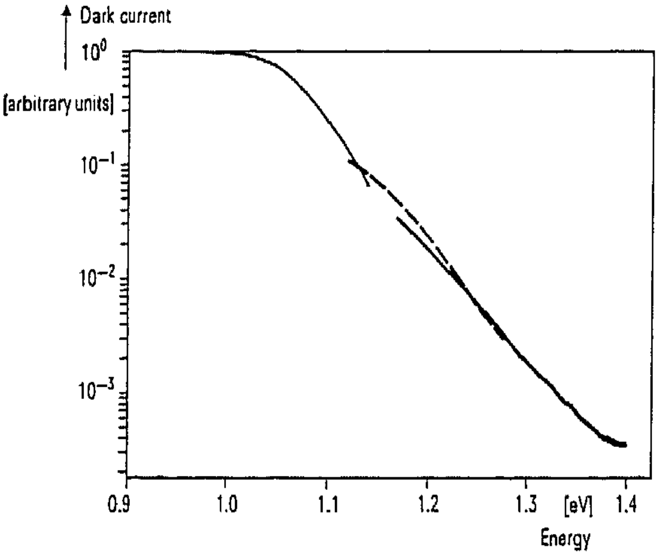

FIGURE 3: Dark current vs. emission energy. The curves are shifted yielding the shape of the emission process.

The change in current indicates an increasing barrier height. From the energies at which the current decreases we conclude that carriers are emitted from states between 1.02 eV and 1.4 eV deep. The effect is not found under vacuum or in N_2 or O_2.
Additional photocurrent decay transient and capacitance measurements show a rise in the midgap density of states.

4. DISCUSSION

We distinguish two different processes: the well-known Staebler-Wronski effect, which is stable at room temperature, and a new phenomenon, a marked increase in dark current of the SBMIS junction after illumination, which is not stable at room temperature.

The Staebler-Wronski effect is caused by an increased density of states near midgap and has been discussed neatly[8]. The dark current increase in air indicates a barrier lowering. We propose that it is due to positively charged interface states 1.0...1.4 eV above E_v. They are created by polar molecules, i.e. H_2O, which diffuse through the porous ITO electrode. Photogenerated holes are trapped in these states. Their thermal emission determines the relaxation. A further indication for this explanation is that the effect is much enhanced with a negative voltage applied during illumination.

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REFERENCES

1) M.Hoheisel, G.Brunst, H.Wieczorek, J. Non-Cryst. Solids 90 (1987) 243

2) M.Hoheisel, N.Brutscher, H.Wieczorek, J. Appl. Phys. (1989), in print

3) N.Brutscher, M.Hoheisel, Solid-St. Electron. 31 (1988) 87

4) A.Mitwalsky, M.Hoheisel, W.Müller, C.Mrotzek, Inst.Phys.Conf.Ser.No.93, Vol.2, EUREM 88, York 1988, p.107

5) K.Rosan, G.Brunst, MRS Symp. Proc. 70 (1986) 683

6) M.Hoheisel, N.Brutscher, H.Oppolzer, S.Schild, J. Non-Cryst. Solids 97&98 (1987) 959

7) H.Wieczorek, W.Fuhs, phys. stat. sol. (a) 109 (1988) 245

8) M.Stutzmann, W.B.Jackson, C.C.Tsai, Phys.Rev. B 32 (1985) 23