Panel Discussion - Europe.

Padraig Dunne, UCD School of Physics
Dublin, Ireland.
Progress in radiative hydrodynamics modeling of LPP EUV sources (I)

EUV photons flux: 13.5 nm \(\sim 5 \times 10^{12} \text{ ph/}(\text{cm}^2\text{pulse})\)

MLM samples (biased)

Detector of absolute radiation power (EUV photon flux)

SPF Zr/Mo (13.5±0.2nm) filter

Grazing-incidence Mo collector

Debris mitigation system

Target type: SD; \(D_{\text{laser}} = 300 \mu\text{m}; E_{\text{laser}} = 0.1 \text{ J}\)
Progress in BEUV (6.2 nm) source investigations

CE % (0.6% band), T & R – transmission and reflectivity of plasma for CO2 laser radiation

**Target numbering (increasing hole diameter)**

**Optimal hole diameter**

**Target – Gd foil 80 µ thick**

- Laser energy: 600 mJ
- Laser spot dia.: 300 µ
- Pulse duration: 100 ns
- Power density: ~$10^{10}$ W/cm²

**Gd flat target**

**Nd – laser, 1.2 nsec, 0.3 J**

CO₂ laser - CE = 1.8 % for Gd has been demonstrated (0.6 % bandwidth).
Nd - laser; 1.2 ns, 0.3 J – CE = 1.05 % for Gd and Tb (0.6 % bandwidth)
Microscopy with extreme ultraviolet and soft x-ray radiation

- high elemental contrast
- higher spatial resolution (20 nm) compared to light microscopy
- larger penetration depths (10 µm) compared to electron microscopes
- high throughput in dark field (scatter) mode
- with high sensitivity to small structures (down to 10 nm)

**Mask blank inspection:**

- Fundamental investigations into defect detection (influence of different kind of defects on signal)
- Fast scanning of large surfaces – with 1 µm resolution and 10 nm sensitivity
- Design rules for an industrial mask blank inspection tool (source, optical system, detector, interaction of EUV radiation with a defect)

Reflection dark field microscope for defect inspection of EUV mask blanks

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Damage of multilayer optics with varying capping layers induced by focused extreme ultraviolet beam

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FIG. 5. CL2-D3, \( F = 1720 \text{ mJ/cm}^2 \) topography and depth profile.
EPPRA (France) together with partners from School of Physics of UCD (Ireland) and KIAM (Russia) continues to substantially redevelop the Z* code to Z+ in the framework of the EU FP7 IAPP project FIRE to include improved atomic physics models and full 3-D plasma simulation of radiative plasma dynamics of EUV & soft X-ray sources.

S. and V. ZAKHAROV with co–authors use improved Z* and Z+ codes:

- to study spectral properties and dynamics of LPP in UCD with different target materials and admixtures
- to examine physical properties of Laser Assisted Vacuum Arc in UCD with rotating electrodes in collaboration with TCD (Ireland) and RWTH Aachen University (Germany)
- to understand the stability issues of Laser Assisted DPP with rotating electrodes at TRINITI (Russia)
- to optimize the 80kA capillary discharge soft X–ray radiation source in water–window range with Institute of Plasma Physics and CTU in Prague (Czech)

NaexStream, a French company located near Paris, started development of high brightness sources in both EUV and soft X-Ray range, for metrology and mask inspection applications.
Dublin: UCD, TCD & DCU

**UCD**
- Colliding plasma work for 13.5 nm
- Time-resolved spectra at 13.5 nm
- Dilute high-Z targets for 13.5 nm
- DPP studies at 13.5 nm
  - Time-resolved Gd spectra for 6.x nm
  - Ga & Ge studies for 6.x nm
- New grant proposal in preparation……..

**TCD**
- DPP studies for 13.5 nm

**DCU**
- Colliding plasma characterisation
Zurich

- ETHZ – Laboratory for Energy Conversion (LEC)
- 6 years work on LPP sources
- New – ALPS II – tin droplet
  - Since March 2013 – new kW laser & droplet generator
  - Development from ALPS I
  - Brightness 259 W/mm²sr
  - In–band EUV collectible of 5W demonstrated

- Adlyte is commercialising the source.
Prague

- Multiple Centres of Activity
- > 50 active researchers + ~20 students
- Optics, sources, applications
- Plasma diagnostics
- Universities, Institutes + RIT Europe
- See P53, Ladislav Pina.
NXE:3300B shows single-digit (9 nm HP) patterning capability using spacer-assisted double patterning (SADP)

**Litho Conditions:**
- ASML NXE:3300B system
- EUVL single expose 18nm HP
- 0.33NA, Dipole-90x illumination
- Resist: 50nm EUV J1099 on 20nm BS AL412 UL on stack wafer with Hard mask

Source: ASML, IMEC, AMAT (Feb.’13)
Summary

- **NXE:3100** in use for process and device development at customers

- **NXE:3300B** tested and qualified, 11 systems in various phases of integration
  - Overlay performance of DCO<2nm and MMO<4nm demonstrated
  - Good imaging performance for 1D (22nm to 16nm), 2D (Contact Holes and Metal 1) shown
  - Dose reduction to <16mJ/cm² for 22nm achieved by utilizing contrast enhancement with off-axis illumination
  - Resolution of 13nm LS and 18nm Contact Holes demonstrated. Further process optimization to be done
  - 40W source power demonstrated with good dose control and under good collector protection conditions in six 1-hour runs, and 55W source power demonstrated in 1 hour run with good dose control and same collector protection conditions

55W EUV Power
1 hour run, 97.5% die yield
EUV EXTENDIBILITY
EUV LITHOGRAPHY + SADP

15 nm hp patterning demonstration enabled by NXE:3100 (NA 0.25) + SADP

9 nm hp patterning demonstration enabled by NXE:3300 (NA 0.33) SADP
TOKYO--(BUSINESS WIRE)--USHIO INC. (Headquarters: Tokyo, Japan; President and Chief Executive Officer: Shiro Sugata; hereinafter "USHIO") (TOKYO:6925) today announced that it will close down the activities of XTREME technologies GmbH (Headquarters: Germany; President: Tatsushi Igarashi, hereinafter "XTREME"), a research and development company for Extreme Ultraviolet (EUV) light sources for next-generation semiconductor lithography, and consolidate the EUV light source business into a single unit in Japan and continue it for inspection and development applications in the future.

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Thank You