Large-area Patterning of Au Nano-particles Self-aligned to Fluidic Channels for Enhancement of Molecule Detection

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Nano-scale metallic (e.g. Au and Ag) particles have been widely used in sensing applications, such as surface-enhanced Raman scattering (SERS)[1], bio-molecule sensing[2], and enhanced fluorescence imaging[3]. In many cases, it is desirable to selectively pattern the Au (or Ag) nano-particles inside sealed fluidic channels. Here we present a new method of patterning Au nano-dots in the selected regions of fluidic channels and self-aligned to the channels, which is based on multiple resist layer etching and nanoimprint lithography.

In our approach, we used a 3D composite mask to create a 2D pattern (Au nanoparticles in fluidic channel) on a fused silica substrate (Fig. 1). The 3D composite mask has three stacks: the bottom stack of SiO_2 and a crosslinked polymer (similar to an anti-reflection coating material, so termed ARC here) defines the fluidic channels (Fig. 1c), the middle stack of SiO_2/ARC defines the channel area for depositing the Au naonparticles (Fig. 1f), and the top stack (nanoimprint resist) patterns the Au particles (Fig. 1h). A key novelty here is that the two stacks of SiO_2/ARC were not removed after their patterning, but kept with the top layer as a part of the final lift-off structure which patterns Au particles only in the selected area of the channel (Fig. 1e-i).

Particularly, first the fluidic channels were patterned in the bottom SiO_2/ARC (15/50 nm thick) and fused silica (80 nm deep, 2~10 μm wide) by photolithography and RIE. Then the deposition windows were defined crossing the channels by another photolithography in middle SiO_2/ARC (15/50 nm thick). Then a 200 nm pitch pillar mold imprinted nanoholes into the imprint resist (~200 nm thick) and planarized the substrate. Finally, Au nano-particles were defined by RIE the resist (coated with a 5 nm Cr shadow mask), evaporation (Au/Cr as 30/3 nm), and liftoff the multi-layer stack.

The atomic force microscopy (AFM) images (Fig. 2) and optical images (Fig. 3a-d) showed the surface profile and multi-layer alignment in the key fabrication steps. Clearly, 55 nm sized Au nano-particles were fabricated in the fluidic channels (SEM images Fig. 3e-f) and no dots were patterned outside. Therefore, the substrate top surface is flat and can be easily bonded to seal the channels for molecule flow. This method can be directly used for fast and real-time biochemical sensing measurements, such as DNA stretching and sequencing[4], molecules sorting[5], fluorescence[3] or SERS[1] enhancing, and others.

Our approach can be extended to high-throughput fabrication of other large-area 2D arbitrary nano-patterns (such as fluidic channels, photonic crystals, and etc.) and many applications in solar cells, light emitting diodes (LEDs), and plasmonics.

Reference:

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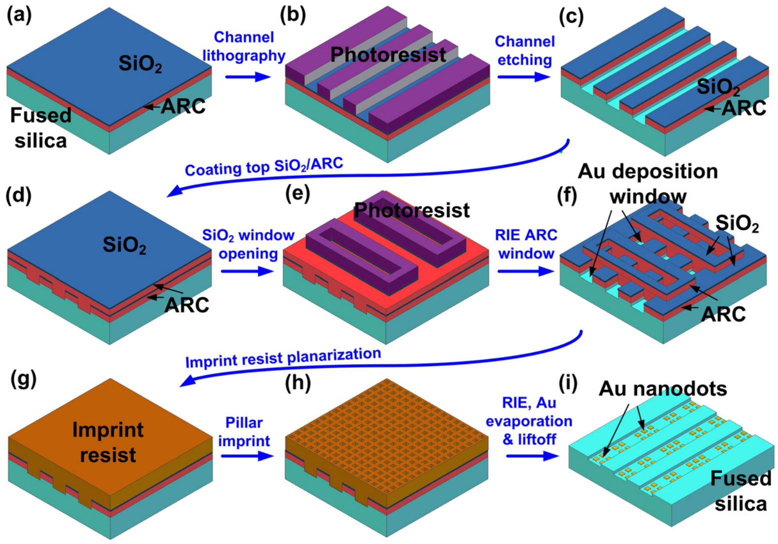

Fig. 1. Scheme of self-aligned patterning Au nanodots in fluidic channels. (**a**) Fused silica substrate coated with bottom stack of SiO_2/ARC; (**b**) Micro-fluidic channels defined by photolithography; (**c**) Channels transferred to bottom SiO_2/ARC layers and fused silica after stripping the photoresist; (**d**) Coating middle stack of SiO_2/ARC; (**e**) Second photolithography to define the au patterning window in SiO_2 (middle stack) for Au-particle patterning; (**f**) Au deposition window transferred to ARC layer by RIE; (**g**) Imprint resist planarized on the substrate; (**h**) Pillar mold imprinted. (**i**) Au nanodots patterned in fluidic channels by evaporation and liftoff.

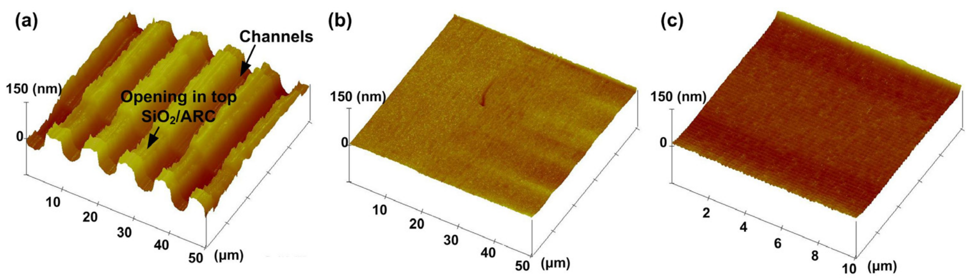

Fig. 2. AFM images showing the surface morphologies of: (**a**) Microfluidic channels (80 nm deep) with opening in top SiO_2/ARC layer; (**b**) Planarized substrate surface with imprint resist; (**c**) Substrate with imprinted patterns.

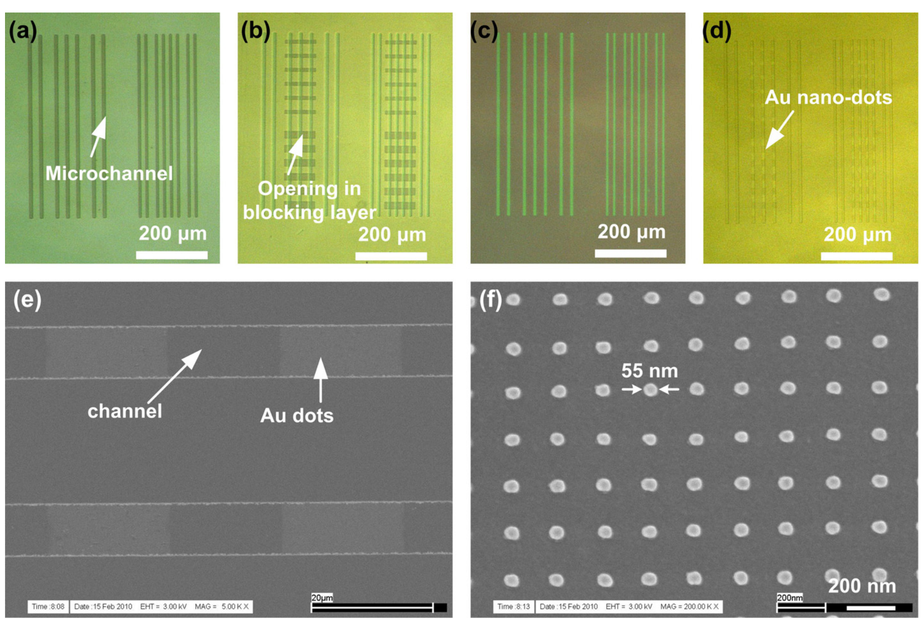

Fig. 3. Fabricated Au nanodots in fluidic channels at different steps. a-d, Optical images of channels with patterned Au dots: (**a**) Micro-fluidic channels patterned into bottom SiO_2/ARC and fused silica; (**b**) Opening window defined in middle stack SiO_2/ARC; (**c**) Planarized fused silica by imprint resist; (**d**) Au dots selectively patterned in channels by imprint and liftoff. **e-f**, SEM images of Au dots self-aligned to fluidic channels.