Correlated disordered nanostructures for light trapping in ultrathin solar cells

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Designing high-efficiency solar cells without significantly increasing manufacturing costs is a major challenge. One solution is to use thin film/silicon tandem cells technologies, but innovations are required to achieve a conversion efficiency over 30%. Improving absorption using advanced light-trapping strategies is an important task. With common approaches absorbing most photons with energy above the band gap requires a thickness of 100 to 500 μm [1], leading to decreased absorption when the cell thickness is reduced.

Significant efforts have been made to trap light using nanostructuring techniques. While random texturing is commonly used in industry [2], there is growing interest in correlated disorder nanostructuring. This approach is increasingly being investigated as it allows the tailoring of optical properties. Recent studies have shown that this method outperforms traditional random texturing, offering improved efficiency and control over optical behaviour [3].

In this context, developing low-cost nanostructuring processes compatible with integration into ultra-thin solar cells is essential. One cost-effective solution is to use correlated disorder nanostructures fabricated by self-assembly processes to enhance light absorption [4], [5].

In this work, we present a cost-effective method for the fabrication of correlated disorder nanoparticles using colloidal lithography. Figure 1a shows an SEM (Scanning Electron Microscopy) image of a disordered array of PS[1]-beads made by colloidal lithography. The pattern is then transfered into silicon via dry etch using a metallic mask. Then, we present several figures of merit to characterize the correlated disorder in our pattern: interparticle distance distribution Figure 1b and structure factor Figure 1c. Our objective is to minimize the structure factor near zero to reduce light scattering at normal incidence and enhance light diffusion at larger angles [6]. To this end, our work aims firstly to understand the impact of the fabrication process on the characteristics and in particular the spatial correlations of the disordered arrangement. We will then study different disordered patterns to establish a benchmark by linking the calculated figures of merit and the measured optical properties. We will discuss the perspectives to integrate such nanopatterning techniques to silicon solar cells.

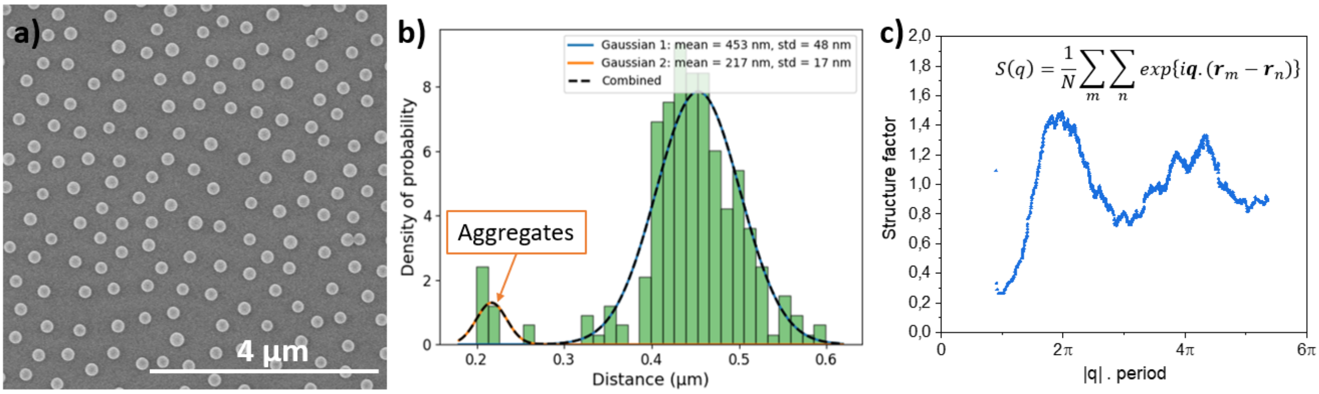

Figure 1: a) SEM image of a disordered arrangement of PS-beads (diameter = 210 nm) assembled on silicon by colloidal lithography b) Interparticle distance c) Structure factor

This work is partly supported by the French National Research Agency through the project 22-PETA-0005 (IOTA) and by the LAAS-CNRS micro and nanotechnologies platform, member of the French RENATECH network.

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