Solar Absorber by Nanoimprint Lithography and Sputter Deposition

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For harvesting solar power efficiently, an ideal absorber is characterized by a high absorption in order to capture the incoming energy while suppressing thermal re-radiation. Selective solar absorbers comprised of plasmonic structures offer a great flexibility in design along with unmatched optical performance [1]. However, the nanopattern generation, typically done with electron beam writing, is a very time-intensive step. In this work, we present a fast, scalable and flexible method for the fabrication of plasmonic absorbers by the combination of a deposition mask prepared by nanoimprint lithography and subsequent thin film deposition by magnetron sputtering.

The deposition mask is a two-layer system. The underlying lift-off layer aids the subsequent mask lift-off, whereas the NIL fabricated top layer is defining the location and shape where the nanodisks are created during metal deposition. The chosen layout, shown in Figure 1 is not optimized for a solar absorber application, but shows feature sizes similar to what is reported in literature [2–5]. Due to the versatility of this process, the absorber features could be tailored by choosing an optimized nanopattern for the nanoimprint step. After calibrating the deposition time and the maximal deposition height, the process was transferred onto polished Inconel NiCr-alloy plates used in high temperature solar absorbers. Two different sputtering methods are compared: direct current sputtering and high-power pulsed magnetron sputtering (HiPIMS). A schematic drawing of the fabrication procedure is shown in Figure 2. First, a substrate having an insulating layer was spin-coated with a lift-off layer (LOR 1A, MicroChem) followed by an UV-curable resist (mr-NIL_212_FC XP, micro resist technology), which is imprinted with a hybrid h-PDMS-PDMS stamp containing the ellipsoidal pattern. After plasma etching and chemical etching to create undercut features in the mask, the material is deposited via magnetron sputtering. The subsequent wet chemical mask lift-off step, shown in Figure 3, results in the desired nanoparticle array on the surface. Figure 4 shows a SEM image of the finished structure.

[1] Azad, A.K.; Kort-Kamp, W.J.M.; Sykora, M.; Weisse-Bernstein, N.R.; Luk, T.S.; Taylor, A.J.; Dalvit, D.A.R.; Chen, H.-T.; "Metasurface Broadband Solar Absorber" Scientific Reports 2016 6,(1).
[2] Bermel, P.; Lee, J.; Joannopoulos, J.D.; Celanovic, I.; Soljacie, M.; "SELECTIVE SOLAR ABSORBERS" Annual Review of Heat Transfer 2012 15,(15) 231–254.
[3] Wang, H.; Prasad Sivan, V.; Mitchell, A.; Rosengarten, G.; Phelan, P.; Wang, L.; "Highly efficient selective metamaterial absorber for high-temperature solar thermal energy harvesting" Solar Energy Materials and Solar Cells 2015 137,235–242.
[4] Han, X.; He, K.; He, Z.; Zhang, Z.; "Tungsten-based highly selective solar absorber using simple nanodisk array" Optics Express 2017 25,(24) A1072.
[5] Cheng, C.-W.; Abbas, M.N.; Chiu, C.-W.; Lai, K.-T.; Shih, M.-H.; Chang, Y.-C.; "Wide-angle polarization independent infrared broadband absorbers based on metallic multi-sized disk arrays" Optics express 2012 20,(9) 10376–10381.

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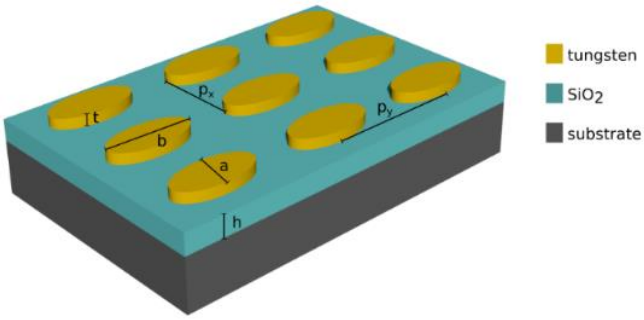

Figure 1. Plasmonic absorber design used for our experiments. An array of ellipses with axes a=100 nm, b=200 nm, t=45 nm up to 100 nm and unit cell of 400x600 nm² sits on top of an insulating layer with height h=100 nm.

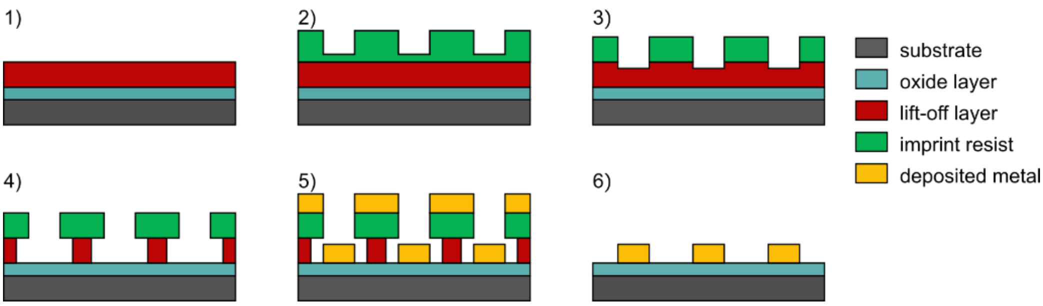

Figure 2. Fabrication of metallic nanoparticles based on UV-NIL. 1) spin coating the lift-off and imprint layer 2) UV-NIL to copy the nanopattern from a stamp to the substrate 3) reactive ion etching for contacting the lift-off layer 4) chemical development of the lift-off layer to create undercut features 5) sputtering of the desired material 6) mask lift-off.

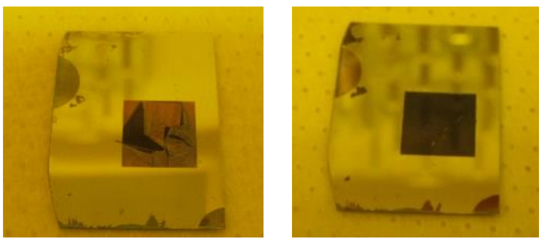

Figure 3. Left: Mask lifting-off and curling up after immersion in etchant solution. Right: Finished absorber structure with layout as shown in Figure 1. The nanostructured area is 1x1cm^2.

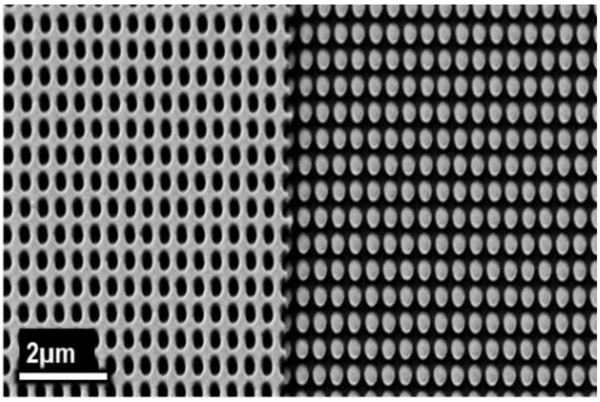

Figure 4. SEM image of a sample fabricated on a Si-wafer after partial mask lift-off and complete removal of the lift-off layer (step 5-6 of Figure 2).