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Nanofluidic Cell for Resolution Improvement of Liquid Transmission Electron Microscopy

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Abstract : Liquid Transmission Electron Microscopy (TEM) is a growing area with a broad range of applications from physics and chemistry to material engineering and biology, in which it is possible to image in-situ unseen phenomena. For this, a nanofluidic device is used to insert the nanoflow with the sample inside the microscope in order to keep the liquid encapsulated because of the high vacuum. In the last years, Si3N4 windows have been widely used because of its mechanical stability and low imaging contrast. Nevertheless, the pressure difference between the inside fluid and the outside vacuum in the TEM generates bulging in the windows. This increases the imaged fluid volume, which decreases the signal to noise ratio (SNR), limiting the achievable spatial resolution. With the proposed device, the membrane is fortified with a microstructure capable of stand higher pressure differences, and almost removing completely the bulging. A theoretical study is presented with Finite Element Method (FEM) simulations which provide a deep understanding of the membrane mechanical conditions and proves the effectiveness of this novel concept. Bulging and von Mises Stress were studied for different membrane dimensions, geometries, materials, and thicknesses. The microfabrication of the device was made with a thin wafer coated with thin layers of SiO2 and Si3N4. After the lithography process, these layers were etched (reactive ion etching and buffered oxide etch (BOE) respectively). After that, the microstructure was etched (deep reactive ion etching). Then the back side SiO2 was etched (BOE) and the array of free-standing micro-windows was obtained. Additionally, a Pyrex wafer was patterned with windows, and inlets/outlets, and bonded (anodic bonding) to the Si side to facilitate the thin wafer handling. Later, a thin spacer is sputtered and patterned with microchannels and trenches to guide the nanoflow with the samples. This approach reduces considerably the common bulging problem of the window, improving the SNR, contrast and spatial resolution, increasing substantially the mechanical stability of the windows, allowing a larger viewing area. These developments lead to a wider range of applications of liquid TEM, expanding the spectrum of possible experiments in the field.

Keywords : liquid cell, liquid transmission electron microscopy, nanofluidics, nanofluidic cell, thin films
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