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Enhanced EUV Lighting with Optimized C-beam Irradiation

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Technologies for enhanced EUV lighting

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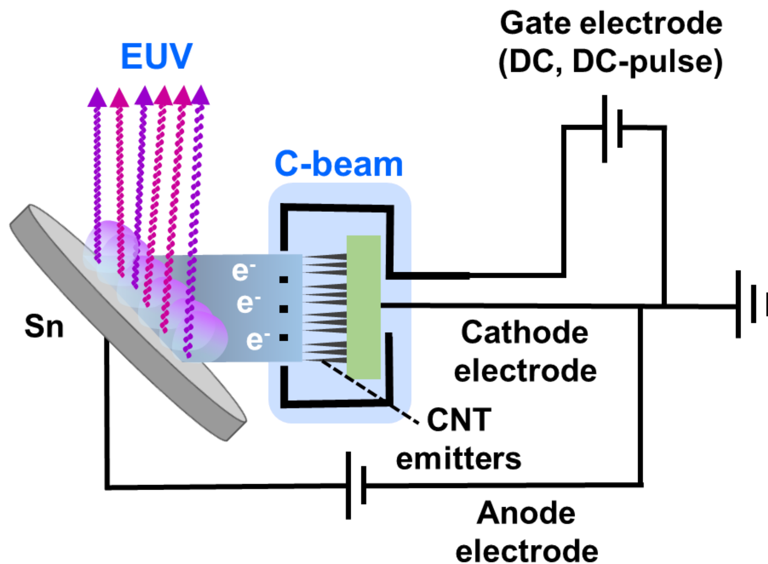

Schematic of EUV generation with C-beam

Technologies for enhanced EUV lighting

1. Multiple C-beam irradiations
2. Minimal debris technique
3. Using DC-pulse driving
4. Focused C-beam irradiation
5. Etc.

- **Among several technologies to enhance EUV lighting, we discuss multiple C-beam irradiations.**

Previous works
- Specifications of C-beam for EUV lighting

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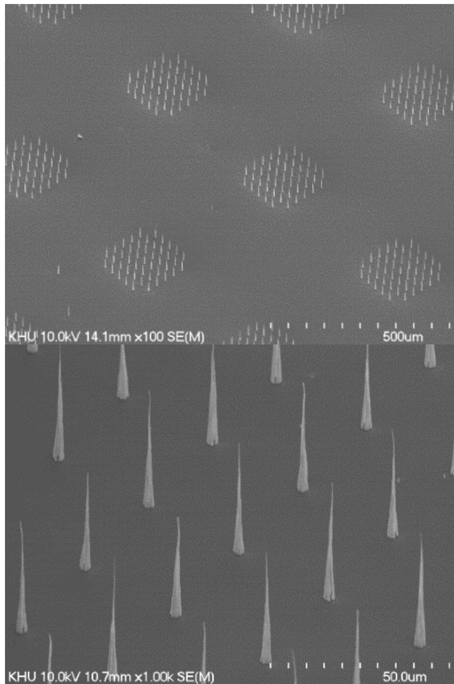
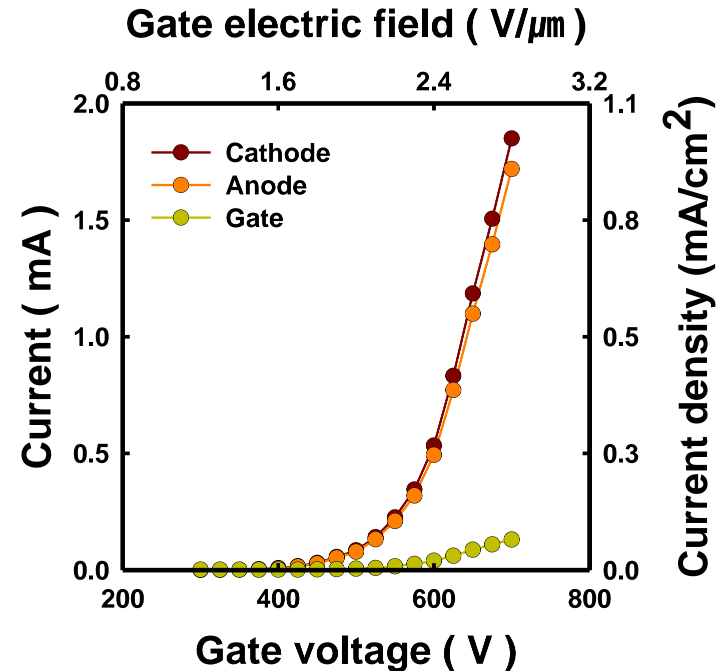
- **Carbon nanotube (CNT)-based cold cathode electron beam (C-beam) was manufactured for EUV lighting.**



SEM image of CNT emitters



I-V characteristics of C-beam

C-beam			CNT emitters	
Anode voltage	Anode current	Gate transmittance	Height of emitters	Dot size of emitters
15 kV	0.4 mA	> 90%	40 μm	3 μm

- Yoo, S. T. & Park, K. C. *2021 Source Workshop* (2021).

Previous works
- EUV lithography using PMMA photoresist

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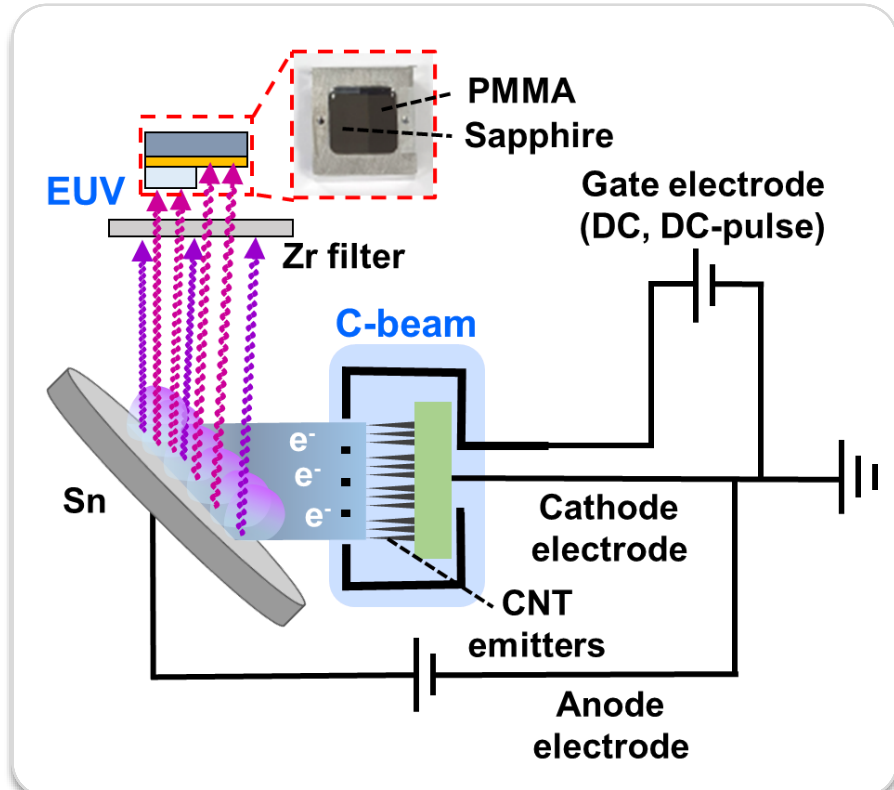

Schematic of EUV lithography with C-beam

Optical microscope image
after exposure and develop (Mag. x500)

- **After EUV exposure and develop, the part covered by the sapphire and the part not covered by the sapphire can be accurately distinguished.**
- **Lithography using EUV is possible by exposing for 30 seconds at a photocurrent of 4 μA measured with a photodiode.**

• Yoo, S. T. & Park, K. C. *2021 Source Workshop* (2021).

Enhanced EUV lighting with C-beam
- Two C-beam irradiations

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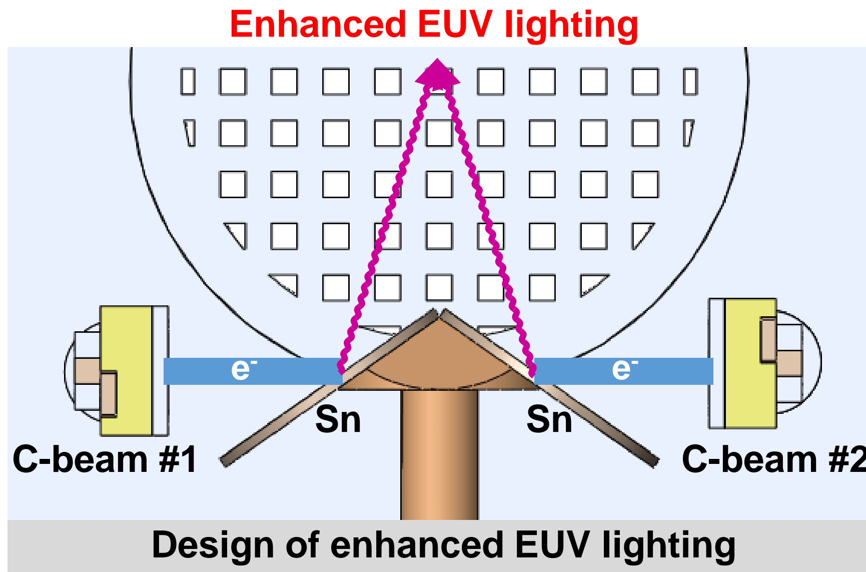


Design of enhanced EUV lighting

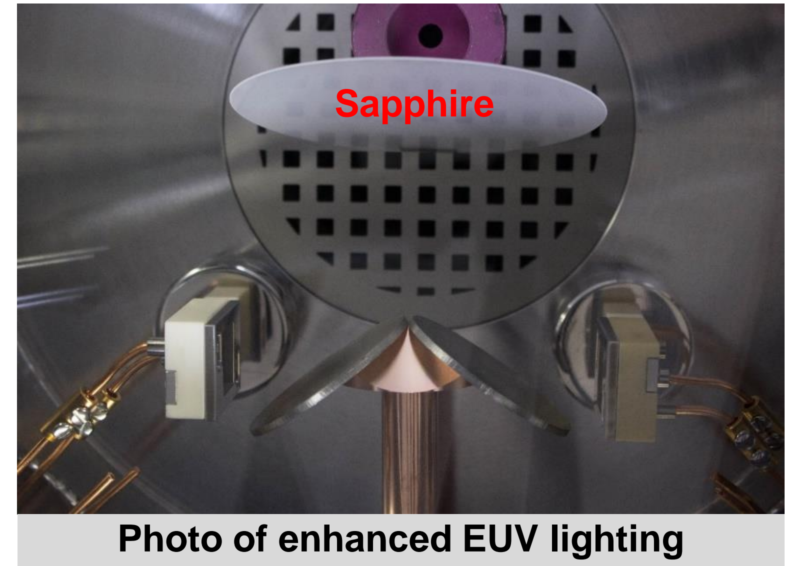
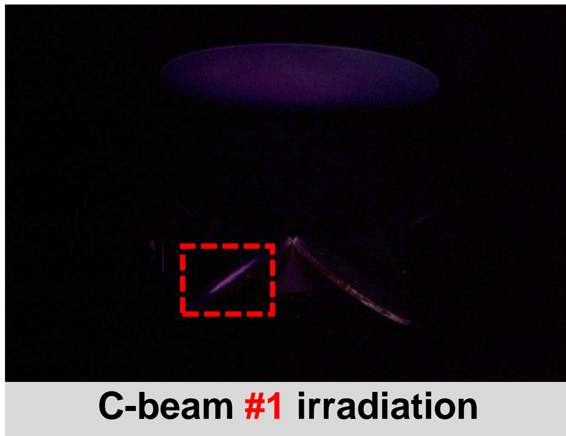
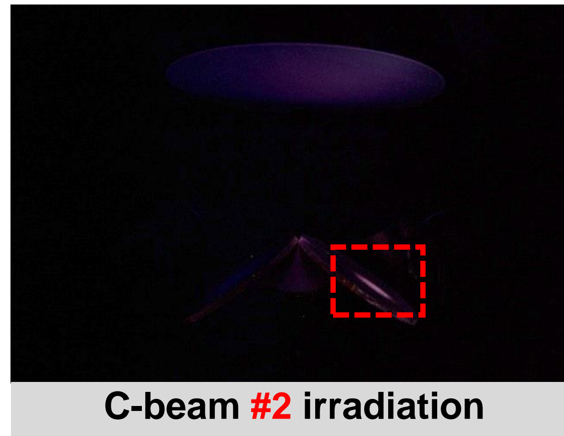


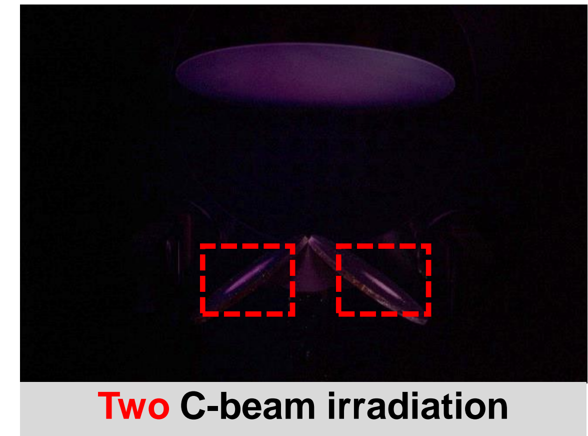
Photo of enhanced EUV lighting



C-beam #1 irradiation



C-beam #2 irradiation



Two C-beam irradiation

※ One C-beam: 15 kV, 0.5 mA

- **It was confirmed that EUV intensity is enhanced through two C-beam using EUV-PL**

Enhanced EUV lighting with C-beam
- Increased photocurrent according to # of C-beams

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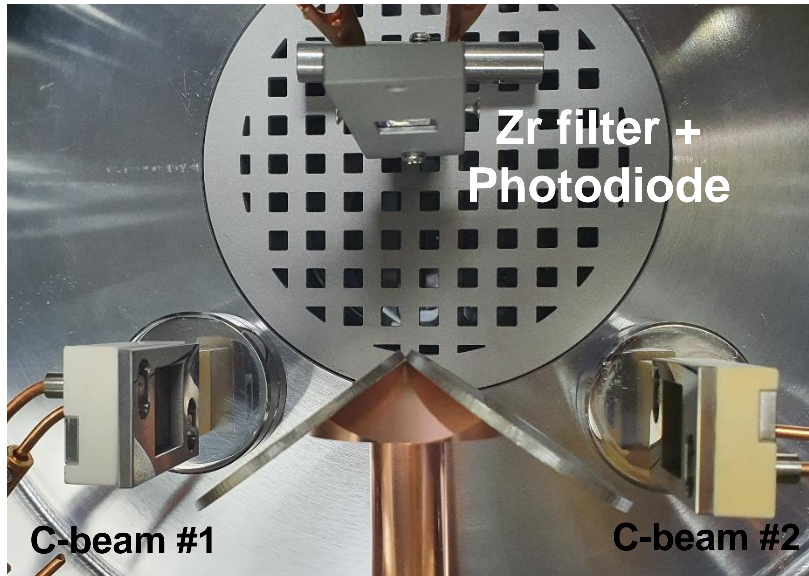
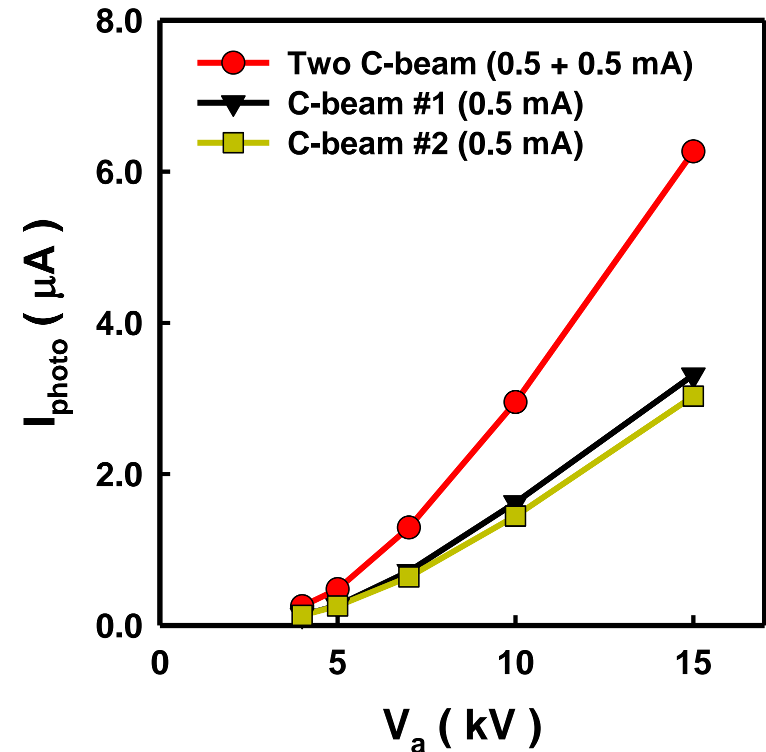


Photo of enhanced EUV lighting



Photodiode response

- Photocurrent is doubled when using two C-beams compared to when using one C-beam.
- EUV intensity is proportional to the number of C-beams.

$$I_{photo} = 2 \times (I_{photo}\ of\ one\ C - beam)$$

Enhanced EUV lighting with C-beam
- The concept of multiple C-beam irradiations

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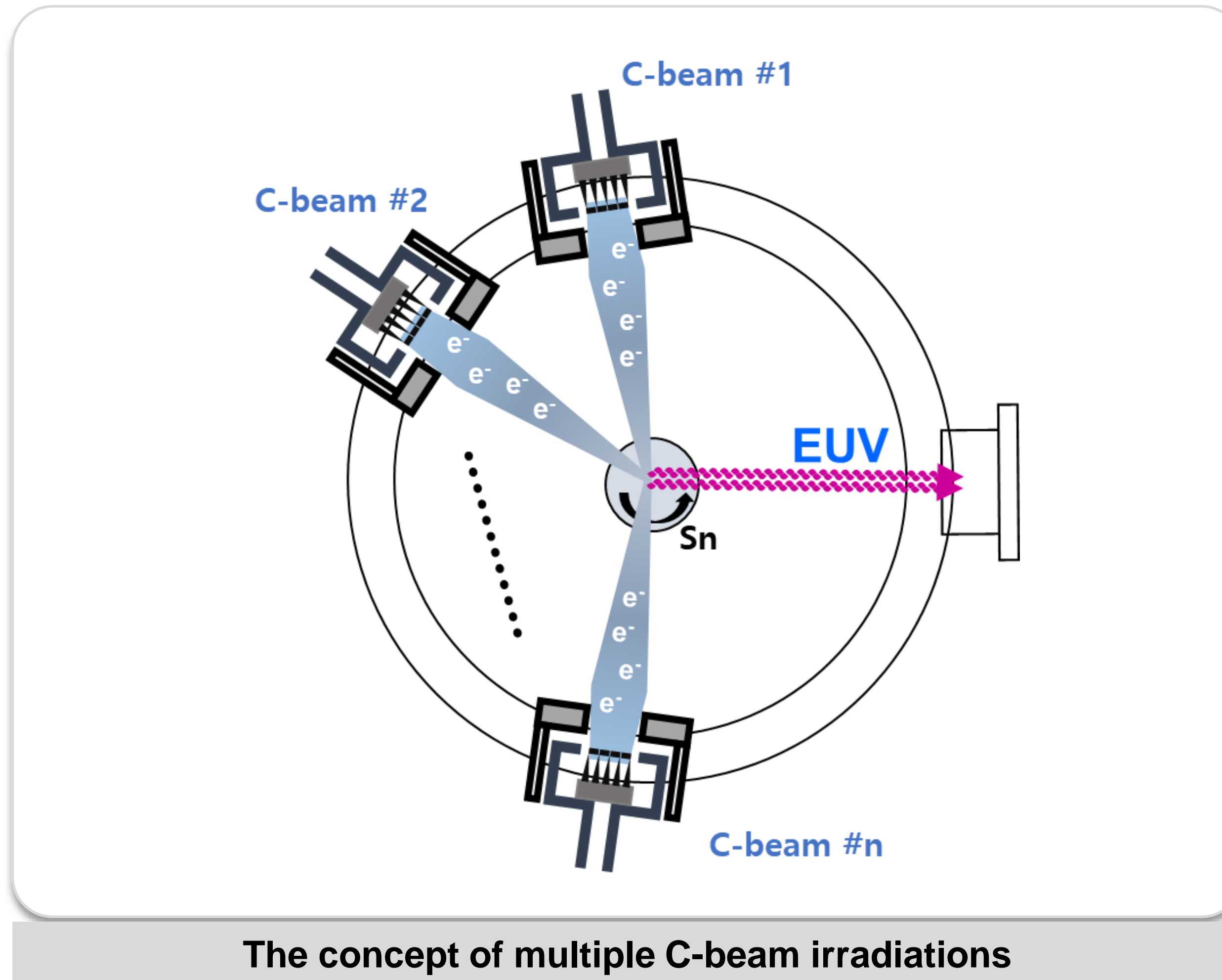

The concept of multiple C-beam irradiations

- **Enhanced EUV lighting can be produced with multiple C-beam irradiations.**

$$I_{photo} = (\#\ of\ C - beams) \times (I_{photo}\ of\ one\ C - beam)$$

Summary

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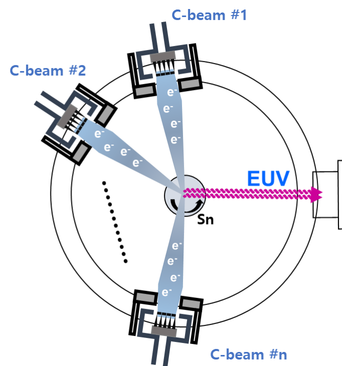
Two C-beam irradiation



The concept of multiple C-beam irradiations

- Lithography with polymethyl methacrylate (PMMA) can be performed using EUV (photocurrent of 4 μA measured with a photodiode) generated by directly irradiating electrons emitted from C-beam to Sn.
- Through two C-beam irradiations, it was confirmed that the EUV intensity is proportional to the number of C-beams.
- Enhanced EUV lighting through multiple C-beam irradiations will be applied to EUV lithography.