doi:10.2533/chimia.2018.339 Chimia 72 (2018) 339

Highlights of Analytical Sciences in Switzerland

Division of Analytical Sciences

A Division of the Swiss Chemical Society

High-resolution, Non-destructive X-ray Tomography

Mirko Holler*, Manuel Guizar-Sicairos, Esther H. R. Tsai, Michal Odstrcil, Roberto Dinapoli, Elisabeth Müller, Ana Diaz, Oliver Bunk, Jörg Raab, and Gabriel Aeppli

**Correspondence:* Dr. M. Holler, Paul Scherrer Institut, CH-5232 Villigen PSI, E-mail: mirko.holler@psi.ch

Keywords: Integrated circuits · Nano tomography · Ptychography · X-ray imaging

Ptychographic X-ray Computed Tomography (PXCT) is a lens-less microscopy technique that can fill the imaging gap between electron microscopy and conventional X-ray microscopy, *i.e.* imaging at high resolution in the 10 nm range in combination with tens of microns thick samples. The method provides quantitative information of the spatially resolved electron density in the sample in 3D. PXCT was pioneered at the Paul Scherrer Institut, and by now two dedicated microscopes have been constructed and are employed by internal and external users of the Swiss Light Source for scientific projects ranging from materials science to biology.

Many projections of the sample are acquired at different rotation angles by scanning it through a coherent X-ray beam and collecting far-field diffraction images. There is no imaging lens between the sample and the detector, the image is formed computationally from the diffraction images using iterative algorithms explicitly developed for this purpose. As a lens-less imaging method, PXCT bypasses limitations of X-ray optical systems, making it currently the X-ray microscopy technique with the highest spatial resolution.

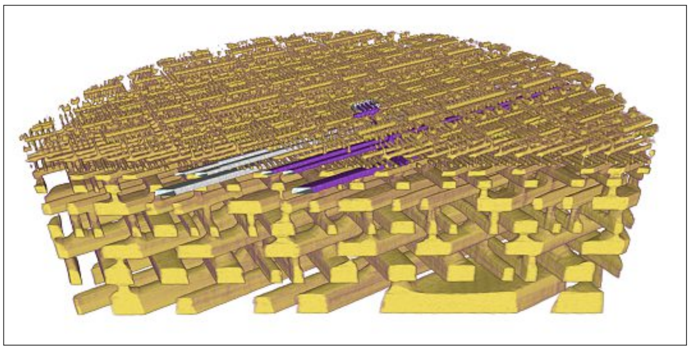
We are continuously exploring new fields of application of PXCT, one of them being non-destructive imaging of integrated circuits. As an example we show here the imaging of an Intel® processor (G3260) manufactured in a 22 nm node. Conventionally such samples are measured destructively in a FIB-SEM (focused ion beam, scanning electron microscope combination) using the slice-and-view technique. We extracted a 10 micron diameter pillar from the chip and using non-destructive PXCT achieved a resolution of 15 nm in 3D which allowed the identification of all electrical connections in the circuit down to the transistor layer. This measurement took 22 h, but with next generation synchrotron sources, improved X-ray optics and detectors, we expect the measurement speed to increase by orders of magnitude. In preparation we are currently building a new instrument in laminography geometry which will no longer require the extraction of a small pillar from the initially flat sample, such that the imaging volume will be purely determined by measurement time.

X-ray ptychography in laminography geometry and foreseeable improvements in imaging speed and resolution may make a significant contribution to chip inspection and lead to rapid and non-destructive imaging of integrated circuits for optimization of production processes, failure analysis and validation of chips used in critical application fields such as healthcare and aviation.

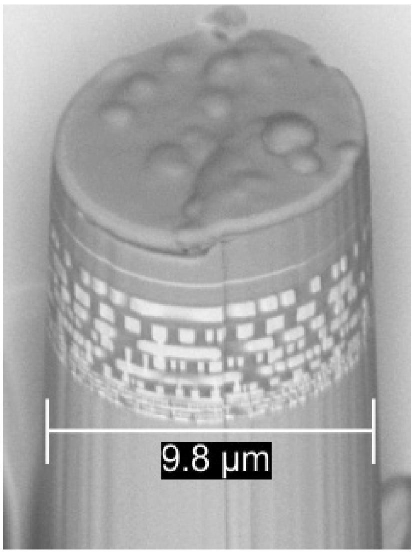
Received: February 27, 2018

Reference

M. Holler, M. Guizar-Sicairos, E. H. R. Tsai, R. Dinapoli, E. Müller, O. Bunk, J. Raabe, G. Aeppli, *Nature* **2017**, *543*, 402.



3D rendering of the internal structure of a microchip (metal components in an Intel processor). A piece of a G3260 processor of around 10 µm diameter was investigated. The layer at the top level shows where the transistors are located. The material in yellow is copper showing the processor's connections between individual transistors.



Chip sample pillar prepared by FIB-SEM for the X-ray measurement.

Can you show us your analytical highlight?
Please contact: Dr. Veronika R. Meyer, Unterstrasse 58, CH-9000 St. Gallen
Tel.: +41 71 222 16 81, E-mail: VRMeyer@bluewin.ch