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B—6—3 MOS Solar Cells on Polycrystalline Silicon

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MOS solar cells on polycrystalline silicon are potentially an alternative for terrestrial application. The MOS structure is simple and requires a less expensive processing, while polysilicon reduces the material cost. Moreover it is believed that the MOS configuration will perform better on polysilicon than a pn junction, the former being a surface barrier with no dead layer. The purpose of this work has been to fabricate and investigate the performance of these devices.

MOS solar cells have been fabricated on both p- and n-type polycrystalline silicon with gold, silver, and aluminum barrier metals in the following manner. N-type polysilicon (SILSO) wafers of 1-10 Ohm.cm resistivity were obtained from Wacker Chemitronic as well as p-type polysilicon (SILSO) wafers of 1-10 Ohm.cm resistivity. P-type polysilicon wafers of 0.1-0.3 Ohm.cm resistivity were also obtained from Monsanto. The Wacker wafers were chemically polished in a mixture of CP4 solution and HNO_3, in which about 10-15 micron material was removed from each side. The Monsanto wafers were not chemically polished, as it rendered the wafer surface unsmooth. The grain size was very nonuniform, varying between 1-10 mm. All the wafers were chemically cleaned by degreasing in solvents, etching in HF, and finally rinsing in deionized water. In most cases, oxidation was carried out after chemical cleaning, in dry oxygen at a temperature varying between 700 and 800 ^{o}C and at an oxygen pressure of 1.0 atmosphere. On these wafers, after oxidation, the front barrier metal layer and then the back metal contact were deposited in an oil-free high vacuum system. The chamber pressure during deposition was held below 1.0×10^{-5} torr. The back metal contact was aluminum for n-type wafers and gold for p-type wafers. The thickness of the semitransparent barrier metal (either Au or Ag on n-type, or Al on p-type polysilicon) layer varied between 40 and 70 Å, and was monitored during deposition with the help of a digital quartz crystal thickness monitor. The barrier layer was deposited through metal masks having circular holes, the diameter of which varied between 2 and 5 mm. No properly designed grid has been used, only a thick contact pad of 1.0 mm diameter at the periphery of the circular area. In some cases, the back ohmic contact was deposited after chemical cleaning, and the oxide was grown either in clean-room air, or in the case of aluminum barrier metal on p-type polysilicon, in dry oxygen (at 1.0 atmosphere pressure) at 500 ^{o}C. In the latter case, the back ohmic contact was also aluminum. No anti-reflection coating was used on any of the cells.

The following electrical measurements were carried out on the cells. The I-V characteristic of the cell was measured under tungsten lamp illumination. The intensity of illumination was adjusted to AM1 with the help of a standard cell and in some cases optical concentration was used. The diode I_D-V and C-V characteristics were also measured in dark and under various levels of illumination. The above measurements have also been carried out, on some cells, at 77 ^{o}K and at temperatures higher than 300 ^{o}K. The cell area was determined with

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the help of an optical microscope. The open-circuit voltage V_{oc}, short-circuit current density J_{sc}, fill factor F, and the conversion efficiency η, were determined from the current-voltage (I-V) characteristic of the cell. The doping density and the silicon band-bending at zero voltage φ_i^o were obtained from the $1/C^2$-V characteristics. The diode quality factor n and the series resistance R_s were obtained from the diode current-voltage (I_D-V) characteristics.

The measured results obtained so far and their analysis reveal the following: For MOS cells on n-type polysilicon with Au barrier metal, the highest open-circuit voltage obtained is 495 mV, the highest short-circuit current density is 26.3 mA/cm^2, the highest fill factor is 0.73, and the highest efficiency is 9.5 percent. For MOS cells on n-type polysilicon with Ag barrier metal, the highest open-circuit voltage obtained is 516 mV, the highest short-circuit current density is 27.0 mA/cm^2, the highest fill factor 0.71, and the highest efficiency is 9.9 percent. For MOS solar cells on p-type polysilicon with Al barrier metal, the highest open-circuit voltage obtained is 467 mV, the highest short-circuit current density is 18.2 mA/cm^2, the highest fill factor is 0.69, and the highest efficiency is 5.9 percent. The only MOS poly cell reported in literature[1] so far had the following characteristic : V_{oc} = 523 mV, J_{sc} = 22 mA/cm^2, F = 0.76, and η = 8.6 percent. The latter had an AR coating while none of ours had.

Of the various oxidation conditions tried, dry oxydation at a temperature between 700 and 800 °C was found to produce, in general, the highest open-circuit voltage. This is perhaps due to a smaller interface state density at higher oxidation temperature[2]. As is the case for cells grown on single crystal silicon[2], both the open-circuit voltage V_{oc} as well as the silicon band-bending at zero-bias φ_i^o were found to increase with the oxide thickness t_{ox}. However, V_{oc} reached a maximum value for t_{ox} in the range of 20 to 24 Å, while φ_i^o tended to saturate beyond 30 Å. In case of Au and Ag barrier metals, the highest short-circuit current density was obtained for a layer thickness in the range of 40 to 60 Å, while for Al barrier metal the same was obtained for a layer thickness in the range of 60 to 70 Å[3]. The lower short-circuit current density in case of Al barrier metal, is due to higher reflection and can be increased with the help of an AR coating[1,4]. Au and Al MOS solar cells were found to be more stable than Ag MOS solar cells which were found to degrade mainly due to diffusion of and reaction with oxidizing species in the atmosphere. This can be prevented by an AR coating or a passivating layer. Optical concentrations upto 11.0 were used on some Au MOS solar cells, and the performance even with an elementary contact pad was found to be encouraging. The open-circuit voltage increased with concentration, the fill factor gradually decreased, and the efficiency changed very slowly.

1. D.R. Lillington and W.G. Townsend, Appl. Phys. Lett. 31, 471 (1977).
2. S. Kar, J. Appl. Phys. 49, 5278 (1978).
3. S. Kar, D. Shanker, S.P. Joshi, and S. Bhattacharya, J. Electrochem. Soc. 126 (1979).
4. E.J. Charlson and J.C. Lien, J. Appl. Phys. 46, 3982 (1975).