

Low-cost non-toxic process for cadmium telluride solar cells

The University of Liverpool proposes the use of magnesium chloride in place on cadmium chloride in CdTe solar cell production.

University of Liverpool researchers propose replacing a toxic treatment step in cadmium telluride (CdTe) solar cell production with one that is benign, but apparently just as effective [J.D. Major et al, *Nature*, published online 25 June 2014].

Presently a cadmium chloride (CdCl₂) doping 'activation' treatment is used to form the photovoltaic junction with cadmium sulfide (CdS) and also to passivate grain boundaries. Both aspects are essential in providing high-efficiency devices. Without treatment, cells have efficiency of ~2%. The treatment increases this to over 10% and laboratory 'champions' have gone beyond 20% — the chart of the US National Renewable Energy Laboratory (NREL) currently gives a 20.4% record. Unfortunately, CdCl₂ is toxic and expensive (~30 cents/gram). Unlike CdTe and CdS, CdCl₂ is water soluble, releasing toxic Cd ions and posing risks to production workers and the wider environment.

The proposed replacement treatment involves magnesium chloride (MgCl₂). The Liverpool team estimates the cost of MgCl₂ at 0.1 cent/gram, since it can be obtained from sea water. The material is widely used for cold-weather road treatments, bath salts, and as a food additive (e.g. in tofu).

The researchers comment: "A process change from CdCl₂ to MgCl₂ has huge potential instantly to reduce the cost of power generation by CdTe photovoltaics and to minimize the risks in industrial production."

The Liverpool cells were deposited on TEC10 soda-lime glass that was coated with fluorine-doped tin oxide supplied by NSG Group. A 120nm layer of CdTe was deposited on a 100nm zinc oxide (ZnO) buffer using sputtering at 200°C and room temperature, respectively. The CdTe layer was extended by close space sublimation in nitrogen with the source at 620°C and substrate at 520°C. Before the chloride treatment the cells were etched using a nitric/phosphoric acid solution.

The standard chloride treatment consisted of evaporation of a 100nm layer of CdCl₂ onto the CdTe. Two

Table 1. Peak solar-cell performance for all chlorides tested.

| Treatment | Peak efficiency (%) | Peak fill factor (%) | Peak short-circuit current density (mA/cm ²) | Peak open-circuit voltage (V) |
|----------------------------|---------------------|----------------------|--|-------------------------------|
| CdCl ₂ | 13.02 | 70.01 | 22.13 | 0.831 |
| MgCl ₂ solution | 12.71 | 69.08 | 22.41 | 0.821 |
| MgCl ₂ vapor | 13.50 | 70.24 | 23.26 | 0.826 |
| NaCl | 6.75 | 53.34 | 19.78 | 0.603 |
| MnCl ₂ | 4.37 | 45.87 | 18.30 | 0.520 |
| KCl | 5.49 | 50.11 | 17.95 | 0.607 |

alternative MgCl₂ treatments were tried: in one, the MgCl₂ was deposited in methanol solution; in the other, the MgCl₂ was applied to a glass slide that was placed next to the CdTe substrate during annealing in a tube furnace. In fact, all samples were annealed for durations of 10–60 minutes in the temperature range 390–450°C.

The optimum anneal for the standard CdCl₂ and the MgCl₂ solution treatments was found to be 20 minutes at 430°C. The MgCl₂ vapor treatment from the glass slide was found to be best at 430°C for 40 minutes.

The cells were completed with a further wet etch and deposition of gold back-contacts.

The performance of devices (Table 1) shows that the MgCl₂ vapor treated cells gave identical performance to the standard process within the margin of error. Alternative materials such as sodium chloride (NaCl, normal table salt), potassium chloride (KCl), and manganese chloride (MnCl₂) gave much inferior results with efficiencies less than 6.7%.

The researchers have also developed a more efficient CdTe cell with MgCl₂ activation that replaced the ZnO buffer with oxygen-doped CdTe and reduced the CdS layer thickness to 40nm. The MgCl₂ was applied in this case in a water solution via spray coating. Also, the back side of the structure was coated with 2nm copper to improve the back contact. The conversion efficiency reached 15.7%. A further notable feature was an open-circuit voltage of 0.857V, "equivalent to that of the current CdTe champion cell", says the team. ■

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