Dreaming in cool colors: x-ray microscopy to see what's there, and to know what it is

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For 120 years, we have known that X rays offer great penetration for imaging of thick specimens, and for a century we have understood how x-ray spectra enable sensitive measurements of the elemental content of materials. Can there be anything new?

The answer is an emphatic "yes!" While progress is being made worldwide, this presentation focuses on several developments at the Advanced Photon Source at Argonne:

- X-ray nanofocusing optics continue to improve in efficiency and in spatial resolution. Our efforts in nanofabrication of Fresnel zone plates are aimed at achieving sub-20 nanometer spatial resolution using overlaid writes[1] and metal-assisted chemical etching[2].
- Simple computational methods can be used to model the interaction of x-ray beams with thick specimens, including diffraction within the specimen. These methods are applicable to a surprising range of x-ray optical phenomena[3].
- One can collect diffraction patterns as a coherent beam is scanned across a specimen to obtain images where the spatial resolution is no longer limited by the optics used. This method, called ptychography[4], has been shown to work with continuous scanning so that it can be used efficiently with future diffraction-limited light sources[5,6]. With this method, we have been able to image sub-20 nm detail in integrated circuits without requiring that the die be thinned[7].
- One can combine x-ray fluorescence measurements of trace elemental content with beyond-lens-resolution images obtained by collecting coherent x-ray diffraction patterns. This combination of fluorescence and ptychography allows one to put chemical content into its ultrastructural context when imaging cells[8].
- One can apply these advances even to radiation-sensitive biological specimens by imaging them at cryogenic temperatures using a scanning x-ray fluorescence microscope[9], with cryo specimen preparations also offering superior structural and chemical fidelity[10].

These and other advances are giving us a new view of materials using X rays.

References

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