Silicon-based microfluidic grating for neutron phase imaging

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Neutron grating interferometer phase imaging is an efficient method for detection of low atomic number elements thus making it an informative non-destructive imaging technique for complex materials such as batteries and concrete. To impart the required quasi-coherence, while maintaining reasonable intensity, absorbing gratings are required. Gadolinium, with its large neutron absorption cross-section, is typically used and presents challenges in realizing high aspect ratio structures.[1] Our collaborative team is developing a novel grating-based far-field neutron interferometer[2] (INFER) that will allow imaging of hierarchical structures over multiple length scales, nano- to micrometers. To exploit the flexibility of the far-field geometry, we seek a source grating whose period can be tuned from about 20 μm to 1 cm to avoid needing a large set of gratings that are independently fabricated, aligned, and installed. Here we present an update on the first microfluidic source grating which, by controlling the positioning of a neutron-absorbing solution, can dynamically tune the grating period, replacing over 500 static source gratings in a single device. The DynAmic ReconfIgUrable Source grating device (DARIUS) enables the desired grating period tunability by selectively infilling patterns in over 5,000 individual grating channels etched in silicon. We have previously presented single-sided devices with 128 to 2,560 active channels sealed with a capping silicon wafer with etch-through holes for well and pumping port access (Figure 1). In this presentation we provide progress on sealing DARIUS device with wafer-scale bonding, selective infilling grating channels with gadolinium-based solution (Figure 2a) and x-ray imaging that demonstrates x-ray beam modulation (Figure 2b). Additionally, we provide our design considerations, fabrication approach and progress towards fabricating at double-sided large area grating. By using DARIUS in the INFER beam line, our team will be able to investigate complex hierarchical structures in a variety of non-homogeneous samples.

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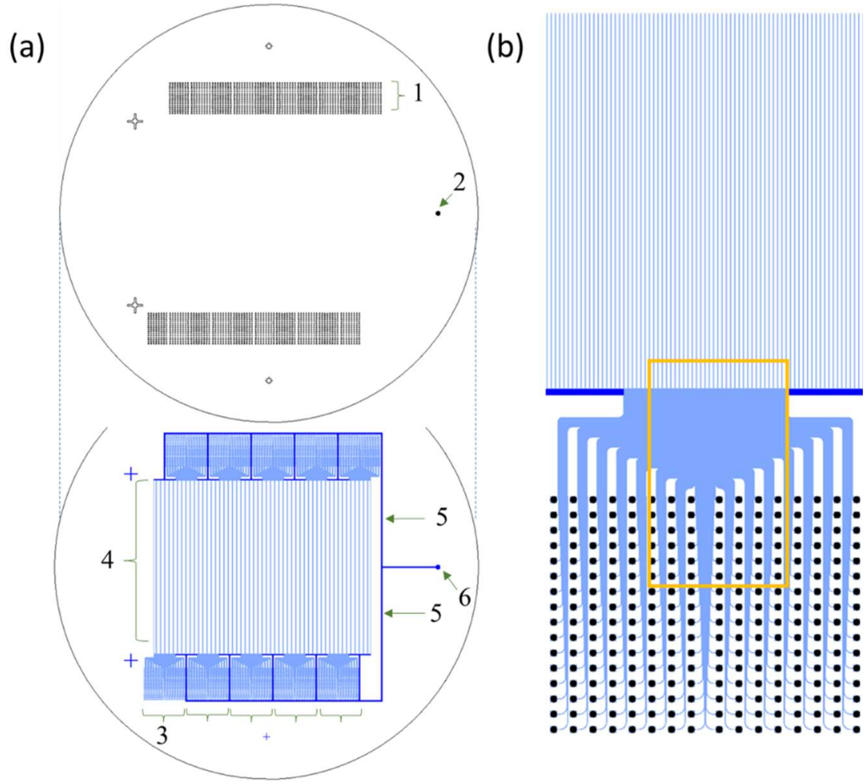

Figure 1. DARIUS 2.0 Design: (a) DARIUS 2.0 is sealed with a capping silicon wafer with two sections of 1,280 x 200 µm diameter through-holes (1) and a pumping port (2) for fluid removal. The main device wafer contains sections of 256 wells (3) individually routing to grating channels, 41 mm x 51 mm grating area (4) containing 2,560 etched channels, common drain line (5) and pumping port (6). (b) Higher magnification of a section of 256 rectangular wells (blue) overlaid with the circular through-holes (black) with a highlighted region of interest (yellow) for x-ray imaging in Figure 2b.

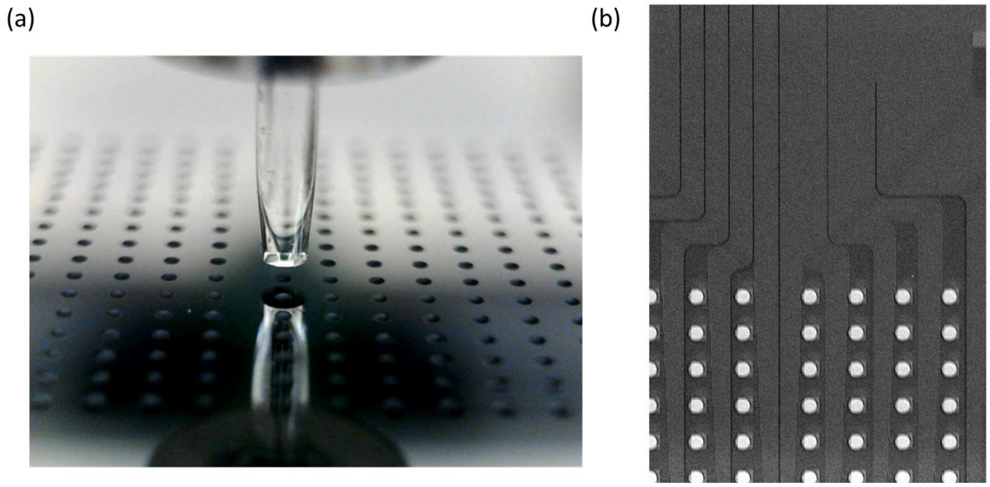

Figure 2. Sealed DARIUS 2.0 Device: (a) Optical image of piezoelectric nozzle infilling a 200 µm diameter well. (b) X-ray image of fluid flowing into channels with capillary action.