High line density free-standing transmission gratings for EUV and VUV emission spectroscopy

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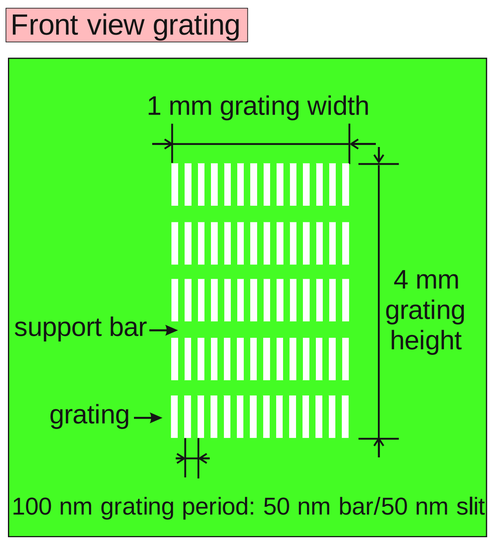
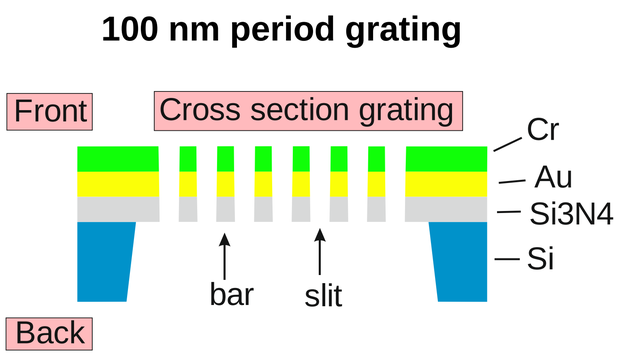
Goal

- EUV and VUV OoB spectroscopy of EUV light sources.
- Construction of portable Flying Circus OoB spectroscopy device enabling cross comparison and precise VUV spectroscopic source characterization.
- Reproducible fabrication of Transmission Gratings (TG) with up to 10.000 periods/mm.
- Reliable, cost efficient, high resolution small series production.

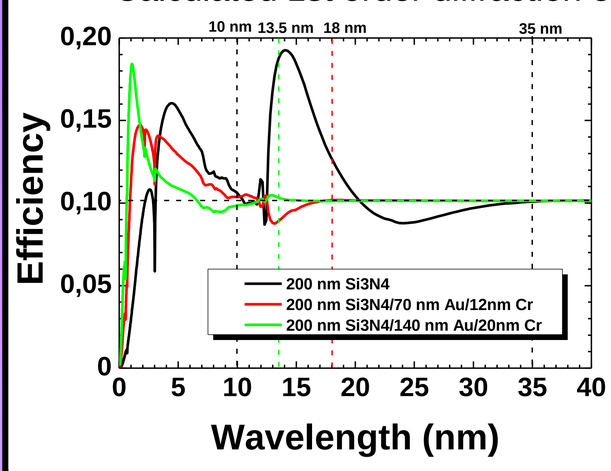
Grating design

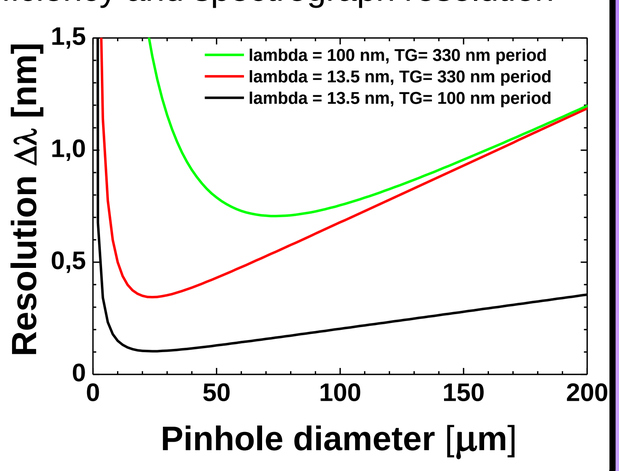




- TG in Si_3N_4 membrane coated with Au (absorber) and Cr (etch mask).
- Period/bar ratio = 0.5 (accuracy better than10%).
- Suppression 2nd diffraction order below 0.2% of 1rst order efficiency.
- Higher order suppression by filters.
- Resolution: λ/Δλ~ 100 at 13.5 nm.
- Diffraction efficiency ~ 10%.
- Available gratings: 500,780,1000,1500, 1850 mm^{-1} and 2000 to 10.000 mm^{-1} (incremental steps 1000 mm^{-1}).

Calculated 1st order diffraction efficiency and spectrograph resolution

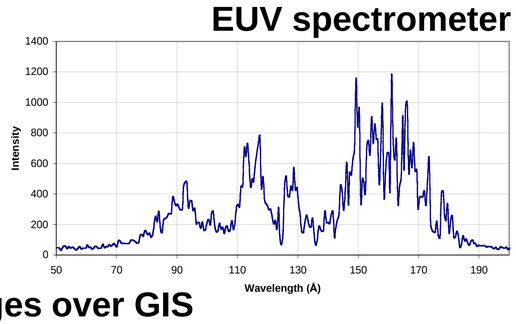


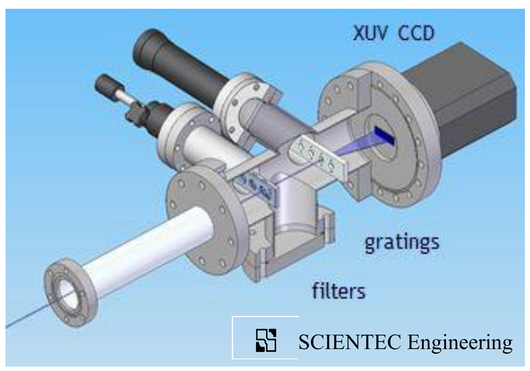


Portable EUV and VUV Flying Circus spectrograph

- Absolute emission spectroscopy for EUV (6 and 13.5 nm for lithography) and soft X-ray sources (coherent High Harmonics).
- Absolute out-of-band (OoB) spectroscopy for EUV light sources.

EUV spectrometer

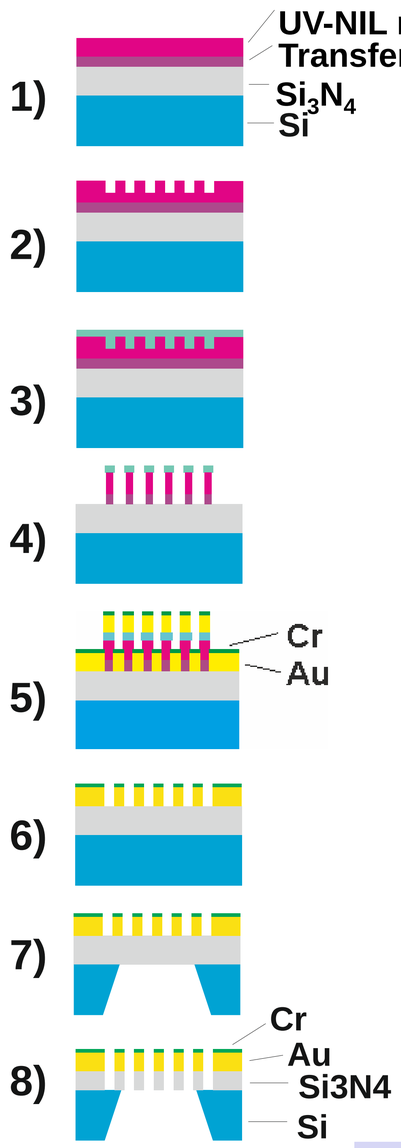




Advantages over GIS

- Simple alignment.
- 'Flat field' spectrum.
- Opaque grating: flat efficiency curve between 10 to 100 nm.
- Wide wavelength range, filter delimited.
- Operation with different gratings allows fast switching between high resolution or large bandwidth.
- Straight forward calibration.

Fabrication flow



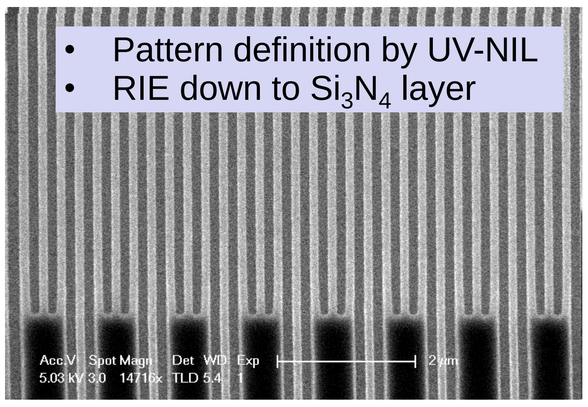
- Deposition of Si_3N_4 and imprint resist on Si wafer.
- UV-NanoImprint Lithography (UV-NIL) for high resolution pattern definition.
- Planarization and etch back of the top layer by Reactive Ion Etching (RIE).
- Pattern transfer down to the Si_3N_4 by RIE with excellent CD control and small under cut for Lift-off processes.
- Deposition of Cr (etch mask) and Au layer (absorber) by evaporation.
- Lift-off to form etch mask and top absorber layer.
- Back etch of Si by wet etching (patterned by optical lithography).
- Grating etching in Si_3N_4 (RIE).

→ Novel process for reproducible fabrication of high-line density transmission gratings

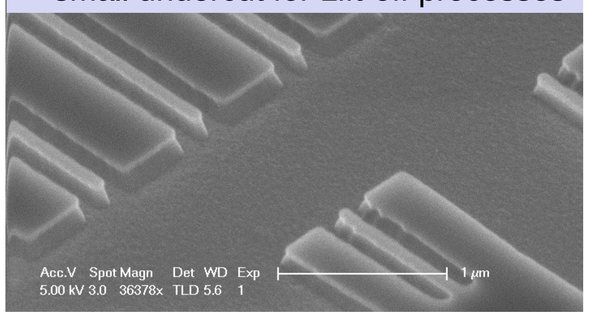
Process development:

Using test stamp with line features down to 65 nm

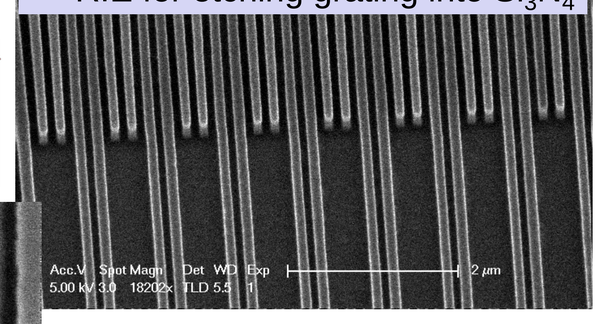
- Pattern definition by UV-NIL
- RIE down to Si_3N_4 layer

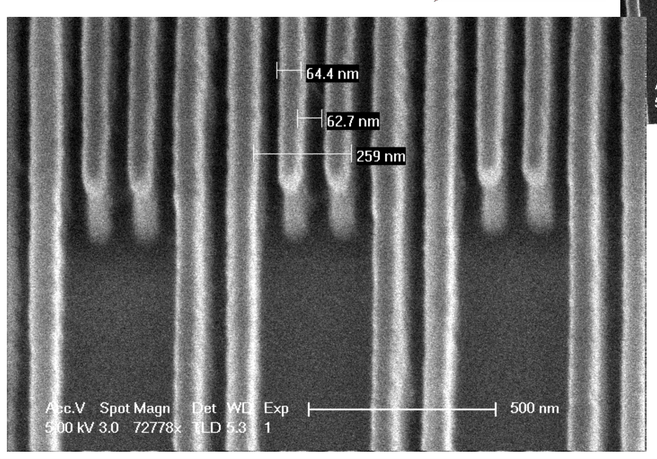


Imprinted and etched layers:
- excellent CD control
- small undercut for Lift-off processes



- Au and Cr etch mask by lift-off
- RIE for etching grating into Si_3N_4





→ **65 nm line features patterned in 200nm Si_3N_4 and Cr/Au/Cr stack (2nm/70nm/10nm)**

Summary

- We have presented the design and fabrication process for high line density transmission gratings.
- We demonstrated reproducible pattern definition by UV-NIL and etch mask fabrication by lift-off.
- We have shown succesful and reproducible fabrication of 65 nm line features in a Si_3N_4 membrane coated with a stack of Au and Cr.

→ Future work: develop backetch process for opening Si carrier wafer and fabrication of 50 nm grating bars and slits with dedicated UV-NIL grating stamp.

→ A portable EUV and VUV high precision spectrograph will be ready for source characterization early 2013.

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