Nano-transmission X-ray Microscopy

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Because of the deep penetration depth of X-rays in matter, the X-ray microscopy is expected to benefit those researches that prefer a non-destructive probe, for example, the analysis of failure mechanisms in microelectronic devices due to electro-migration, thermal breakdown or inhomogeneity and the characterization of porous materials such as soils and rock. Furthermore, the X-ray microscopy can be applied in the researches of cells in life science.

A nano-transmission X-ray microscope has been installed at beamline BL01B of the Taiwan Light Source, National Synchrotron Radiation Research Center (NSRRC). It provides 2D imaging and 3D tomography at energy 8-11 keV with a spatial resolution of 25-60 nm, and is equipped with the Zernike-phase contrast capability for imaging light materials. Fig. 1 depicts the schematic optical layout of this microscope. The X-rays are condensed onto sample by a tapered capillary and thereafter magnified by a zone-plate. Then the ultimate images are formed onto a two-dimensional area detector (CCD).

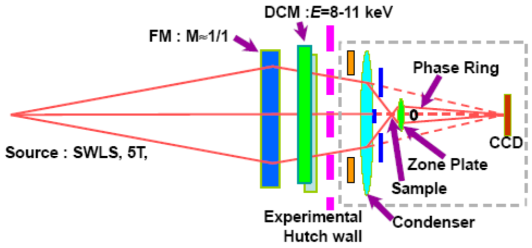

Figure 1. Schematic optical layout of nano-transmission X-ray microscope.

The resolution of microscope was tested by imaging an electroplated gold spoke pattern in first order and third order diffraction mode (Fig. 2). The filed of view of the images were 15µm×15µm and 5µm×5µm for first order and third order diffraction mode, respectively. The visibly resolved 50 nm finest line widths imaged in first order diffraction mode indicates the achievement of theoretical 60 nm spatial resolution. A further modulation transfer function (MTF) test of the third order diffraction mode demonstrates a 25 nm spatial resolution.

Fig. 3 shows the images of a one m thick plastic zone-plate imaged with (left) and without (right) phase contrast enhancement. For one µm thick plastic, the absorption contrast is 0.01% almost invisible at 8 keV. The phase contrast in the test is estimated of 12%, one can clearly see the cracks formed on the plastic zone-plate surface with phase contrast enhancement, in contrast to the nearly vague one without phase contrast enhancement.

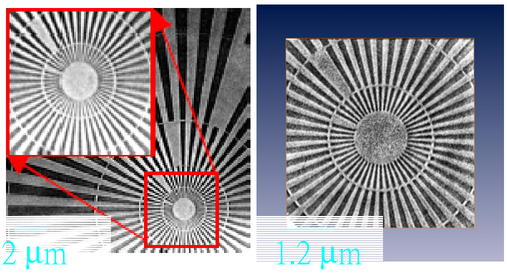

Figure 2. The microscope spatial resolution of 60 nm and 25nm were obtained by testing an electroplated gold spoke pattern with 50 nm finest line width in first order (left) and third order diffraction mode (right), respectively.

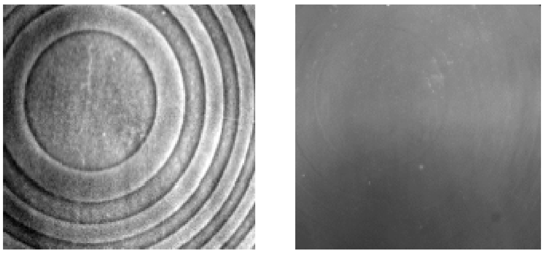

Figure 3. The images of a one µm thick plastic zone-plate imaged with (left) and without (right) phase contrast enhancement. The contrast in the phase enhanced mode is estimated of 12%.

The tomography of the microscope was measured by imaging an electro-plated gold spoke pattern and an integrated circuit (IC) provided by PSC Inc. (Fig. 4). The spatial resolution for the gold spoke pattern is estimated 60nm×60nm×80nm. For the IC investigation, the hollows in tungsten plugs related to an essential failure problem in IC performance can be clearly seen in three dimensional reconstructed images.

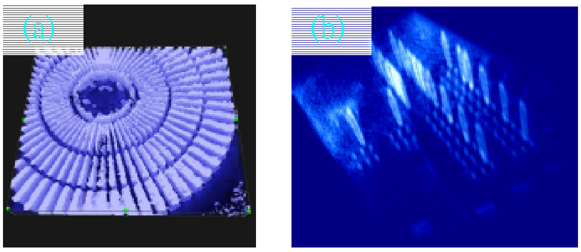

Figure 4. (a) 3D tomography resolution of 60nm×60nm×80nm by observing a gold spoke pattern. (b) 3D tomography of an integrated circuit clearly