An EUV source for CMOS lithography and materials characterization

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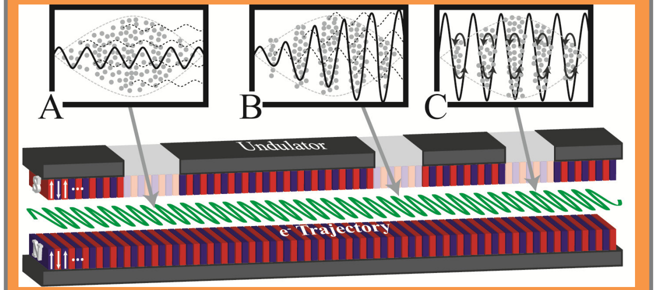
Introduction

Alternative Extreme Ultra-Violet (EUV) sources are examined [1-5]. One system, based off of Self-Amplification of Stimulated Emission (SASE) occurring within an undulator, could provide 13.5 nm Free-Electron Laser (FEL) EUV photons capable of supporting 10 lithography stations at 10 KW each. Combining this with a synchrotron would allow for electron re-circulation. The entire system could then also support multiple materials characterization/metrology capabilities with two examples being: Angle Resolved PhotoElectron Spectroscopy (ARPES) and Coherent Diffractive Imaging (CDI) Ptychography.

Undulator (FEL source)

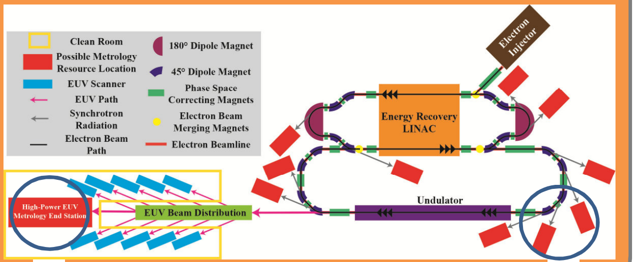
- SASE produces in a highly coherent (in phase) beam



- Coherency allows for a significantly greater photon source brightness + additional possibilities, i.e. CDI-Ptychography

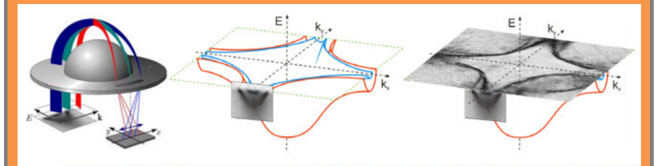
Recirculating accelerator

- Pictorial illustration (top-down) of examined system



1: ARPES

- A synchrotron for supporting an 13.5 nm EUV source can provide VUV (10-100eV) non-coherent photons.
- These photons can be monochromatized and directed into an ARPES end-station (Omicron)→
- ARPES provides electron momentum distributions 2D (films) and 3D (bulk) from solid surfaces (outer 10 nm).
- Electron momentum distributions provide insight into electrical conductivity/resistance, superconductivity, magneto-resistance, etc.



The detector of a modern photoelectron analyzer (left) acts as a window into the 3D energy-momentum space of a 2D metal (center). By moving this "window" in (ω, k)-space, a complete distribution of electrons and, in particular, its cross-section by the Fermi level, the Fermi surface (right), can be obtained. Here, the electronic band structure and the ARPES spectra are shown for high-temperature superconductor Bi-2212.

- ARPES geometry and imaging example is shown above [6]

Two materials characterization options

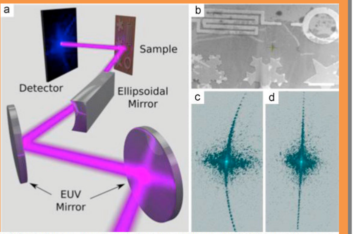
2: CDI-Ptychography

- 13.5 nm wavelength coherent photons used to support EUV lithography can also be used to image surfaces via CDI-Ptychography
- CDI-Ptychography provides both composition (from amplitude) and film thickness/height (from phase) via phase retrieval
- A CDI-Ptychography example (geometry and imaging) using a 40 nm high harmonic generator source is shown below [7]

Reported results reveal [7]

- Spatial res ~1.3 λ
- Depth res ~ 0.6 Å

Higher energy photons (13.5 nm) will improve resolution



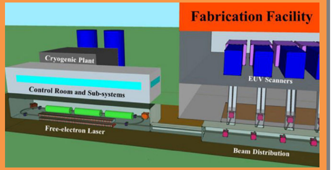
Tabletop EUV ptychography. (a) Schematic of the tabletop EUV microscope. (b) SEM of the sample with a scale bar is 10 um. (c) Representative diffraction pattern from the ptychographic scan. (d) Diffraction pattern from (c) after tilted plane correction.

Other characterization possibilities

- Spin Resolved (SR) PES
  For valence electron spin states
- Time resolved PES
  For electron dynamics
- Core level XPS (<100eV)
  For composition and speciation
- UV-vis, FTIR and Raman spectroscopy
  For bonding and molecular structure
- Spectroscopic Ellipsometry inclusive of scatterometry
  For optical properties (n and k), critical dimensions
- Terahertz (THz) spectroscopy
  For local field, electron mobility, carrier dynamics

Summary

- A SASE EUV source plus a synchrotron could theoretically power 10 lithography stations, each to a power of ~10 KW



- Such a system could also support multiple materials characterization/metrology end stations. Two specific examples of interest include:
  - ARPES
  - CDI-Ptychography
- Although significantly greater up-front costs would be realized, such a system could supply greater power and uptime relative to existing EUV systems.

References

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