Patterning Solar Cell Metal Grids on Transparent Conductive Oxides using Self-assembled Monolayers

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The conductor grids of heterojunction (HJT) solar cells are typically made of screen-printed silver paste with significant costs. They are limited in curing temperature to less than 250°C to prevent silicon passivation damages. However the low curing temperature causes a higher resistivity of the paste compared to high curing temperature [1]. Copper plating is thus seen as a cost-effective alternative to screen-printed silver. The technological challenges consist in reaching precise patterned structures without parasitic-ghost plating, which demonstrate a high adhesion to the cell TCO, a low contact resistance, a high line conductance, as well as minimum shading (<30 µm line width [2,3]. We propose here a novel concept based on self-assembled monolayers (SAMs) in order to obtain patterned copper lines on TCOs. Since SAMs utilize an extremely small amount of material, this approach could achieve plating selectivity with ultra-low costs.

Self-assembled monolayers (SAMs) have attracted enormous interest for a wide variety of applications in micro- and nanotechnologies. We apply commercially available fluoro-surfactants to form hydrophobic SAMs on transparent conductive oxides (TCO). Our concept is shown in Figure 1. The cost of such layers is estimated to be approximately significantly lower than currently available processes with different molecules such as thiols or silanes. Moreover, we might not require stripping of the SAM at the end of the process [4].

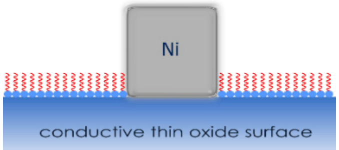

Figure 1: Schematics showing self-assembled monolayers (SAMs) used as a masking layer for electroplating of nickel, then copper on thin conductive oxides.

A spraying method was developed to produce perfluorinated alkylphosphonic acids self-assembled monolayers on pyramid-textured and polished silicon coated with indium tin oxide (ITO) surfaces. On textured substrates, superhydrophobic behavior was observed as shown on Figure 2.

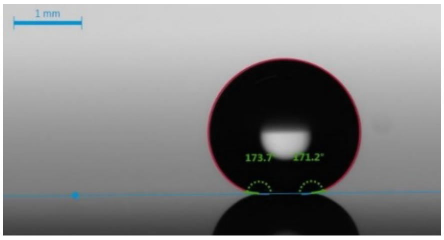

Figure 2: Water droplet behavior on pyramid-textured ITO surfaces.

The dynamic water contact angle measurements show very small hysteresis between the advancing and receding contact angles. This demonstrate the high quality of the self-assembly of molecules on the surface. We also observed that the self-assembled monolayer provides ITO with a resistance to highly acidic electrolytes electroplating solutions. Figure 3 shows the etching effect of the solution. When the surface was not exposed, a smooth white image is observed. Bare ITO was visibly attacked and completely etched by the solution. On places where the ITO is removed, a blue color appears on the microscope images. Microstructures are observed, showing that the SAM presents weaker spots that are more readily attacked by the acidic solution.

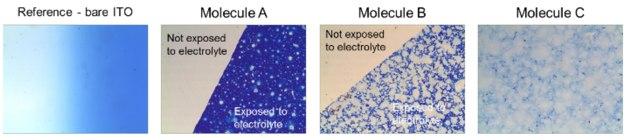

Figure 3: Microscopic images of the etched ITO after 10 minutes dipping in a highly acidic electroplating solution.

The process flow for production of HJT solar cells requires a first layer of nickel to be electroplated on the TCO in order to provide sufficient adhesion for the copper lines. Figure 4 shows the patterned nickel lines obtained in a mild (pH=4.4) sulphamate nickel electroplating bath. The SAM was patterned by a directional oxygen plasma through a silicon hard mask.

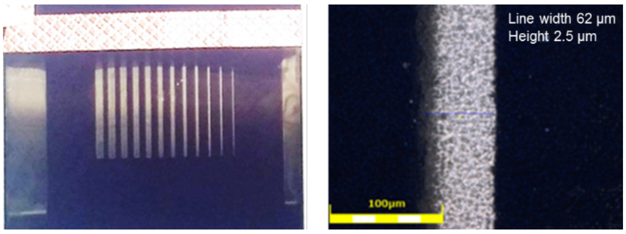

Figure 4: (left) Picture of sample after nickel electroplating using a SAM as resist; (right) Scanning confocal microscopy image taken on the thinnest line of picture shown left.

We are thus able to use the SAM as a resist for electroplating nickel. However, some ghost-plating is observed on the surface where the SAM remained after the plasma treatment. We plan to improve this by strengthening the organization of the SAM. We also will investigate further the quality of the SAMs, patterning methods and the use of SAMs for copper electroplating in the future.

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