Dry-Release Self-assembling of Microtube Arrays for Catalytic Micropump Application

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Efficient tiny pumps, mixers and stirrers are essential elements of the microfluidic "factories" on a chip. Bending of strain-engineered nanomembranes into self-assembled round-shape microchannels and wrinkling networks have making the microfluidic integration more promising. For the strain-engineered wrinkles and tubes, common process involves the wet chemical etching of sacrificial layers, which frequently causes the process-induced adhesion and diffusion etching. Here we present a new method to make the predefined stained nanomembranes self-assembled into microtubular pump arrays by a simple thermal induced dry-release process. With a catalytic Pt layer inside, the micropumps can be activated by the catalytic decomposition of peroxide into oxygen microbubbles and water.

The fabrication process is illustrated in Figure 1. In order to enable the dry release, PMMA using O-xylene as solvent is firstly spin-coated on a silicon substrate as the under shrinking layer. Then pre-strained SiO/Cr/Pt tri-layer membranes were subsequently deposited on the PMMA layer by e-beam evaporation. A metal hard shutter mask was used in the deposition process to pattern the metallic membranes. The dry release of the strained nanomembranes with the PMMA under layer was achieved by simply baking the sample at 180 ^{o}C for 2 minutes. The fast evaporation of the O-xylene solvent boosts the rapid shrinking of the PMMA polymer layer. Due to the brittleness of the upper SiO layer, the upper nanomembranes are detached from the under PMMA rather than adhering together. The intrinsic strain in the released SiO/Cr/Pt tri-layers made them automatically rolled up into microtubular structures (See Figure 2). We have thus proved the possibility of creating long-range ordered catalytic microtubular pump arrays over a large area by fine-tuning the size. The pumping of fluid through the microtube and/or agitating of the liquid were powered by catalytic decomposition of low-concentration peroxide in the inner catalytic Pt surface of the microtubes (See Figure 3). By immersing the micropump arrays in a peroxide solution, tiny oxygen bubbles are fast expelled out from one end of the pump to agitate the liquid and the fuel were filled in through the other pump end for efficient fluid transfer. Our dry-release technique is quick, robust, low-cost and compatible with regular MEMS fabrication. The prepared microtubular pump arrays provide a unique opportunity for the applications in bio actuators, mixers and drug delivery.

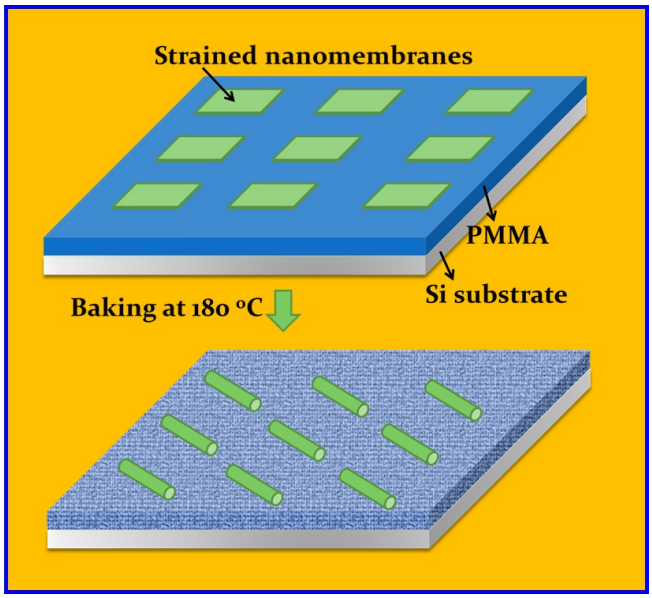

Figure 1: The schematic diagram of the dry-release self-assembling process. The predefined strained nanomembranes were release from from the PMMA by simply baking the sample at 180 °C for 2 minutes. Then the released nanomembranes automatically rolled up into microtubular structures.

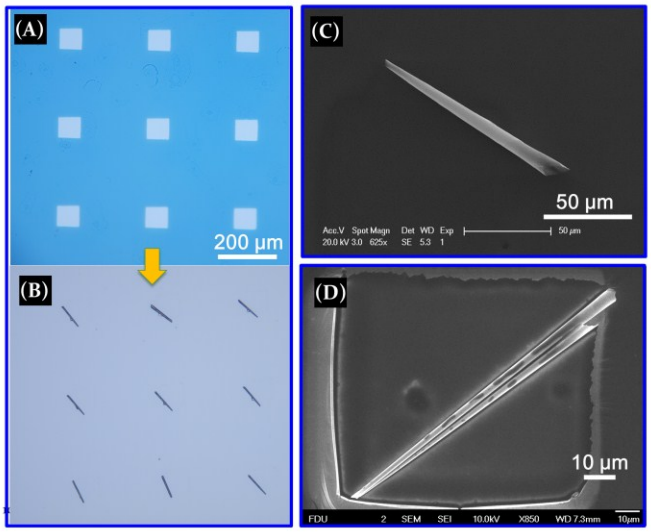

Figure 2: Optical image of the patterned nanomembranes before (A) and after (B) the dry-release process. SEM image of a microtube rolled by SiO/Cr/Pt nanomembranes with thickness of 20/20/10 nm (C) and a dual microtube rolled by by SiO/Cr/Pt nanomembranes with thickness of 10/10/5 nm (D).

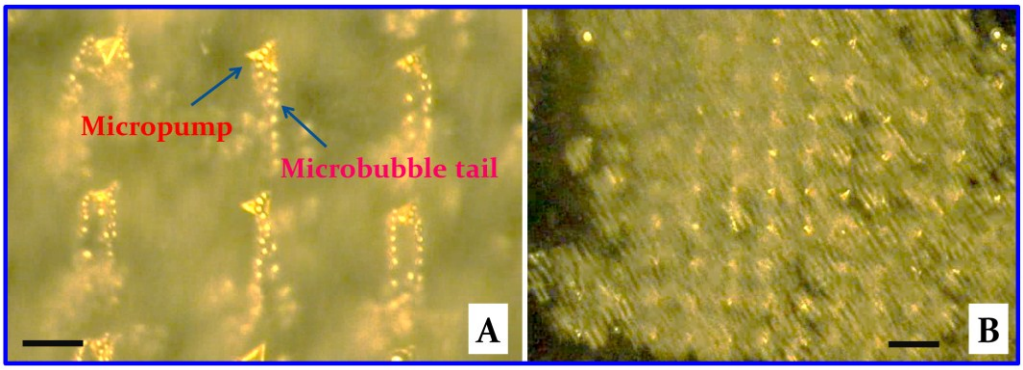

Figure 3: Selected images of a micropump array immersing in a 1% peroxide concentration. The microbubble tails can be clearly visualized by microscopy. Scale bar is 200 μm in（A）and 500 μm in (B).