Semi-transparent photovoltaic glazing based on electrodeposited CIGS solar cells on patterned molybdenum/glass substrates

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Photovoltaic glassware with controlled transparency is an emerging application in the field of Building Integrated Photovoltaics (BIPV). Classically, this is achieved by means of standard crystalline silicon modules where open areas are left between the cells. Thin film solar cell technologies are also well adapted for such applications, for aesthetic, design flexibility or cost reasons. CIGS in particular is very promising for entering this field since it can deliver high efficiency solar cells (22.6% record) or modules and is already present in the market for power applications.

In this work, we aim to develop this technology for PV glazing applications, while keeping the advantages of the classical glass/Mo/CIGS/buffer/ZnO structure. As this structure is opaque, part of it needs to be removed to create open glass areas. As classical deposition methods are not area selective, the deposition takes place all over the substrate, which imposes to partly remove the layers after device formation. A more elegant approach is to start from a patterned Mo back contact, and selectively deposit the CIGS layer only on the Mo covered areas. A key method allowing such selective deposition of CIGS is electrodeposition. Electrodeposition has already been proven to be an efficient industrial method for standard modules, with efficiencies up to 14% [1], making it quite suitable for PV glazing manufacturing.

Electrodeposited CIGS solar cells have been prepared in the classical configuration on glass/Mo substrate using an electrodeposition route introduced recently in the field, and known as the oxide route [2]. It consists in depositing a layer of mixed copper, indium and gallium oxides/hydroxides by cathodic deposition from an aqueous solution of nitrate salts. Then the oxides are reduced to metals through hydrogen thermal treatment, followed by selenization to form CIGS. A record efficiency of 12.4% [3] has been obtained with mean values around 11% [4]. This process has been adapted for the deposition on patterned Mo substrates. Differences are observed with the deposition on plain Mo substrates since the diffusion regimes from the solution are different. We succeeded in obtaining conformal deposits of CIGS on the patterned substrates as shown in figures 1a and 1b. Typical figures are 500 micron diameter holes with 700 micron spacing, leading to 200 micron wide Mo channels at minimum. Device completion with buffer layer and ZnO deposition led to devices presenting good PV properties, with open circuit voltage of 400 mV and good internal photocurrent generation as shown by the spectral responses obtained locally, which fit the 35% aperture of the Mo pattern (figure 1e). This is confirmed by the LBIC photocurrent generation map obtained on a 4x4 cm^2 sample shown in figure 1c. However it appears that the LBIC response decreases as a function of the distance from the contact, which can be related to series resistance in the Mo layer; this is currently under study.

These first results already represent a proof of concept of the feasibility of the electrodeposition approach for PV glazing.

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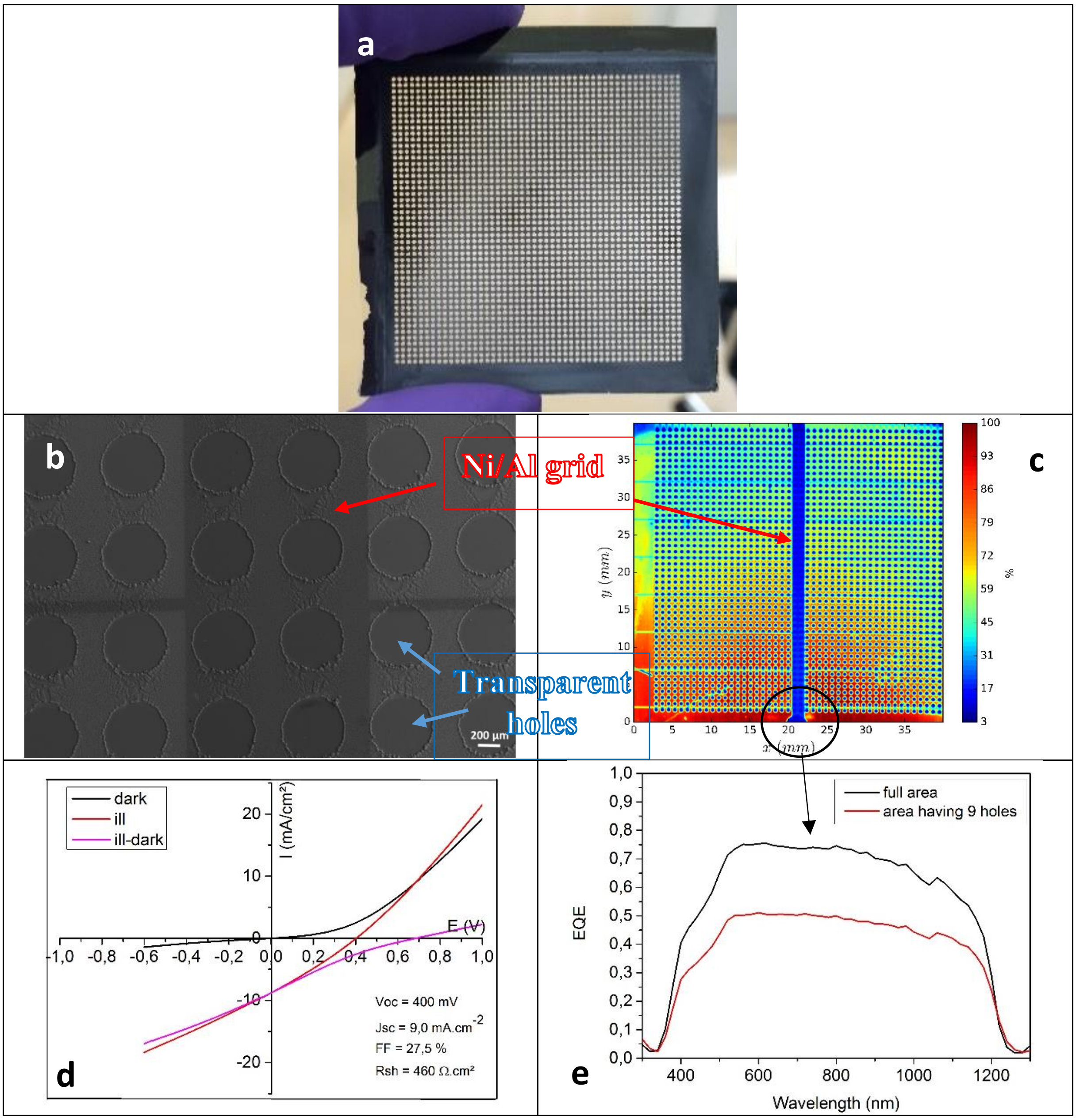

Figure 1: (a) The patterned Mo back contact with CIGS (4x4 cm²). (b) Details of the patterned Mo with conformal CIGS cells. (c) LBIC photocurrent map of the sample. (d) Global I-V curve (4x4 cm²). (e) Spectral response of the sample, by region.