Microfabricated X-Ray Optics for CHESS

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Abstract:
We report on the fabrication and testing of three x-ray optics: a silicon nitride Transmission Mirror (TM), a Spoked Channel Array (SCA), and a von Hamos x-ray energy analyzer. Transmission mirrors together with traditional x-ray reflection mirrors form a tunable broadband optic, which is useful in selecting appropriate x-ray energies for Laue diffraction experiments, and therefore functions as a bandwidth filter. The SCA optic is a fan-shaped arrangement of deep reactive ion etched channels in silicon made using the Oerlikon tool at the CNF. The channel width determines the linear size or collection resolution of x-ray fluorescence from the sample being probed. These measurements determine elemental composition vs. depth of the sample.

Summary of Research:
The Transmission Mirror (TM). The objective of this project is to develop TM optics that are robust and have very long lifetimes. The critical parameters that determine the optical properties must satisfy the conditions of being thin, flat, smooth, and uniformly thick. In previous attempts, the TM lifetime was not long enough in the x-ray beam; lasting from a couple of hours with soap-bubble films to a day or two with Mylar films [1-2]. Si₃N₄ serves as the appropriate material because of the low atomic number and being radiation-hard. Low stress silicon nitride (LS-SiN) is deposited on a double-side polished silicon wafer. The windows are formed from a backside 80°C KOH etch. A topside dry etch is also performed across the front end prior to the wet etch to make it much easier to free the TM after the through etch.

The von Hamos Analyzer. A von Hamos analyzer is used to collect, energy resolve, and spatially disperse x-ray fluorescence so a detailed line shape is recorded. This optic is realized by the cylindrical bending of an SOI wafer. The scheme as seen in Figure 2(b) [3] is achieved by processing a slotted bar pattern on the handle of the wafer by a deep reactive ion etch of silicon. The handle used to diffract x-rays is about 400 µm thick. It is etched down to the oxide stop layer using photoresist as an etch mask into 121, 10 mm × ½ mm diffracting elements spaced 32 µm apart (Figure 2(a)). The 40 µm device layer can permit a bend radius as small as 100 mm to focus more intensity with no sacrifice to the energy resolution.

Spoked Channel Arrays. The technique of using x-ray fluorescence in obtaining elemental vs. compositional information from heterogeneous samples is the focus of this project. Here, we have added some refinements based on our prior work in fabricating SCAs from silicon for confocal-XRF (CXRF) as an alternative to the glass polycapillary [4-7].

Figure 1: (a) Schematic of silicon nitride TM windows on a silicon wafer. (b) Etched silicon wafer with 300 nm thick silicon nitride windows.

Figure 2: (a) A von Hamos bar analyzer etched from an SOI wafer. (b) Schematic of the analyzer illustrating the geometrical principle of operation.
To improve the efficiency of collecting x-ray fluorescence from a point source, we modeled alternative channel configurations that enable us to achieve better etch depths. Our optic design consisted of three variations having channel widths of 1, 2 and 5 µm. We also included a 1 µm thick sacrificial etch-wall at the entrance and exit of the channel to protect the integrity of the channels. The principle of operation, as shown in the inset of Figure 3, shows the fan-shaped arrangement of the etched channels, which collects a slice of the hard x-ray fluorescence from a point source. The point source is formed by focusing the x-ray beam using a single-bounce monocapillary. By translating the sample through the 3D active volume, a composition vs. depth information can be extracted from the sample as also shown.

References: