Wrinkle / buckling 현상을 이용한 나노채널의 제작과 그 응용

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Fabrication of nanofluidic channels with directed wrinkle/buckling patterns

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Abstract - Interest has grown recently in the concept of "unconventional nanofabrication", the creation of nanoscale features by methods that avoid the technical hurdles and high cost of nano-lithographic processes. One of the challenges has been to reliably and inexpensively produce channels of nanometer dimension, as small as 60 nm, in the materials commonly used for soft lithography. In this manuscript, we present new approaches based on simple concepts of wrinkle and buckling patterns.

1. introduction

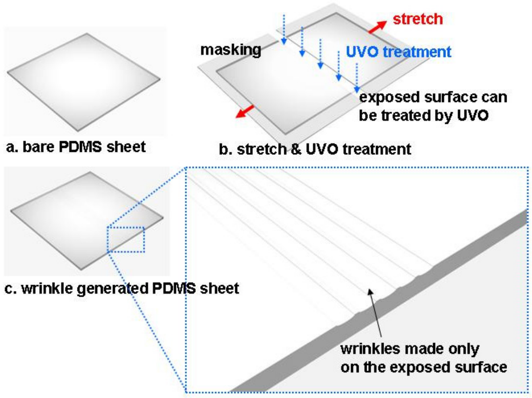
When planar strain in an elastic material with a stiff surface layer is relaxed, the surface forms wrinkles with a well-defined amplitude and wavelength, which are determined by the thickness and the relative modulus of the surface layer as well as the magnitude of the imposed strain. Such gradients in stiffness can be produced in a controlled manner on a flat PDMS surface or at a desired position on molded PDMS microfluidic circuits, and be easily closed by bonding to another surface, generating integration between the well-defined nanochannels and a microfluidic circuit.

Another concept to create intricate networks of fluidic channels formed from metals and ceramics is also proposed and demonstrated. The method exploits buckle delamination of a thin compressed film bonded to a substrate to form a network of closed channels. A low adhesion layer coinciding with the desired layout of the channel network is laid down on the substrate prior to deposition of the film. Once triggered, the buckle delamination propagates along the low adhesion pathways driven by release of the elastic energy stored in the film and assembling the entire channel network without external intervention. The directed buckling patterns can be used as nanofluidic channels or molds for nanochannel casting.

2. wrinkling patterns

2.1 wrinkle generation

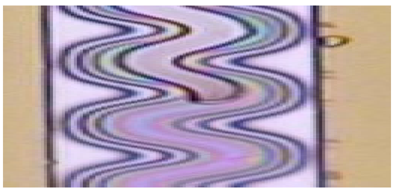
We applied strain to a bare PDMS sheet by a home-made stretching apparatus, then subjected the sheet to plasma treatment. The plasma was ignited by normal air showing a bright pink color. Before applying the treatment, a transparency film was cut and attached to the stretched PDMS surface to mask those regions from plasma exposure where wrinkles were not desired. After plasma treatment, strain was released resulting wrinkles on exposed PDMS surface (Fig. 1). To create the homogeneous WNCs (wrinkle nanochannels) of PDMS, the wrinkled PDMS layer was bonded onto the other PDMS layer with microfluidic channels. The layers were plasma treated again for 30 seconds by the same plasma cleaner and bonded together to form nanochannels aligned with microfluidic channels. To create an inhomogeneous WNCs, with three sides of PDMS and one side of glass, we applied strain directly on the PDMS layer with microfluidic channels, covering undesired region by the trimmed transparency film and exposed it by the plasma. The wrinkled PDMS layer with microfluidic channels was then bonded to glass coverslide. Wrinkle dimension was measured by Atomic Force Microscopy and WNCs dimension was measured by Scanning Electron Microscope [1].



<그림 1> wrinkle generation method

2.2 buckling generation

A metal layer coinciding with desired channel network was patterned on Si substrates with lithography techniques followed by diamond-like carbon (DLC) film deposition. The DLC film was deposited by PECVD using a capacitively-coupled r.f. glow discharge with gas phases of C_6H_6 at a pressure of 1.33Pa with deposition time ranging from several seconds to three minutes resulting in DLC film thickness of 15nm ~ 300nm with residual compression between about 0.9 and 1.5 GPa in the equi-baixial state. Buckling delamination of DLC film was triggered on the patterned metal layer generating gap between metal and DLC film, proved by SEM, due to the low adhesion between the materials. The gap was used as BNCs (buckling nanochannels) or the buckling patterns was used as molds for casting PDMS nanopatterns [2].



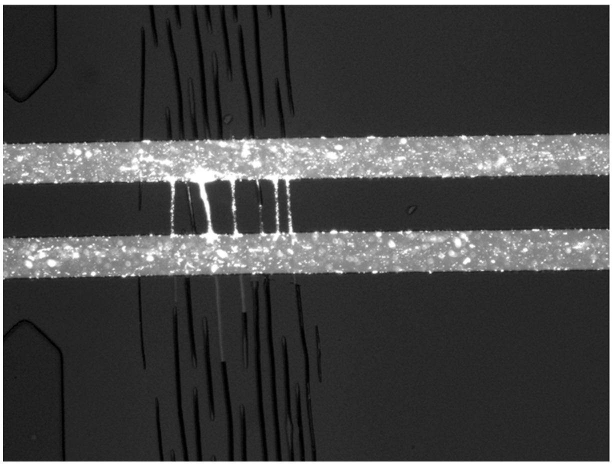
<그림 2> flow in telephone cord buckling nanochannel

3. results

Patterned BNCs formed on gold layers were created with inlet and outlet ports. Water was introduced into the BNCs. Tip of the liquid remains perpendicular to the centerline of the channel as the fluid moves through it. The BNCs network could also be integrated with an microfluidic channels of PDMS. Fluid flow in the system was demonstrated with pure water, showing nano-scale mixing at Y-shaped junctions of BNCs. Submicron particles in a fluid could also be sorted in the tapered BNCs having different cross-sections [2].

WNCs were also applied to demonstrate the unique capabilities of this approach, a microfluidic device integrated with the nanochannel array concentrating proteins by electrokinetic trapping. A depletion layer could be formed within 5 seconds near the WNCs when we applied a tangential field on the anodic side. Fluorescence intensity was biggest in the device with the smallest WNCs, rising from an initial concentration of 40 nM to 4 uM β-phycoerythrin after 10 minutes. Preconcentration of protein varied almost linearly in time for conditions 2 and 3. With the smallest wrinkles, a preconcentration factor more than 100 was achieved within 10 minutes[1].

A manuscript introduced cracks as a master to make tuneable nanofluidic channels of PDMS[3]. This promises to be a relatively easy way to make nanofluidic channels, but this approach is not suitable for many nanofluidic applications because the dimensions and location of the cracks cannot be precisely controlled. Other nanofabrication or nanolithography methods including laser ablation, e-beam lithography or focused ion beam process, are expensive and complex, representing a significant advancement of WNCs and BNCs, which are inexpensive, easy and controllable. They have now been demonstrated to be useful in some important applications, that of protein preconcentration and mixing, which requires strictly defined nanofluidic channels.



<그림 3> Nanobeads of 75 nm diameter in WNCs between two microfludic channel

[참 고 문 헌]

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