Nanoscale Multilayer Membranes as Optical Elements for EUVL

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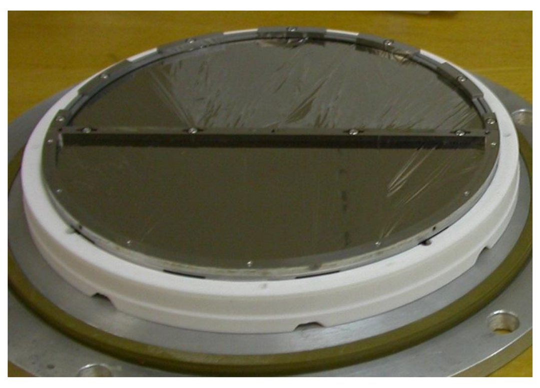
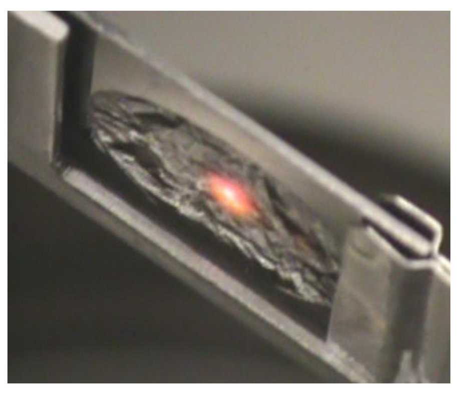
Transparent optical elements for EUV could have several critical applications, from spectral purity filtration to optics particle protection. No material is transparent to EUV, the only solution is to make the optical element extremely thin. This results in enormous challenges in fabrication of free-standing membranes, meeting requirements on heat load, mechanical strength, EUV transmission, handling.

Spectral purity filters to suppress DUV and IR radiation

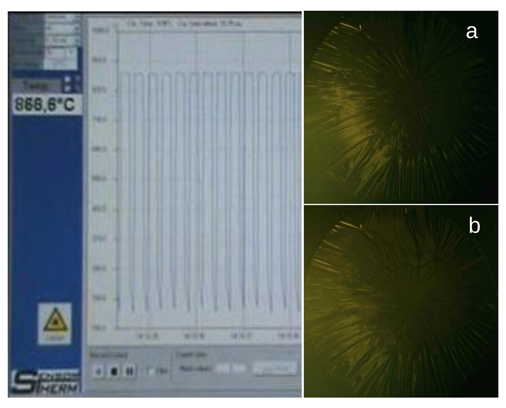
Membranes 52 ÷ 40 nm thick and as large as 160 mm, providing inband transmission up to 74-76% are considered as potential spectral purity filters to suppress DUV and 10.6 μm radiation with coefficients $10^2 \div 10^3$. SPF membranes withstand prolonged heating at absorbed power >5 W/cm^2 and repetitive deformations under modulated power load.



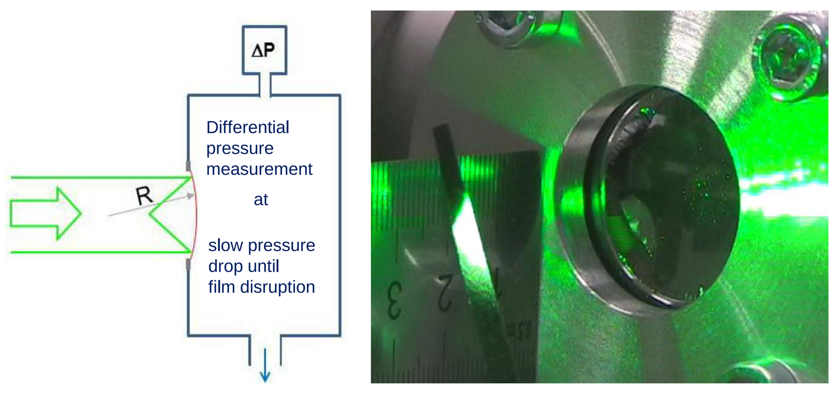
Sample of a multilayer SPF membrane, Ø160 mm, assembled of two semi-circular parts. Inband transmission > 72%, 10.6 μm suppressed by factor >100



Structural resistance to temperatures up to 1000 °C at absorbed power >5W/cm^2 demonstrated in exposures with duration 100 hours



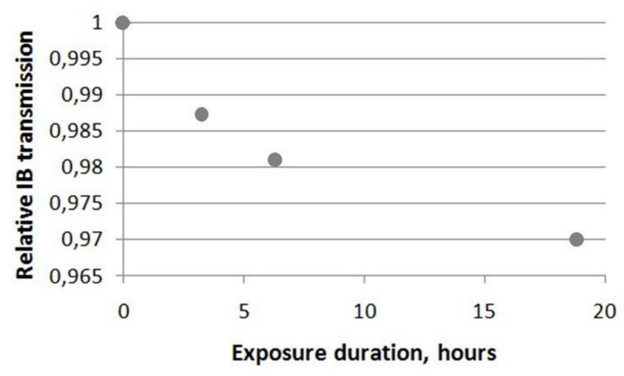
Thermo-mechanical resistance: after $2*10^6$ temperature modulations (b) no defects observed with backlight microscopy



Estimation of film tensile strength from pressure differential and curvature

$\sigma = \Delta P \times R / 2h \Longrightarrow 1 \div 2$ GPa

At apertures Ø26 mm $\Delta P \approx 15 \div 35$ mBar

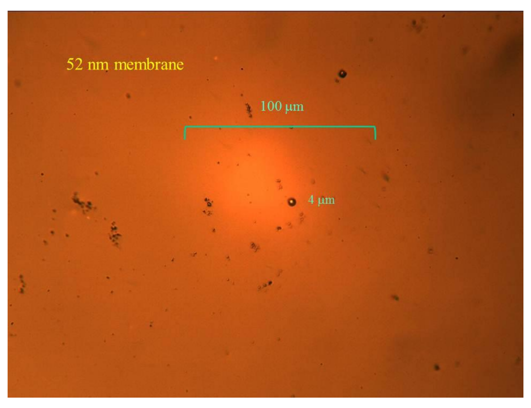


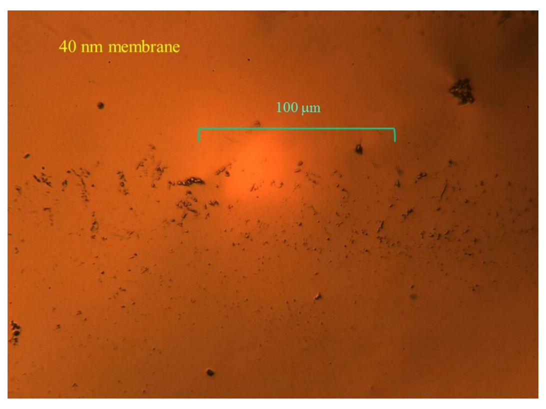
Inband transmission drop of a multilayer SPF membrane, annealed at 950 °C (5 W/cm^2), residual H_2O pressure 10^{-7} mbar

Stopping fast debris particles

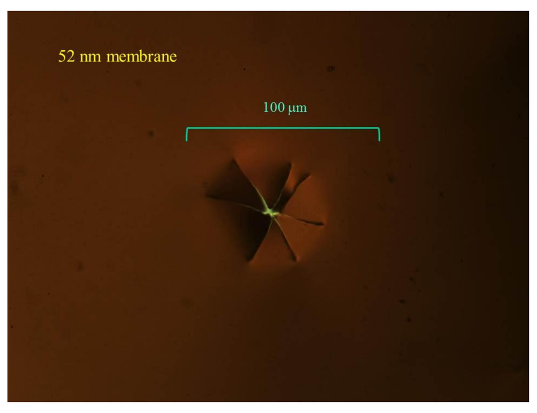
Stopping fast debris particles as valuable additional functionality of SPF membranes has been studied with an LPP source and a particle velocity filter. It was found that membranes are not punched through by metal particles with sub-micron dimensions and velocities up to 1000 m/s.

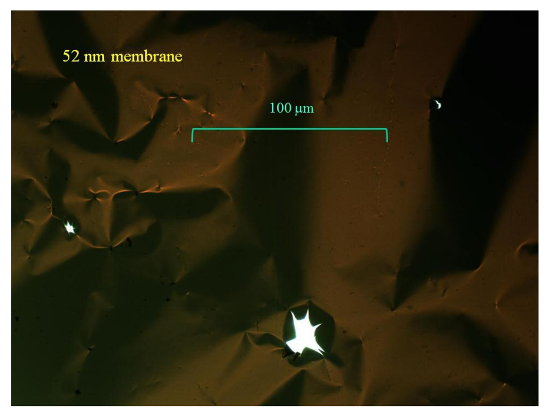
"Edge" velocity filter using honeycomb disc (60×20 mm, cell 3 mm) transmits particles with $V > V_{min}$. One of channels is shown. No synchronization with LPP is needed.





Punch damages by < 2 μm particles have not been found on both 52 nm and 40 nm exposed membranes. This result is coupled with a total number of visible particles (> 0.5 μm) on membrane surface >>1000/mm^2

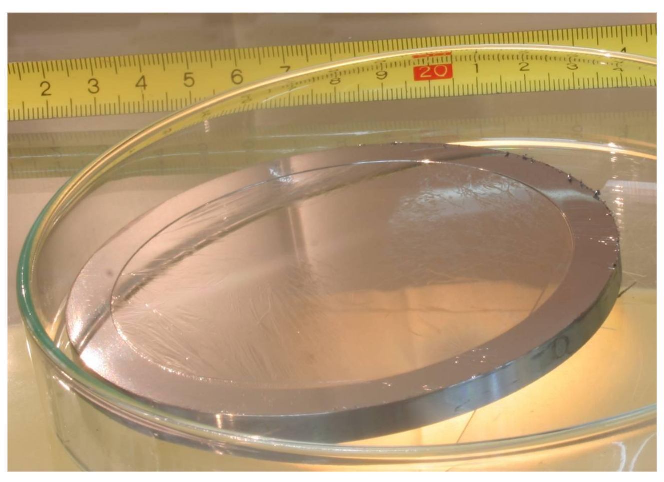




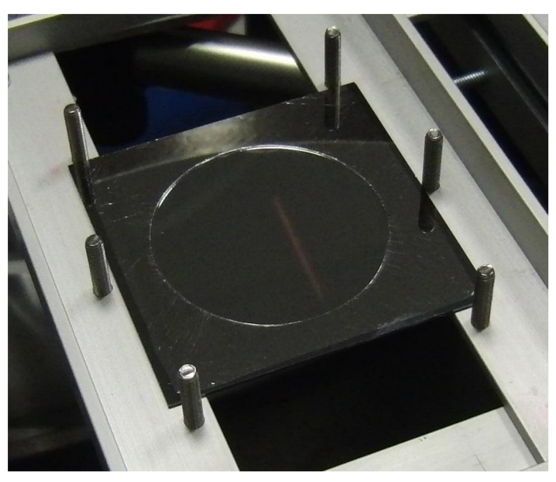
After attempts to find holes punched by particles under standard target irradiation conditions, exposures of 52 nm membranes were arranged to include particles of larger sizes. The low velocity limit was reduced to V_{min}= 300 m/s, laser beam was re-focused to generate large target fragments.

Reticle protection by pellicle

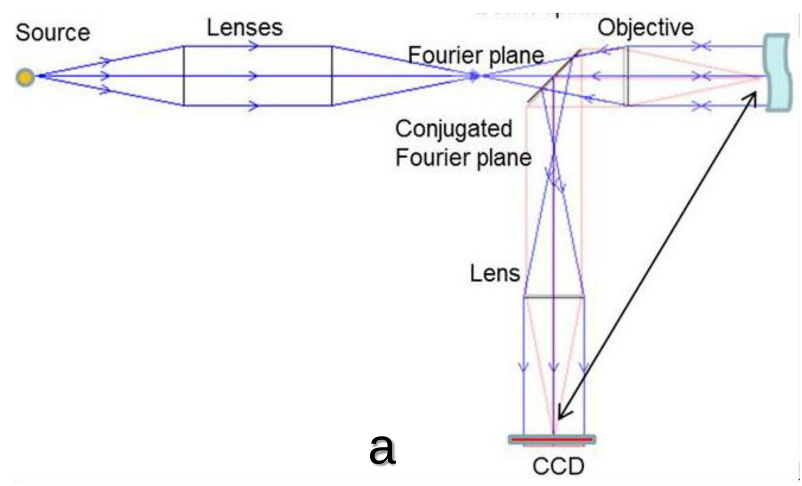
Development of super-thin membranes as pellicles is targeting a two-pass inband transmission above 80%. Currently a one-pass transmission of 86% has been demonstrated with 25 nm membranes on 80 mm aperture frames. The samples sustained absorbed power loads above 1 W/cm^2 with < 0.1 mm deviations from the initial quasi-stretched surface shape and in-plane acceleration of at least 15 g. Achievement of higher inband transmission is in progress.



Ultra-thin multilayer membrane on 80 mm aperture frame. Total thickness 25 nm, inband transmission 84%



Stretched 25nm multilayer membrane on 30 mm aperture frame, placed on a fast translation stage for modelling tests under specified conditions



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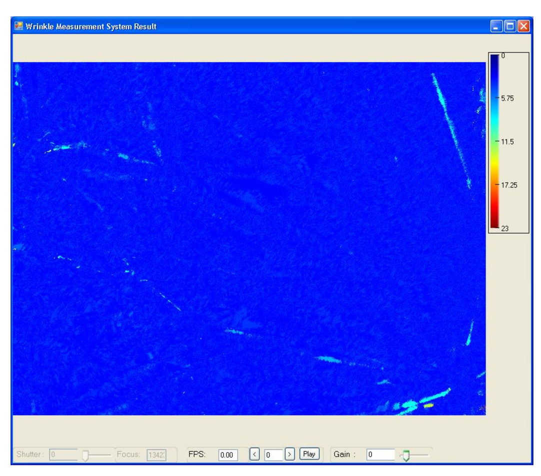

b

a) Optical set-up for surface shape inspection of pellicle samples, enabling mapping of deviation angles in wrinkles of non-stretched films.
b) Map of maximal wrinkle angles in a 25 nm non-stretched film on a 30 mm aperture frame. Numbers in the colour scale represent angles in degrees multiplied by 4, i.e. the maximal surface deviation angles are in range 1-2°