Fabrication of nanostructures for enhanced resolution in X-ray tomographic imaging

A. Masurkar, T. Stark, E. Lavely
BAE Systems, Burlington, MA 01803
amrita.masurkar@baesystems.com

A. Stein, Y. Gao, A. Kiss, R. Smith, J. Wang, Y. Chu
Brookhaven National Laboratory, Upton, NY 11973

This work demonstrates the fabrication and use of "nanotargets," nanostructures that serve as the X-ray source in spectral computed tomography (CT). Nanotargets help achieve high spatial resolution by splitting the primary beam into smaller X-ray sources (Figure 1). Thus, spatial resolution is set by the size of the nanotarget. In addition, multi-material nanotargets can spectrally enhance CT by generating many characteristic X-rays that provide complementary yet independent information for image reconstruction.

Au nanotarget and Cu imaging samples were fabricated at Brookhaven National Laboratory (BNL) Center for Functional Nanomaterials, and projection imaging was done at BNL National Synchrotron Light Source II SRX Beamline. All patterning was done on 0.5 mm, 100 nm-thick suspended Si_3N_4 films using a poly-methyl-methacrylate (PMMA) lift-off recipe and JEOL 6300 Electron Beam Lithography System. The Au nanotargets had 500 nm diameter and 1 um height; Cu structures were 0.5 to 2 um laterally and 1 um vertically (Figure 2). The nanotargets, Cu sample, and an 8-um thick O_2 plasma-patterned polyimide spacer were assembled with a Nanoscribe-printed tool and epoxied together.

The SRX beamline supports transmission measurements and raster-like motion of a Vortex X-ray detector for emulating a distributed pixel array. Kirkpatrick-Baez mirrors focused the 12 keV X-ray beam down to 2 um. 2D projection data from a 1 um Cu structure was collected by positioning the X-ray beam onto a nanotarget in close proximity to a Cu structure and translating the Vortex detector. Au_L transmission data (Figure 3) demonstrates that using a 2 um primary beam, a 1 um Cu structure can be resolved with a nanotarget.

Monte Carlo simulations were used to analyze X-ray fluorescence (XRF) from 1 um-tall Au nanotargets in the electron and X-ray primary beam cases. In the former case, the majority of XRF is generated in the bottom half of the structure as a result of electron scattering and absorption; in the latter, XRF is spatially uniform. The results indicate that a primary electron beam requires additional nanotarget design considerations, as a taller structure may not necessarily provide increased photon flux.

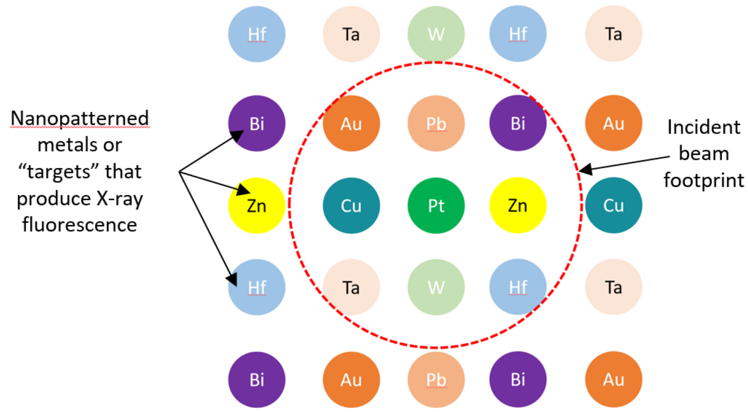

Figure 1: Nanotarget concept: An incident beam is converted into several, distinct, smaller secondary X-ray sources.

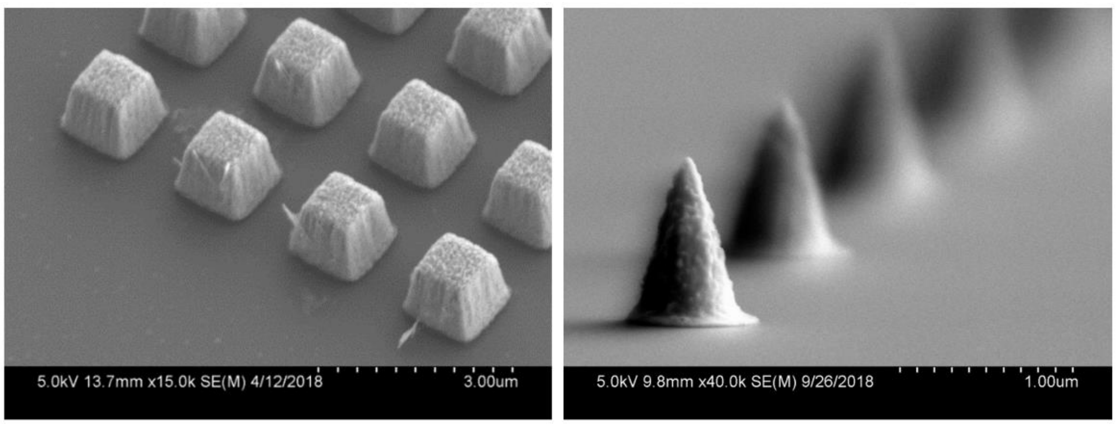

Figure 2: Fabricated Cu imaging sample (left) and Au nanotargets (right)

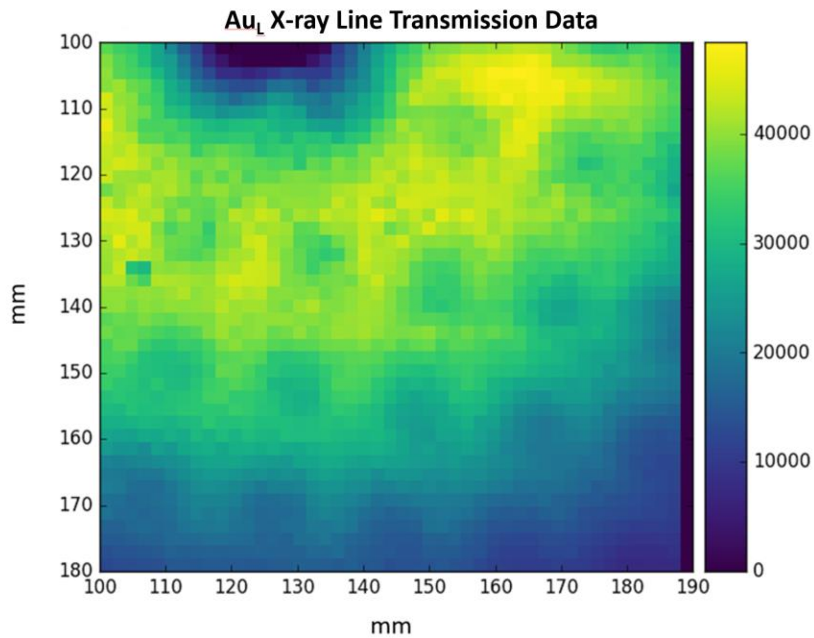

Figure 3: Projection image of 1 um Cu structures: Darker areas indicate where Cu structures are. Cu_K data (not shown), for comparison, exhibits no features.