Study of Gold Nanoparticles Quasi-Periodic Array using Dynamic Templating

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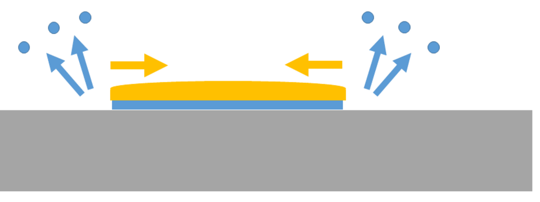
Introduction

- Large scale production of periodical array of nanostructures is needed in solar cell and microelectronic industry. However, current technics are too expensive for large scale or have to low resolution.
- Dynamic templating is a novel process presented by Farzinpour et al. [1] that allows to produce high quality periodical array of nanoparticles from template produced by large-scale low resolution technics.
- This study proposes, in a first time, to assess the use of dynamic templating to create quasi-periodical nanoparticles array and compare it to passive dewetting. In a second, simulations of periodical and quasi-periodical array of nanowires will investigate reduction of diffraction losses.

Dynamic templating

Dynamic templating is a thermal assembly process using a templated bilayer. The bilayer consists of a capping layer, the material of the futur particle, and a sacrificial layer. The main steps are shown below.

1. The sample is heated in order to sublimate the sacrificial layer. Sublimation occurs only from the side as the capping layer passivates the top surface. The top layer is forced to shrink with the sacrificial layer.



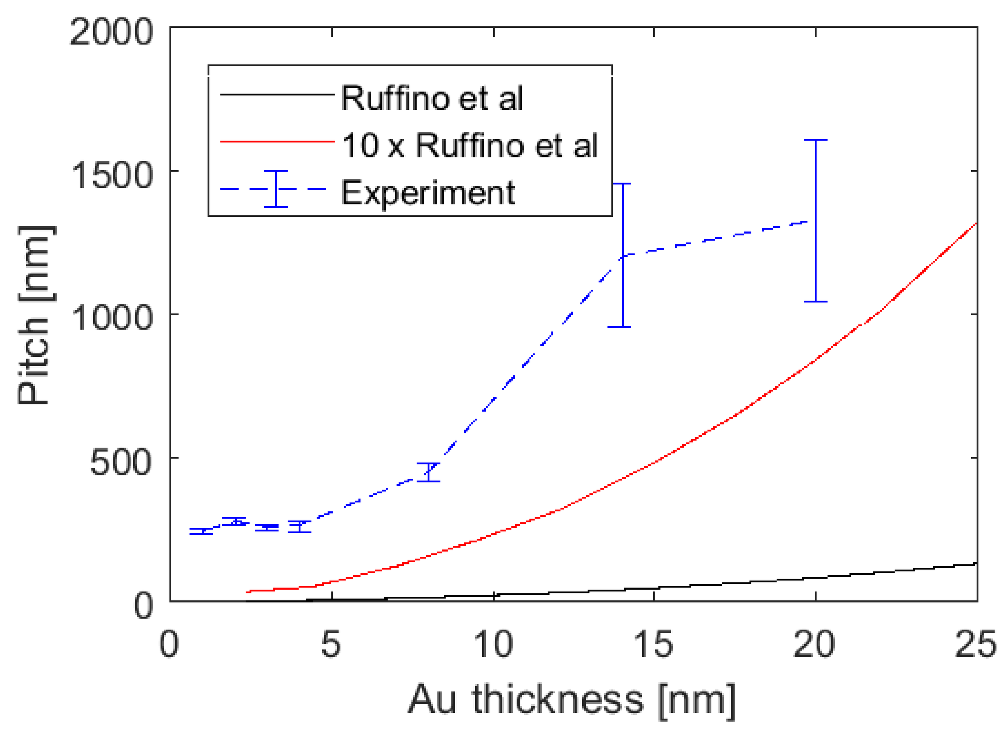
2. Last step results in a big particle composed of the two elements. The temperature is increased to remove the remaining part of the sacrificial layer.

3. Once the sacrificial layer is completely removed, the sample is cooled down and the particle recrystallized.

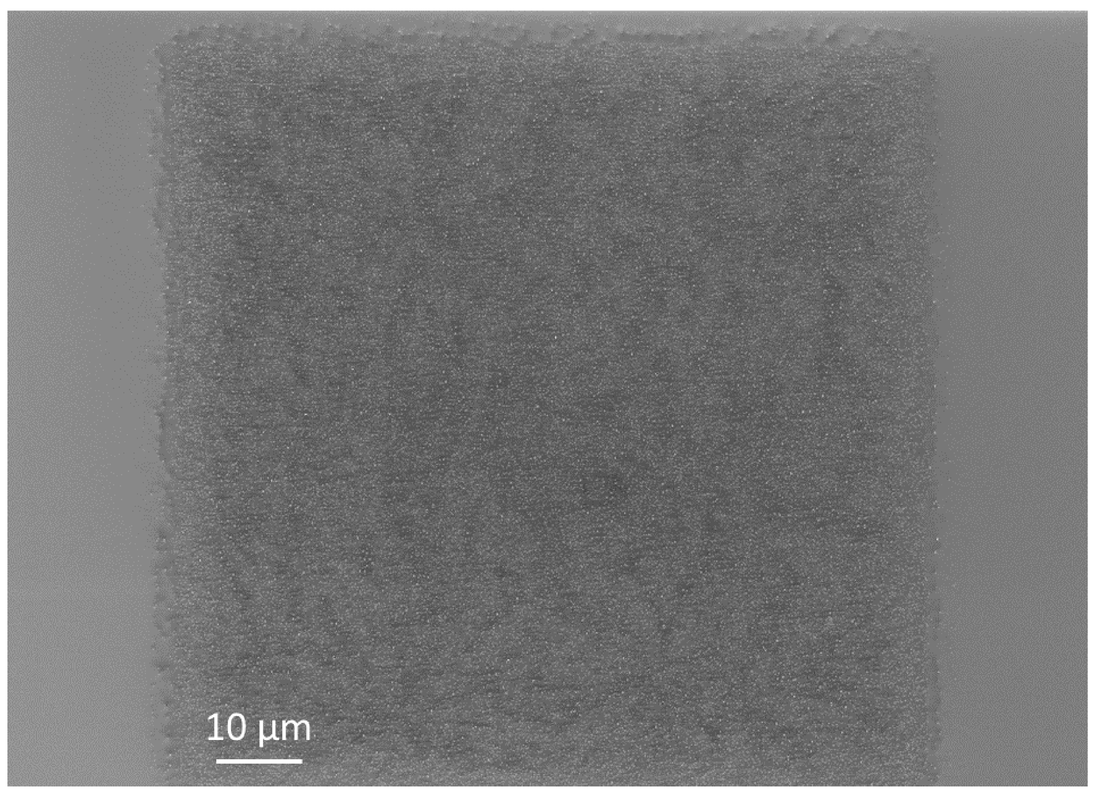
For most of the samples the temperature profile used was: a first step at 615°C for 30min and a second at 1050°C for 10min with an heating rate of 60°C/min for both. Template width to layer thickness ratio up to 125 where obtained. Increasing this ratio allows to use a bigger template to reach a given nanostructure size which simplify processing.

Sacrificial layer dewetting

The use of sacrificial layer allows to increased by a factor of at least 10 the pitch distance between particle compared to passive dewetting [2] when no template is used.



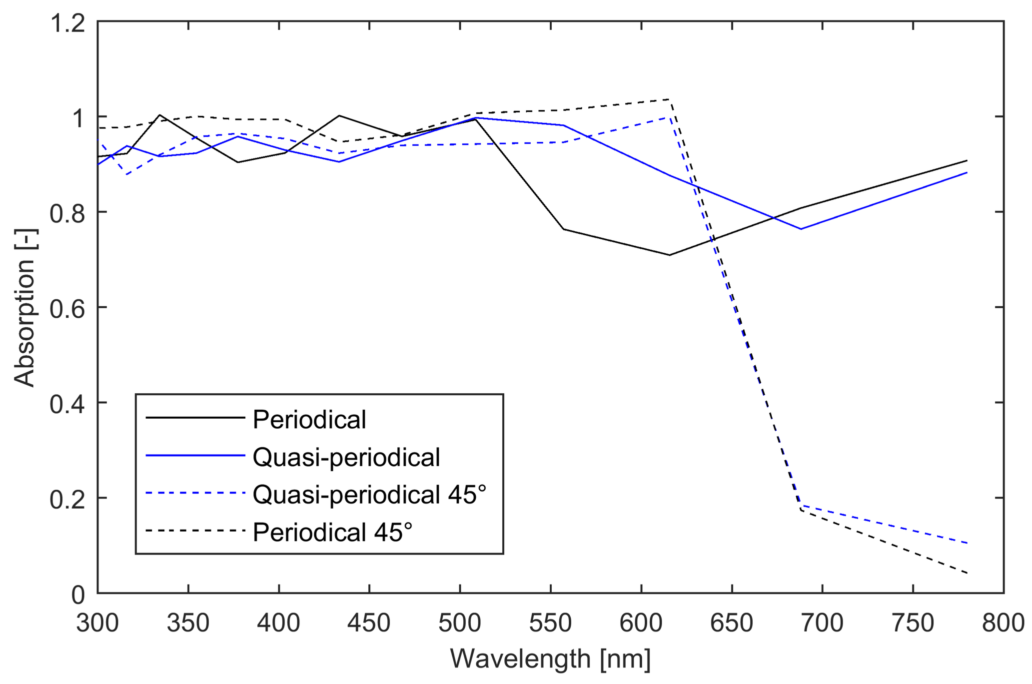
Pitch distance for untemplated particle obtained by passive dewetting and sacrificial layer assisted dewetting



Untemplated particle were obtained having a big template and considering only the center

Diffraction consideration

Kelzenberg et al. [4] showed a decrease in diffraction losses when an array is not periodical. Simulations of our quasi-periodical array with nanowires at nanoparticle's position have shown a similar trend.

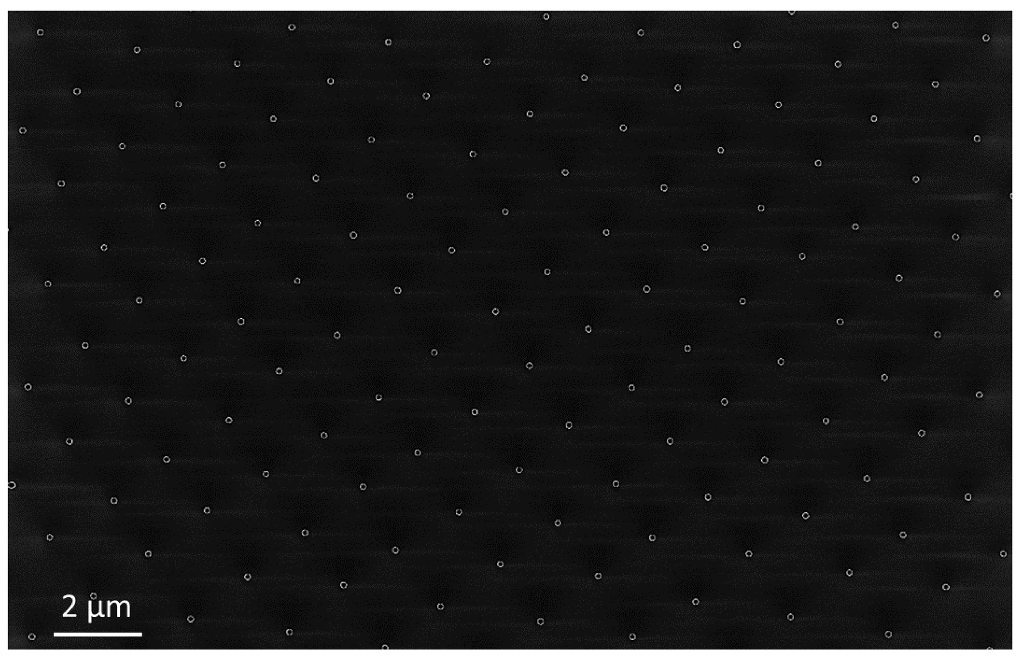


Total absorption of an array of 9 GaAs nanowire for a periodical and a quasi-periodical array at normal angle as well as 45°.

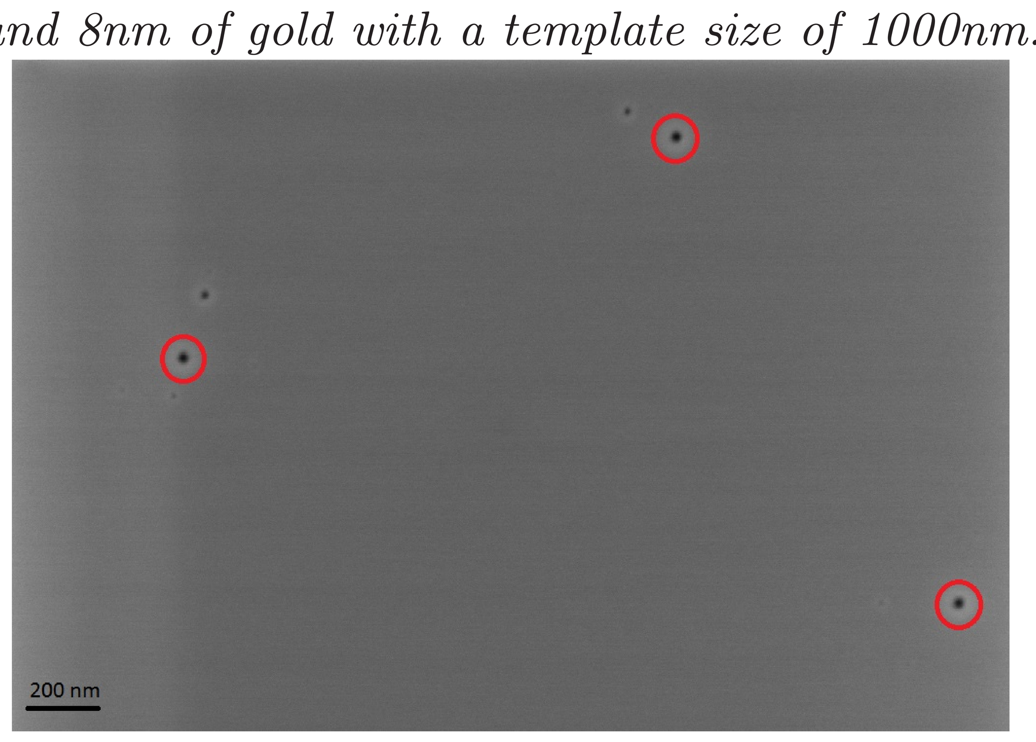
Quasi-periodic array

Samples produced using dynamic templating had a template width to layer thickness ratio up to 250. Two alternative temperature profiles where used:

- A single step at 1050°C for 1h in rapid thermal annealing was used to study heating rate effect. A ratio of 250 was obtained.
- A long annealing of the quasi-periodical array obtained with the first profile was used to induce nanopores formation by nanoparticle digging. The digging process occurs due to an increased ceramic transport at the particle-oxide interface [3].



Quasi-periodic array produced by dynamic templating. The bilayer used is 100nm of antimony and 8nm of gold with a template size of 1000nm.



Sample annealed for 60h at 900° C. Nanopores are highlighted in red.

Conclusion

In conclusion, it has been shown that :

- sacrificial layer increases size and pitch distance even without template.
- dynamic templating allows to increase template width to layer thickness ratio. A ratio of 250 was achieved.
- Silicon oxide mask can be done by a subsequent heat treatment and etching of the particle array.
- Quasi-periodic array produced show a reduced diffraction loss in comparison to a periodical array.

References

[1] Pouyan Farzinpour et al. Dynamic templating: a large area processing route for the assembly of periodical arrays of sub-micrometer and nanoscale structure. *Nanoscale*, 5:1929–1938, 2013.

[2] Francisco Ruffino and Grazia Grimaldi. Controlled dewetting as fabrication and patterning strategy for metal nanostructures. *Physica Status Solidi A*, 212(8):1662–1684, 2015.

[3] Lennart J. De Vreede et al. Nanopore fabrication by heating au particles on ceramic substrates. *Nano Letters*, 15:727–731, 2014.

[4] Michael D. Kelzenberg et al. Enhanced absorption and carrier collection in si wire arrays for photovoltaic applications. *Nature Materials*, 9:239–244, 2010.

Acknowledgements

I would like to Pablo Romero-Gómez and Anna Fontcuberta i Morral for their supervision and help throughout the project, Christian Jürgensen for his collaboration and all the other persons that helped me along this thesis. I would also like to thank the whole LMSC laboratory for their warm welcome.