Manufacturing of high resolution X-ray masks for LIGA technology in SSTRC

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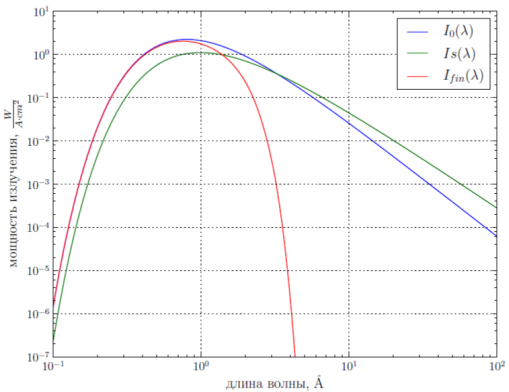
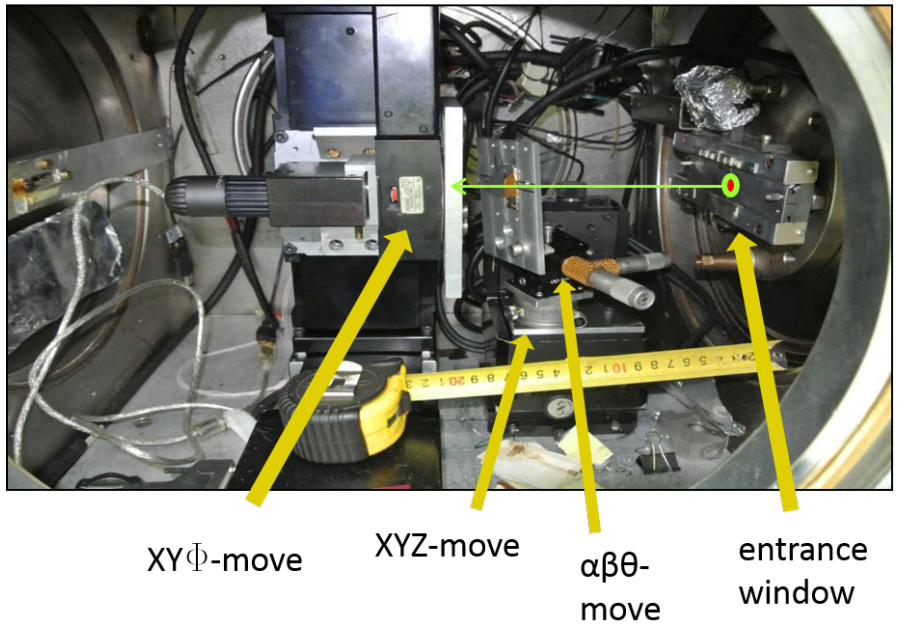
Introduction

Deep X-ray lithography is promising technique that allow to fabricate resist structures with aspect ratios, sidewall roughness and verticality superior to any other microfabrication technology. It allow to obtain structures with height 1 mm and even more. Such parameters are essential for manufacturing of X-ray optics elements, for example X-ray refractive lenses and collimators.

“LIGA” station

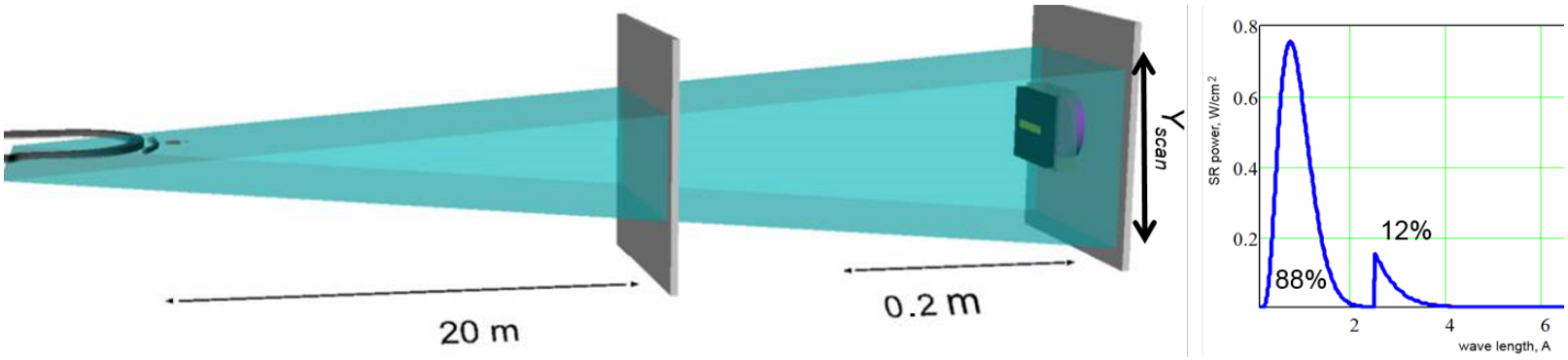


The spectral distribution has a wide range of 0.3 to 9 Å(1.4 to 40 keV)

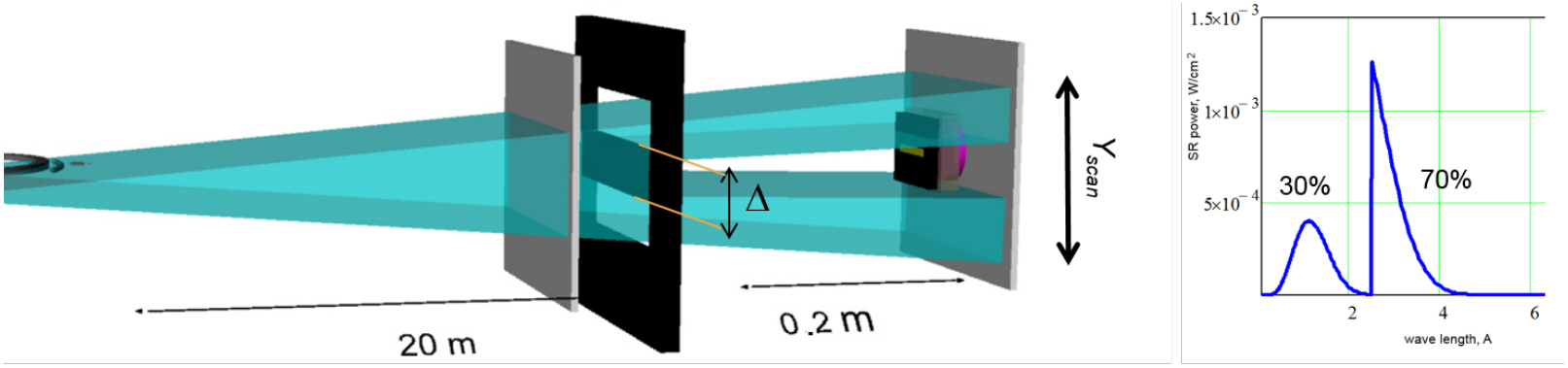


“LIGA” station at VEPP-3 SR source

Exposure regimes

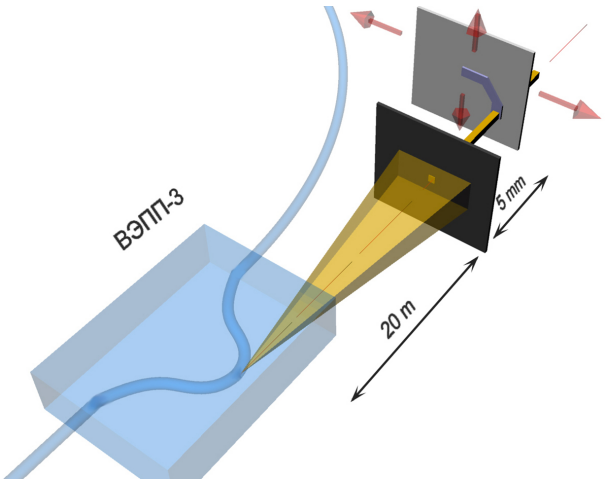


Scaning regime for large-area samples (up up to 60x100 mm).
Different filters for spectra correction may be used



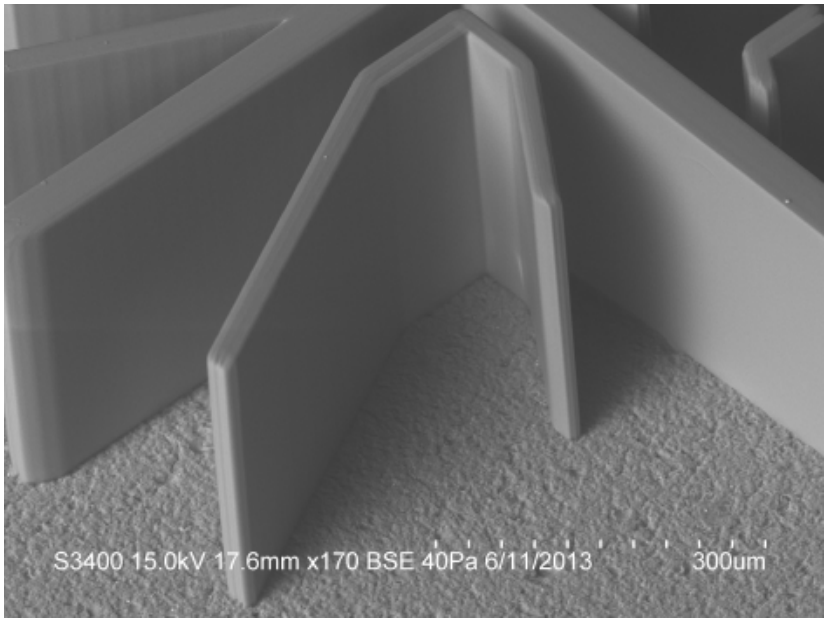
Spectra correction with beamstop

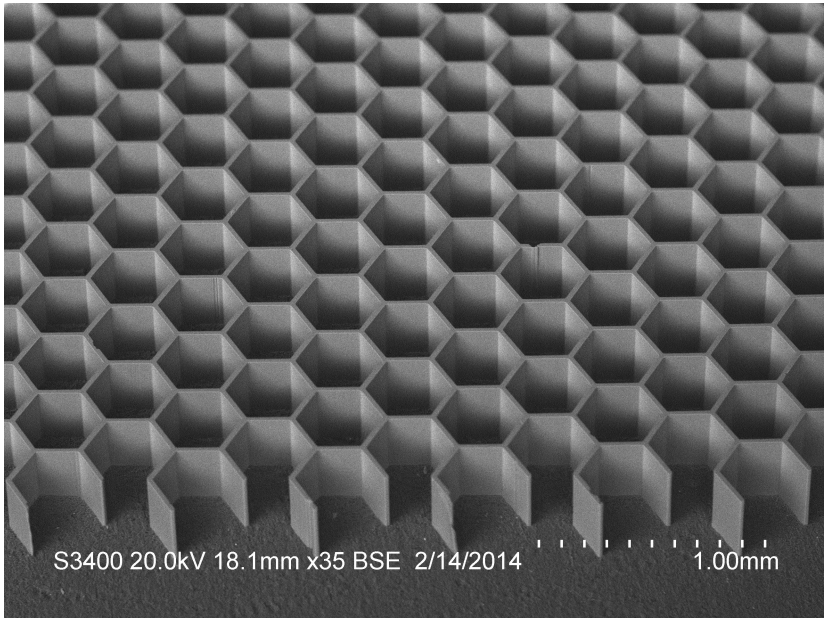
Exposure regimes. Microbeam X-ray Lithography

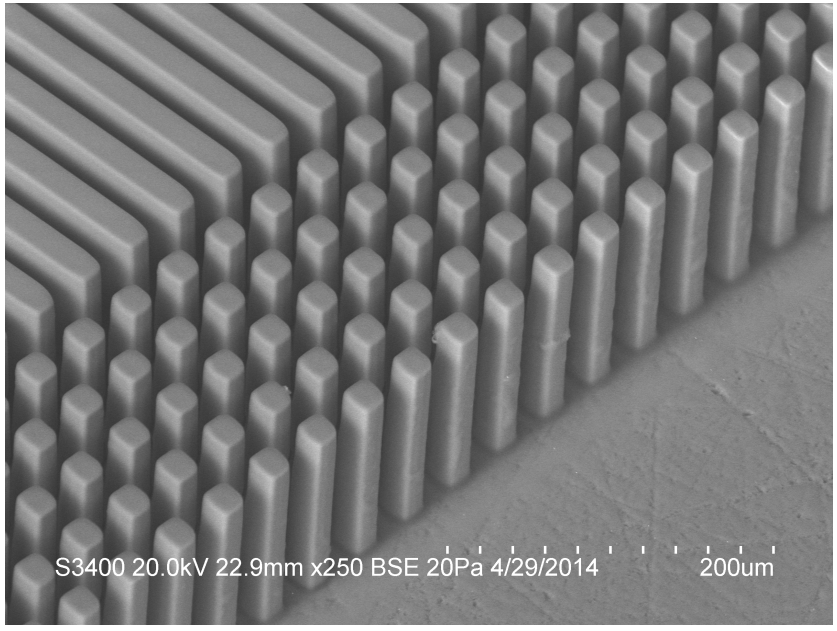


Preliminary opening, which limits the irradiation field, and an X-ray mask with a microopening of 15 to 60 microns in size are installed in the SR beam. The shape of microopenings on the mask is variable. Combining a microopening with a pre-opening yields a pencil beam of required size. Using such a pencil beam and moving the XYΦ stage, one can draw directly on a thick layer of highsensitivity resist.

Examples







SU-8 microstuctures, thickness is about 100 μm. Width of pinches is 20 μm, period is 40 μm

X-ray masks manufacturing

The key element of DXRL is X-ray mask. X-ray masks for deep X-ray lithography have to meet a number of requirements. To provide sufficient contrast X-ray masks have to have thick layer of high-Z material on X-ray transparent substrate. For example, for LIGA station on VEPP-3 SR source, gold layer with thickness 25–30 μm is needed.

X-ray masks manufacturing

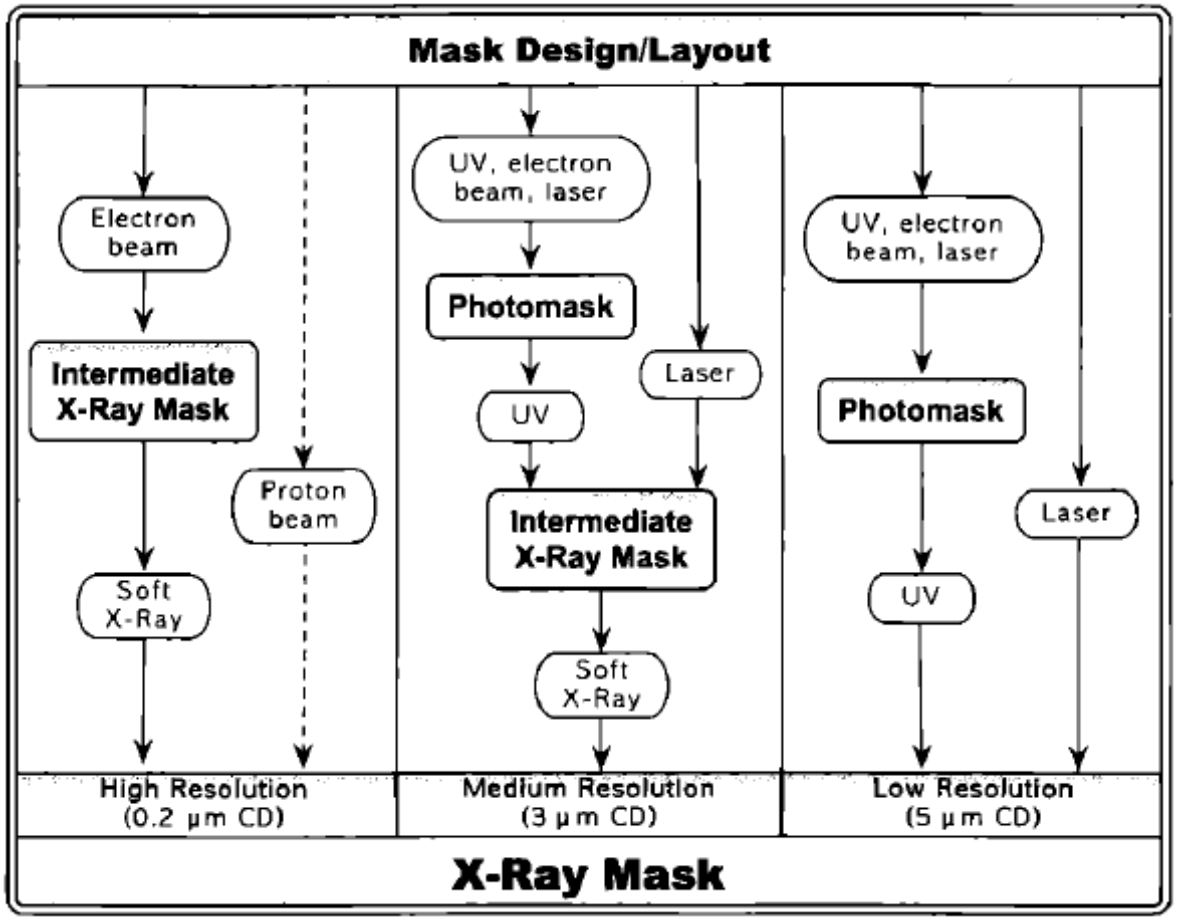
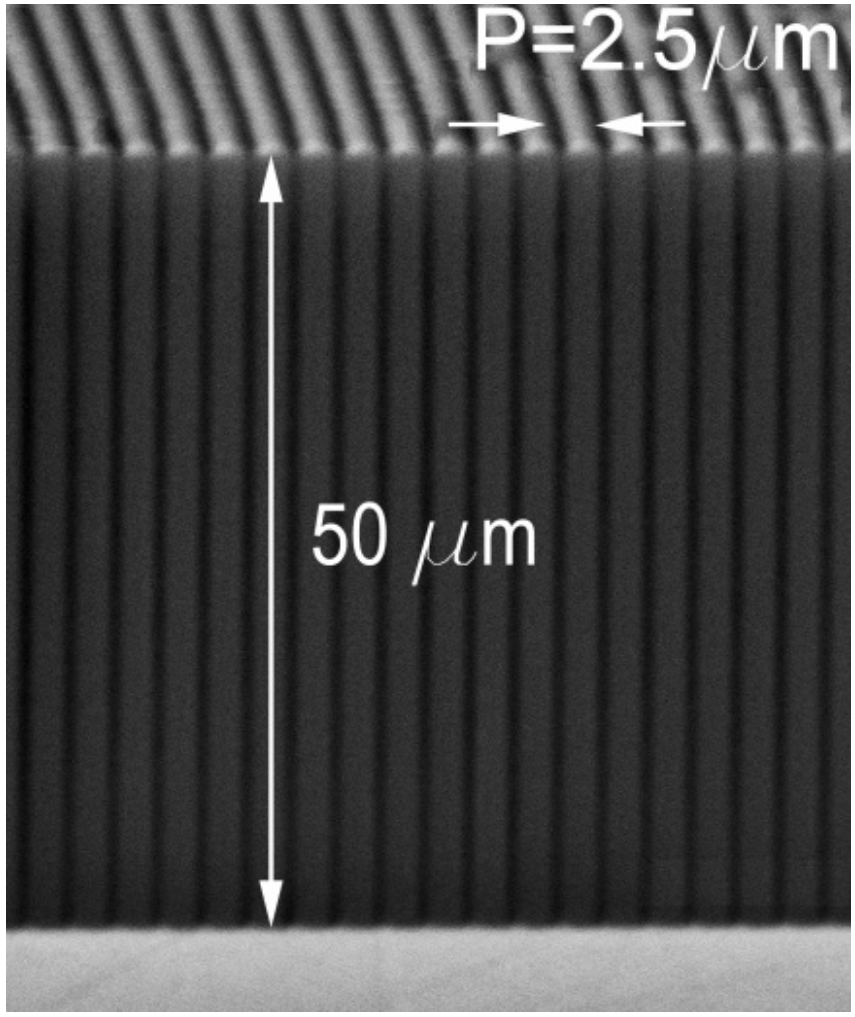


Figure: Overview of X-ray mask fabrication methods.Y. Desta and J. Goettert. X-ray Masks for LIGA Microfabrication. In *Advanced Micro & Nanosystems Vol. 7. LIGA and Its Applications, page 28, 2009*

Intermediate X-ray mask

One of techniques of manufacturing high resolution X-ray masks is in using of intermediate X-ray mask. The pattern of intermediate X-ray mask can be manufactured by convenient methods e.g. e-beam lithography or photolithography. These methods provide sufficient spatial resolution accompanied with critical dimension (CD) 1..2 μm, on resist layers 1–3 μm thickness. The electroplating of gold pattern 1–2 μm thickness follows. To achieve sufficient contrast of the gold pattern, the soft X-ray lithography (wavelength 4–6 Å) is needed. The substrate for such an X-ray mask have to have sufficient transparency in the aforementioned spectral range. Additionally, the resolution of X-ray lithography is limited by secondary electrons free path and depend from photon energy. Therefore, to obtain microstructure with critical dimension about 1 μm the soft X-ray lithography (wavelength 4-6 Å) is needed. In such case intermediate X-ray masks are useful for direct manufacturing of microstructures.

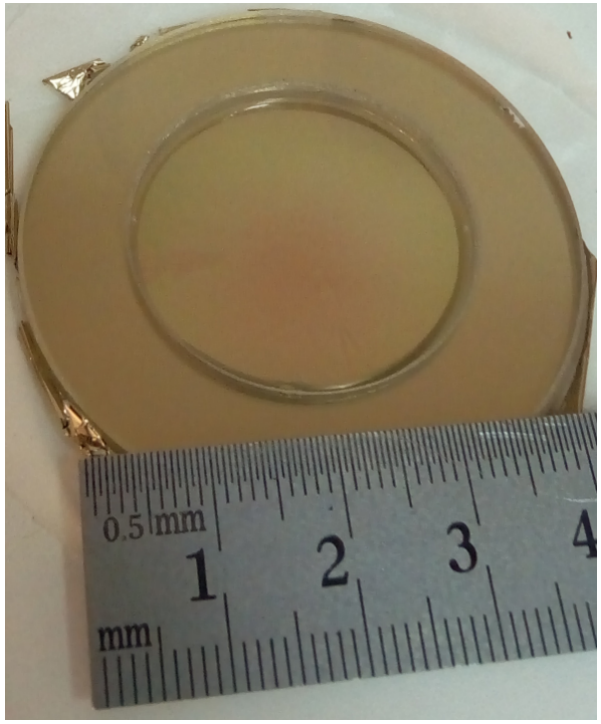
Soft X-ray lithography



Fragment of grating of SU-8 resist. Exposure was at “LIGA” station with beamstop.

Ti membrane

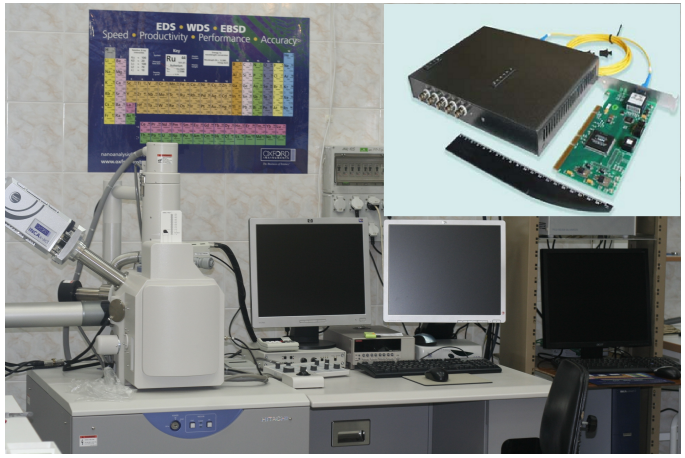
The technique of manufacturing thin Ti-membrane was developed. Number of samples with Ti 1.5 μm thickness are obtained.
It is durable enough to be operable.



Ti-membrane with gold seed layer on glass supporting ring

e-beam lithography

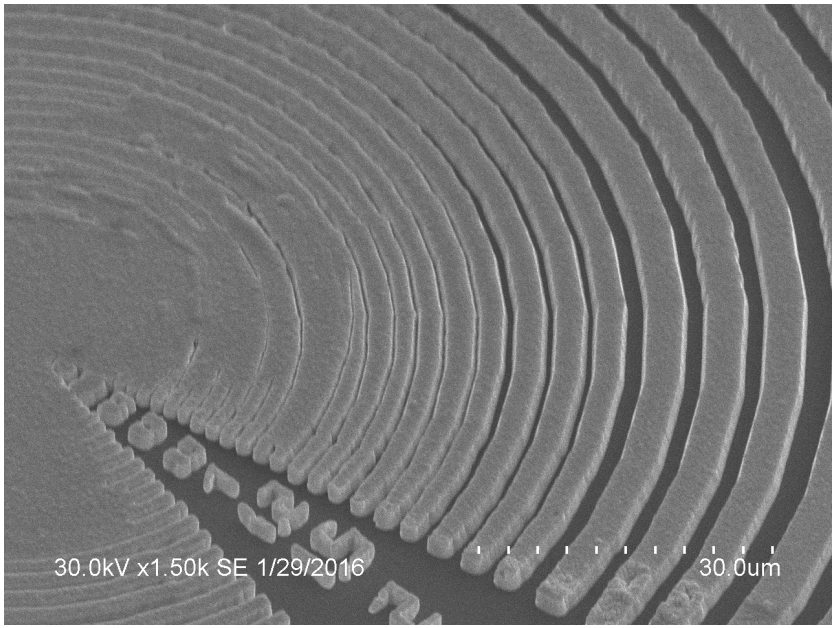
Our laboratory have scanning electron microscope Hitachi with NanoMaker — the software/hardware system for SEM based lithography. Nanomaker features:

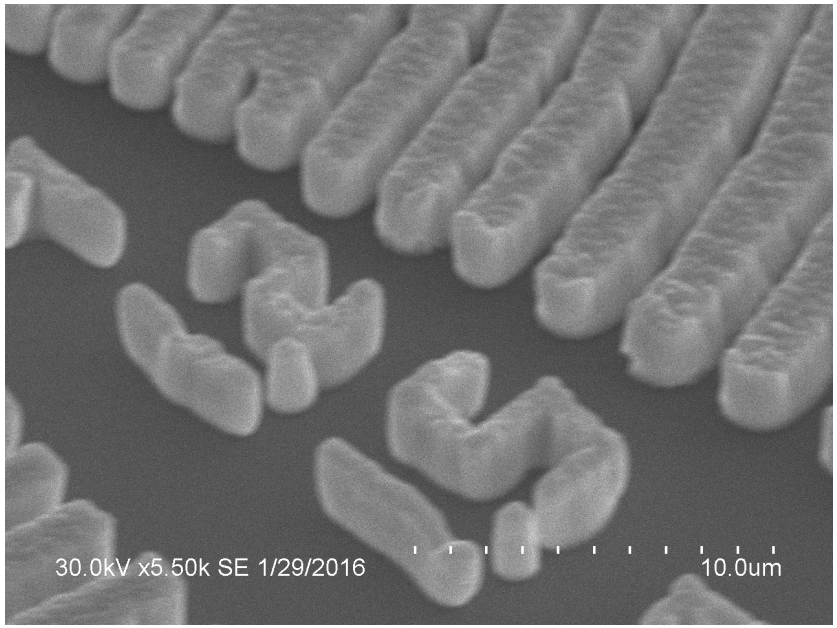


- Two 16-bit Digital-to-Analogue Converters
- The software package provides Proximity Effect Correction
- Modeling of exposure and resist development
- Video control for alignment and system tuning

The maximum electron energy is **30** keV.

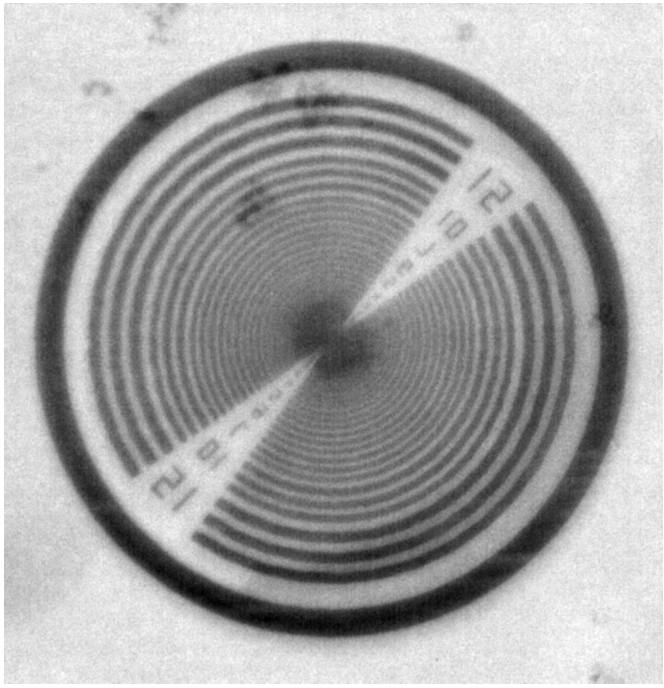
X-ray absorber manufacturing

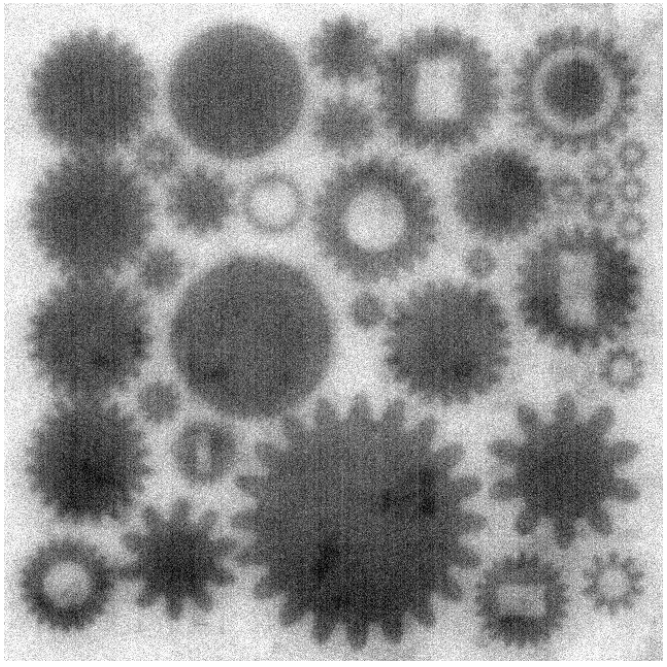




Examples of electroplated gold pattern.

X-ray mask testing





Images of X-ray mask patterns recovered at the X-ray microscopy station. Photon energy 6 keV. At figure a) outer ring have linewidth 20 μm

Conclusion

- The development of process methods and re-equipment of the station never stops.
- Soft X-ray lithography on “LIGA” station was developed.
- The technique of Ti-membrane based intermediate X-ray masks manufacturing is developed. The number of test structures was obtained.
- Preliminary testing of intermediate X-ray masks was carried out by X-ray microscopy on VEPP-3 SR source.

Thank you for your attention