Design, Development and characterization of thin film filters for high brilliance sources in the UV-X-ray Spectral range.

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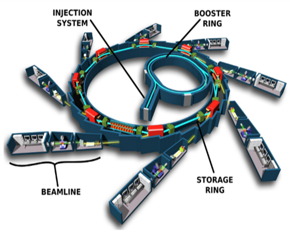
High brilliance sources such as synchrotron and free electron laser (FEL) are very appealing for many applications in the development of science and technology. One strong requirement on the beam delivered by these sources besides brilliance, coherence and bandwidth is often related to the spectral purity; in fact the beam can be the superposition of various harmonics. The rejection of high harmonics or diffuse light in order to improve the quality of the beam can be achieved by suitable optical systems acting as band pass filters. (1-3)

Since materials present high absorption in the EUV spectral range, the selection of devices acting as filters in order to select suitable spectral bandwidth or reject harmonics is quite challenging. This project will be focused in the searching for potential materials, design, fabrication and characterization of self standing transmittance thin films filters between 4-20 nm and 20-100nm spectral range , which correspond to intervals into the Extreme Ultraviolet and soft- x ray spectra Region, to be inserted along Synchrotron and Free Electron Laser (FEL) transport optics.

Some properties like fragility, resistance against oxidation and carbonation of the films and resistance to the high power of these light sources have to be taken in consideration.

Synchrotron Radiation

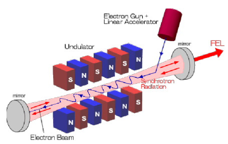
Radiation which is generate when relativistic electron (or positron) are accelerated (also could have a change of direction) in a magnetic field. In synchrotron radiation electron emit temporally incoherent, characterized by only partial transverse coherence light pulses. The electrons can be made to emit in phase (coherently radiation), in this process the electron density can be modulated along the bunch with the period of the radiation wavelength A device in which this modulation is created, and coherent emission takes place, is called a free-electron laser.



Some applications are:

- Environmental spectromicroscopy and Biomicroscopy.
- Spectromicroscopy of surfaces.
- Surface and material science.
- Chemical dynamics.
- Photoemission spectroscopy of strongly correlated systems.
- EUV interferometry and Coherent optics.
- Atomic and molecular physics studies.
- Magnetic materials and polarization studies.

Protein crystallography.



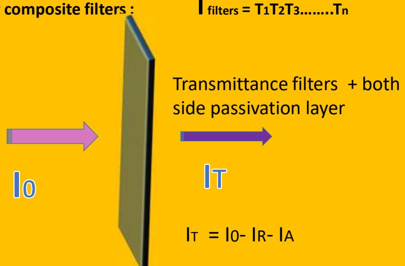
Transmittance Filters

Transmittance: is the ratio of transmitted energy to incident energy. The transmittance T of a filter respect a particular wavelength is determined by the relationship:

$$T = \exp(-\mu x)$$

μ= linear absorption coefficient at the chosen wavelength
X= thickness of the material.

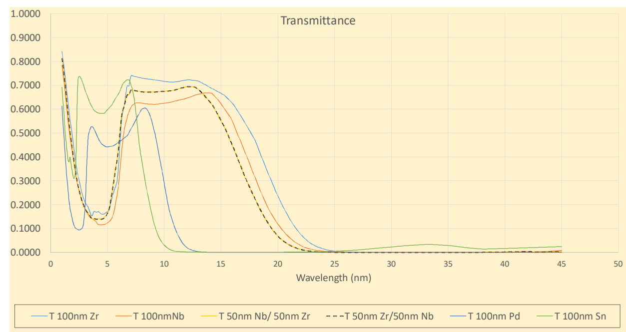
For composite filters : $T_{filters} = T_1 T_2 T_3 \ldots\ldots T_n$



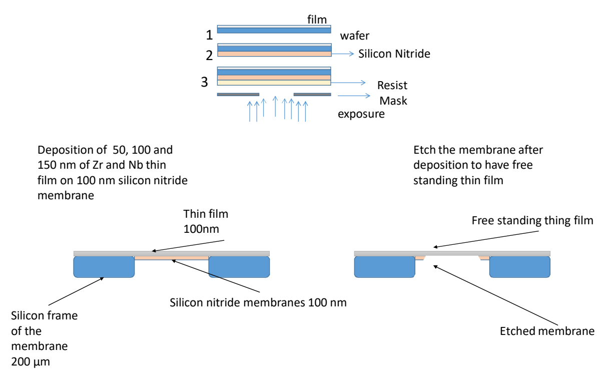
For filters to perform in the EUV and soft X-ray spectrum, thin films must be ultra-thin. Filter foils are most often a few hundred angstroms reaching occasionally up to several microns in thickness. Bandpass characteristics and mechanical properties are the two most important factors in determining filter materials.

Simulations, Material selection and design

We use IMD extension for XOP for simulate transmittance, reflection and absorption of different materials, taking in account the wavelength spectrum target

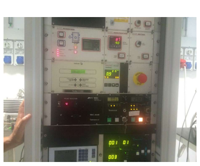


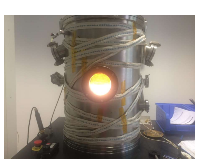
The FERMI FEL in Trieste is endowed with two FELs: FEL-1 covers the wavelength range 100-20nm and FEL-2 the wavelength range 20-4nm. (4). Nb and Zr are suitable materials for band pass filters development. In fact, simulation shows high transmittance and low absorption bands percentages in Zr and Nb filters in the same wavelength range that FEL-2 works (5). Furthermore they are very stables and reliable, suitable for e-beam deposition process (6), then perfect for the fabrication of filters to be inserted along synchrotrons beam lines and FEL transport optics.

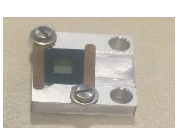


Next Steps: Deposition and Measurements

- Samples were made using Electron beam physical vapor deposition techniques, a special holder was fabricated to make possible the management of the samples.

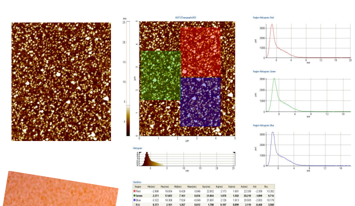


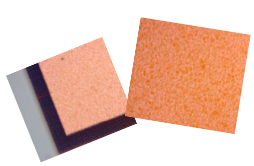




- Silicon and silicon nitride substrates, were studied with AFM and interferometer, in order to obtain roughness and other information for future studies of stress and effect of the chosen substrate in the thin film mechanical properties.

Thickness = 107 nm
RI @ 632 nm = 2.097
Roughness= 1.2-1.4 nm





Other measurement programmed :

- **Film Thickness.**
- **Roughness and Surface Morphology.**
- **Stress**
- **Transmittance vs wave length measurements**
- **Stability**
- **Contamination**

Acknowledgments

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References:

- Hatayama et al., Japanese Journal of Applied Physics, 48, 2009.
- M Fernandez Perea et al., Proc. SPIE 7101 (2008).
- Gann et al., RSI 83, 045110 (2012).
- Marco Zangrando et all, Journal of Synchrotron Radiation, 22, (2015).
- Luis Rodriguez de Marcos et all, Journal of Applied Physics 111. 113533 (2012).
- Filter windows for EUV lithography Forbes R. Powell, Terry A. Johnson. Luxel Corporation; Sandia National Laboratories.

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