Large Area Nanoreplication on Flexible Substrate

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We report on the development of a replication process for the production of nanotextured substrates. The targeted application is the fabrication of thin, flexible photovoltaic cells. The selection of materials, which had to withstand the cell deposition process, the control of surfaces and interfaces and the upscale of our replication process up to samples sizes of 300 × 300 square millimeters proved to be critical. Samples produced have then been used for the fabrication of flexible thin film solar cells.

CSEM has developed within the multi-interdisciplinary project Wear-a-Watt an ultra-low power watch operating only off the solar energy harvested from its environment [1]. One of the main achievements is the fabrication of thin, flexible solar cells and their integration in the wristbands of the watch. The development of these custom solar cells required specific substrates with a high transparency and an optimized surface texture to enhance light trapping.

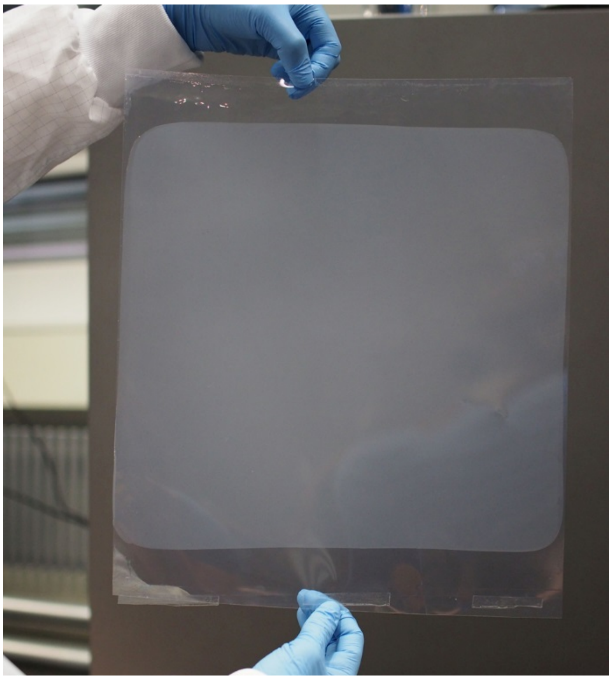

Figure 1: Photograph of a 300 × 300 mm² sample. The nanoimprinted structures give a milky aspect to the substrate. The final thickness of the textured foil is 130 micrometers.

In this work, our standard nanoimprint process has been up-scaled for the production of flexible, textured substrates with a maximal size of 300 × 300 mm². This size was deemed to be a good compromise between lab scale samples and substrates produced using high throughput techniques such as roll to roll replication. Several conditions had to be met such as transparency and heat resistance during the solar cell deposition process.

Many high temperature substrates (withstanding temperatures above 200°C) were benchmarked and ranked according to their compatibility with the different process steps, their mechanical properties (rigidity) and the performance of the final solar cells. The nanoimprint process involved first a coating of the substrate with a UV curable resin followed by the imprinting step using a textured mold. We identified a robust surface preparation of the substrates to ensure good adhesion of the coating at temperatures up to 200°C. Good results were obtained using a hybrid primer directly deposited on the substrate.

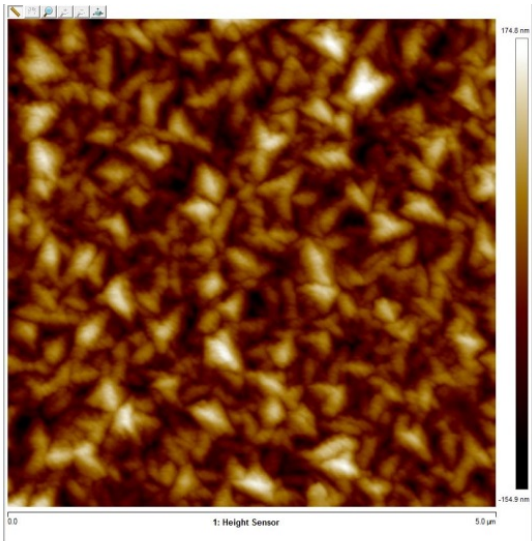

Figure 2: AFM image of the surface of a nanoimprinted replica with light trapping structures.

Cross cut tests (ISO 2409) have been performed to characterize the adhesion of the UV-curable coating on the primed substrate. The results were similar to those obtained using our standard plasma activation. However, the deposition of the primer was easily up-scaled to the targeted sample-size. Concerning the nanoimprint step itself, specific equipment was designed and fabricated for the processing of 300 × 300 mm² samples.

As shown in Figure 1, large nanoimprinted samples have been produced. The fabrication of such samples leads to an increase in throughput of one order of magnitude in comparison with the lab-scale fabrication of textured substrates done until now. Figure 2 presents an AFM image of the textures obtained on the nanoimprinted substrates. The patterning process is homogeneous over the 300 × 300 mm² area and faithfully replicates the original structure of the master.

Ongoing work focuses on the validation of these textured substrates for the fabrication of thin flexible solar cells and their integration in low-power wearable devices. Further investigations will ensure a complete evaluation of their mechanical performances.

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[1] J. Bailat, *et al.*, "Wear-a-Watt—Energy Autonomy for the Wearables", CSEM Scientific and Technical Report (2015), 12.