DEVELOPMENT OF A LASER PRODUCED-PLASMA SOURCE FOR EXTREME ULTRAVIOLET LITHOGRAPHY

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PREUVE project

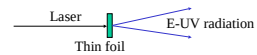
PREUVE GOALS

- To put together the skills of all the partners, laboratories and companies : *SOPRA*, CEA/DTA/LETI, **CEA/DAM**, CEA/DSM/DRECAM, GREMI, LORXN/L3M/LOE SAGEM/REOSC, SESO, THALES* (* : since January 2001).
- To acquire savoir-faire concerning the technical elements of the E-UV lithography. *The **E-UV sources @** 13.5 nm, the **multilayer optics (realization et metrology)**, the **reflection masks (realization et metrology)**, the **resist process.***
- To develop and assemble the parts of a laboratory E-UV photo-stepper. , The **"Banc d'Essai pour la Lithographie"** (BEL), and E-UV metrology devices.

CEA/DAM role inside PREUVE

- Conception of a E-UV source (Rear-side emission of a laser-produced plasma) (Patents)
  Numerical optimization of the target and the interaction, experimental validation with a dedicated diagnostic, conception of a source prototype for the BEL
- Multilayer mirrors metrology
  Multilayer mirrors absolute metrology with synchrotron radiation.
- "Banc d'Essai pour la Lithographie" Integration
  BEL integration, assembly, alignment

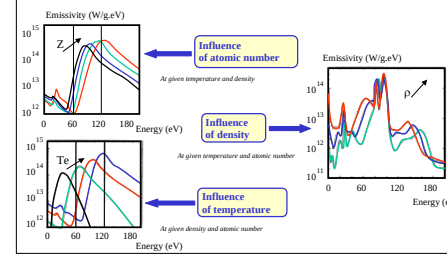
The proposed EUV source is based on the collection of rear-side emission of thin foils irradiated by low intensity lasers



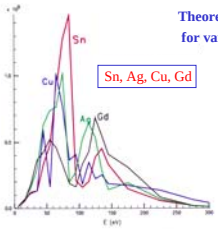
Theoretical strong points :
High directivity emission ⇒ higher collection efficiency
Low debris production ⇒ higher lifetime of the optics
No reabsorption of radiation between the optical system and the source point

For given laser parameters and target atomic number, existence of an optimal target thickness that maximizes the rear-side EUV conversion efficiency

The theoretical parametric study of radiative properties of materials has shown that strong EUV emission can be expected



Numerical optimization (Material selection)



Theoretical rear-side spectra for various materials

Sn, Ag, Cu, Gd

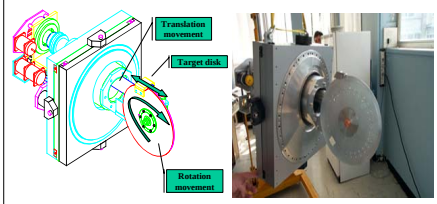
λ_{laser} : 1.06 µm
Δt_{laser} : 7 ns
(pulse with a fast risetime)

E_{laser} ~ 2 J sur ϕ ~ 200 µm
(low intensity laser ≤10 ^{12} W/cm^2)

Target thickness : 1 à 2 µm

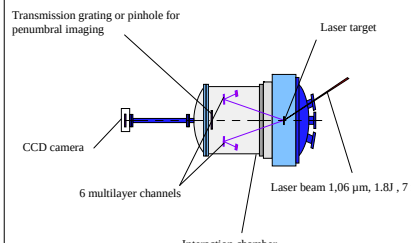
E_{EUV} (mJ/sr/tir) in-band : 20

Target holder

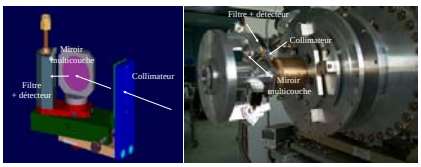


The targets are placed along a spiral.
A translation movement and a fixed speed rotation movement put in position the target at the focal point of the laser beam.

Source EUV Diagnostics



Diagnostic with interferential multilayer mirror



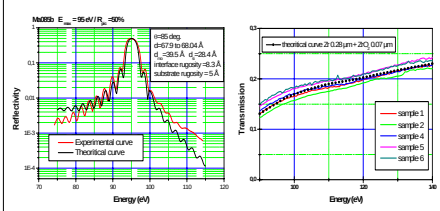
Filter : 0,35 µm zirconium @ λ =13 nm

Multilayer mirror :
Mo / Si : d = 68 Å, θ = 85° @ λ =13 nm

Detector :

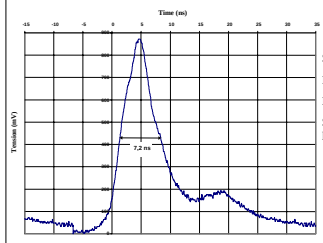
IRD photodiode for spectral analysis
Long rise time
High sensibility

Multilayer channel parts metrology at LURE



Spectral precision : 0,1 eV (0,2 Å)
Relative precision on the reflectivity : 3 %

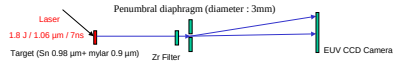
Temporal profile of a laser pulse



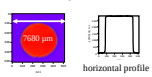
Single mode pulse
FWHM : 7,2 ns (± 2 %)
Laser energy : 1,8 J
Stability of the emitted laser energy : < 3 %

Source EUV penumbra image

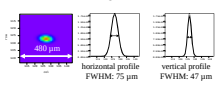
E-UV penumbral imaging @ 9.39 nm (132 eV ΔE =90 eV)
penumbral diaphragm (diameter: 3mm) + Backlighted CCD camera + Zr filter



Coded image of the source



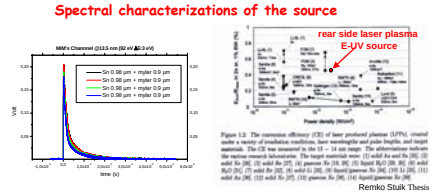
Decoded image of the source



Uniform space of EUV emitted distribution on elliptic spot of 94 µm out of 150 µm

We gratefully acknowledge Mr. A. Rouyer for his assistance.

Spectral characterizations of the source

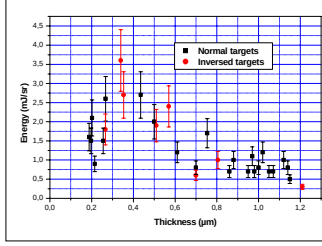


Remko Stuik Thesis (October 2002)

For this comparison we have calculated the Conversion efficiency (E_{EUV}/E_{Laser} source in 2 π sr for 1 % of bandwidth) => it is 0.46 %

Laser repetition rate: 10 Hz / Pumping power: 18 W @ 1064nm (1.8 J, 10 Hz)
Mean energy emitted @13.5 nm by laser pulse: 4 mJ / sr in the band (3eV at 92 eV)
Resulting EUV mean power: 0.040 W / sr in 3% BW @13.5 nm
Stability of the emitted intensity (shooting with shooting): 15 %

Variation on the emitted energy following the tin thickness



My : Mylar Thickness 0.9 µm
Normal target : Sn / My
Inversed target : My / Sn

Conclusion and Prospects

Good spatial and temporal stability of the laser beam allowing a good reproducibility of the focalisation spot

Mean energy @ 13.5 nm by laser pulse : 4 mJ / sr in a band de 3 eV à 92 eV

Intensity stability shot to shot :15%

In the Future :

Characterization the emission cone with a goniometer placed inside the interaction chamber
•Complete characterization of the debris production
•Study to improve our source :
Improvement of the conversion efficiency by optimization of the interaction, nature of the target (structure, composition, multilayer, …) and nature of the substrate (structure, composition, …)
Increase of the source frequency (close to 1 kHz)

DAM Île-de-France