Fabrication of hard x-ray zone plates with high aspect ratio using metal-assisted chemical etching

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Zone plates are key elements in x-ray focusing optics and are widely used in x-ray microscopes. These microscopes have unique characteristics of shorter wavelength than visible light and higher penetration than electrons, so they are especially well suited to high resolution imaging of thick structures such as integrated circuits and biological specimens such as whole cells and tissues. Higher spatial resolution and higher focusing efficiency zone plates require narrower and thicker zone structures which lead to very high aspect ratio.

Metal-assisted chemical etching (MACE) has recently been shown to be a promising approach for high aspect ratio zone plate fabrication[1]. Starting with 150-μm-thick silicon wafers, electron beam lithography is used to pattern zone plate structures on PMMA resist, followed by metallization (Ti and Au thin films) by e-beam evaporation. After liftoff, these metal structures act as catalysts for directional etching of Si in hydrofluoric acid (HF), hydrogen peroxide (H_2O_2), and water. To reduce x-ray absorption, prior to MACE, the silicon substrate behind the zone plate positions is thinned to about 10-15 μm from the back-side using deep reactive ion etching (DRIE). A substrate of 15 μm Si membrane has a transmission of more than 90% for 10 keV x-rays. After MACE, critical point dryer was used to avoid zone collapsing. Finally, zone doubling is attained via atomic layer deposition (ALD) of Pt to achieve narrow, high aspect zones[2].

Our process combined MACE with ALD and back-etch for fabricating Fresnel zone plates with the potential for high absolute efficiency and fine spatial resolution for x-ray nanofocusing applications. With this process, 16 nm outermost zone width, 2 μm thick zone plates have been fabricated, thus achieving a very high aspect ratio up to 120 shown in Figure 1. X-ray tests are planned.

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[1] Chang and Sakdinawat, Nature Communications 5, 4243 (2014).
[2] Jefimovs et al., Phys. Rev. Lett. 99, 264801 (2007).

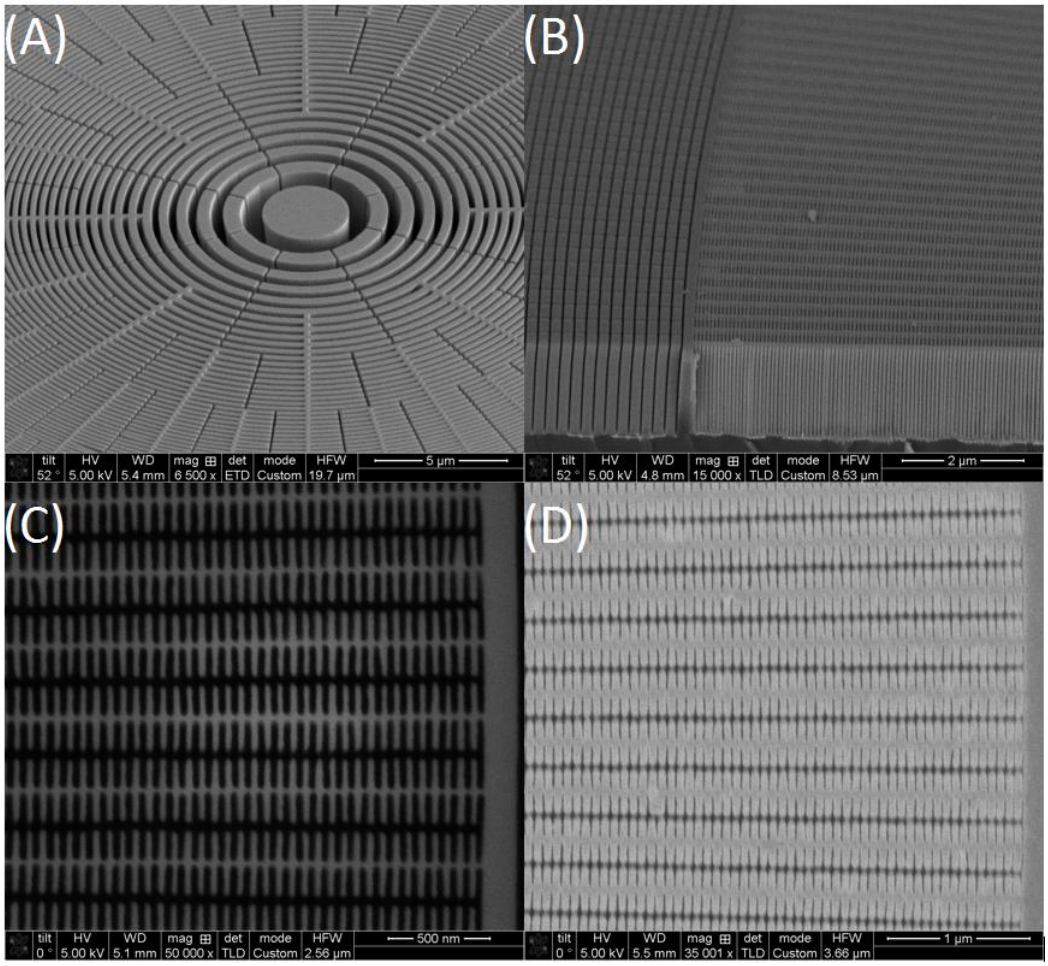

Figure 1: Zone plate fabricated using Metal-assisted chemical etching (MACE) and atomic layer deposition (ALD) with 10 nm Pt. SEM images of (A) the inner zones, (B) outer zones, (C) before ALD and (D) after ALD. The thickness is about 2 μm and outermost zone width is 16 nm. The corresponding maximum aspect ratio reaches up to 120.

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