



# He irradiation of HEA at HAL

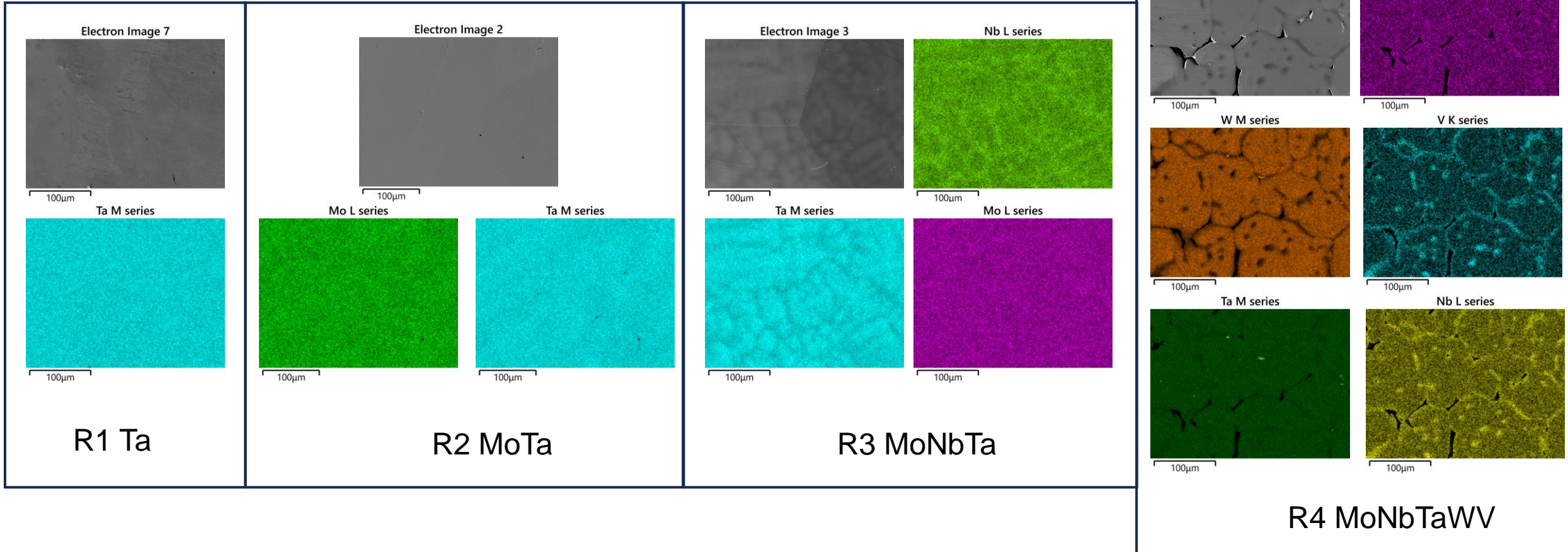
**Zhehao Chen**

13.06.2024



# 1. He in Ta series RHEA

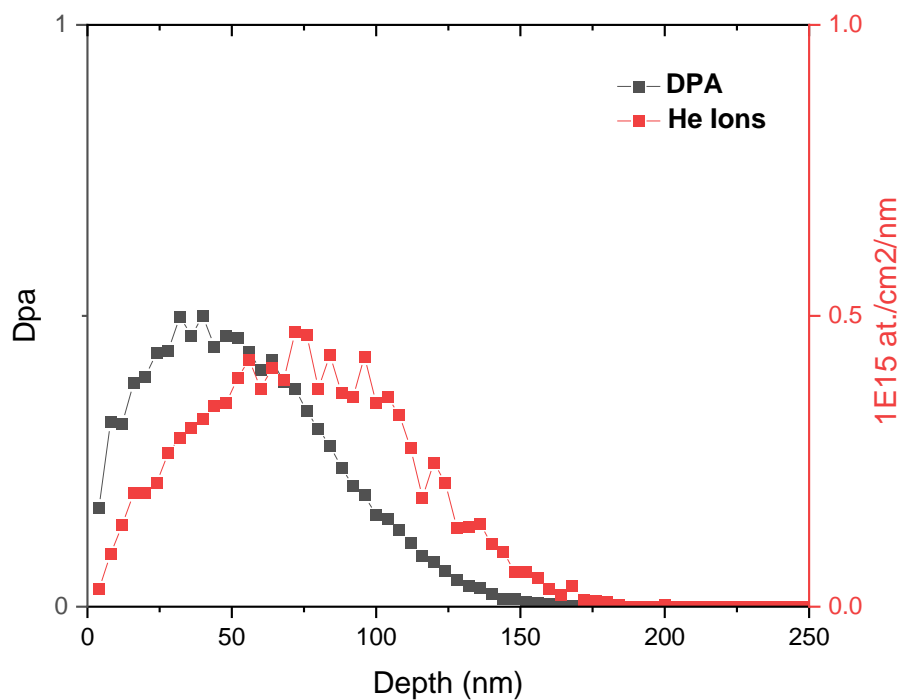
Samples: Arc-melted Ta(R1), MoTa(R2), MoNbTa(R3), MoNbTaWV(R4)



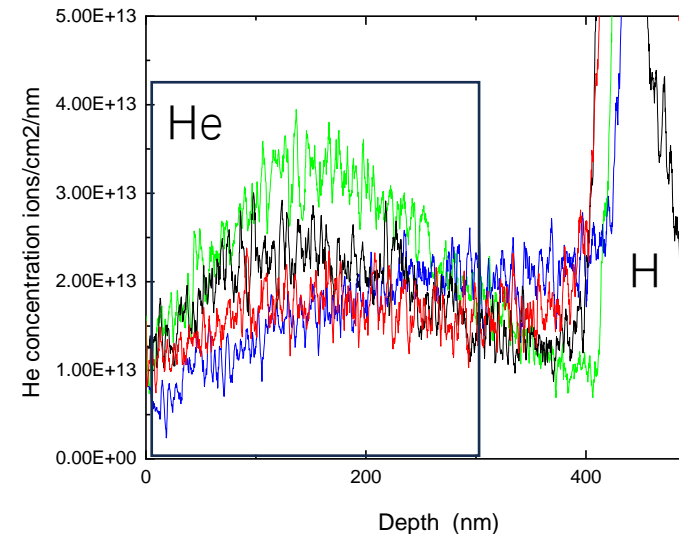
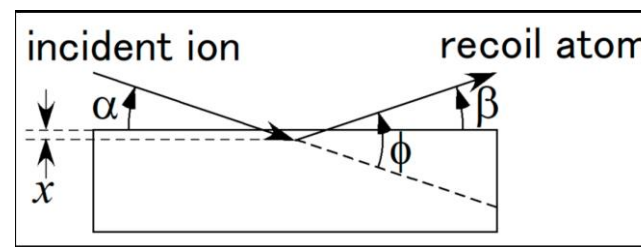
# 1. He in Ta series RHEA

Irradiation:  $5E16$  25 keV He (ions/cm<sup>2</sup>) , room temperature

ERDA and TEM characterization of He concentration after annealing at RT -1473k for 1h



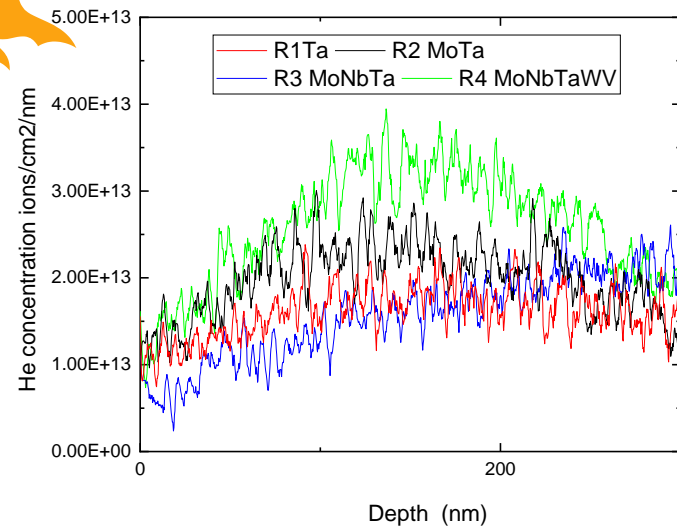
SRIM simulation of 25 keV He in Ta



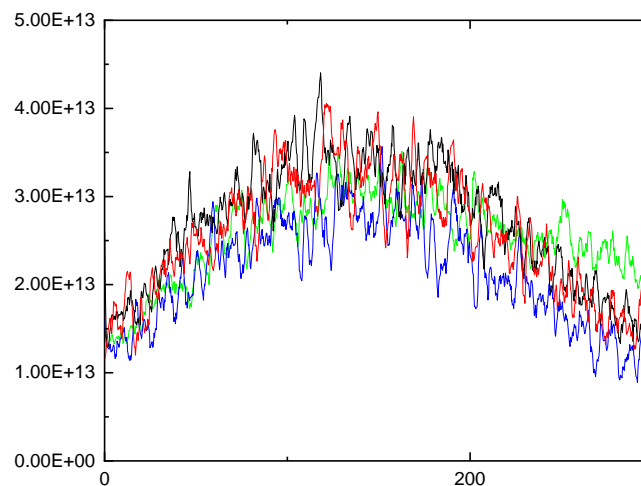
ERDA principle and a example spectrum

# 1. He in Ta series RHEA

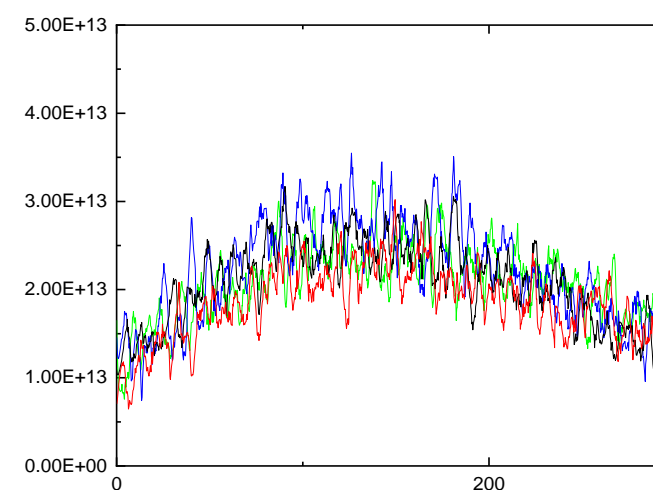
ERDA measurements of helium depth distribution after annealing at RT -1073k for 1h



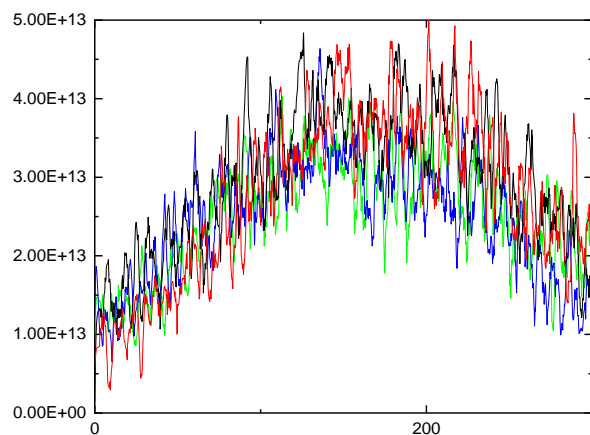
RT



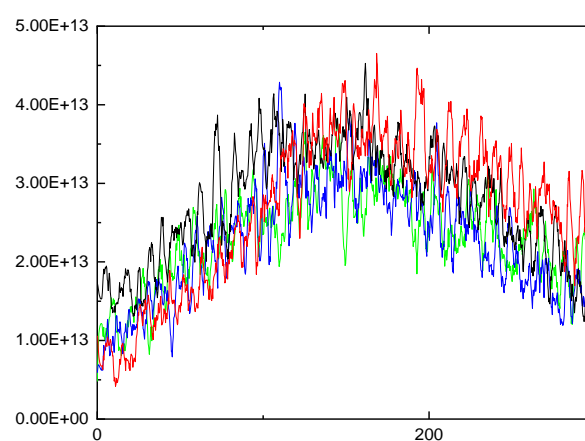
473 K



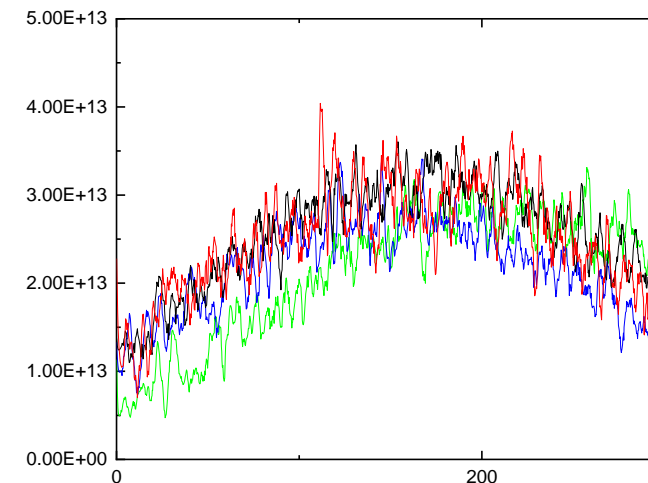
673 K



873 K



1073 K



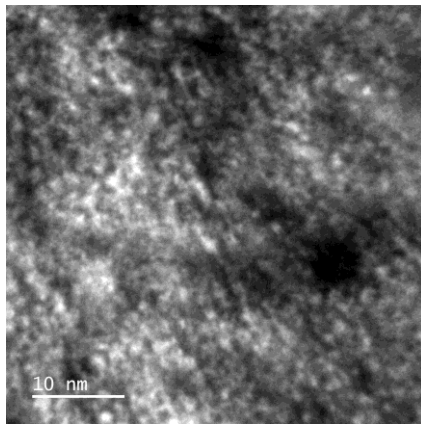
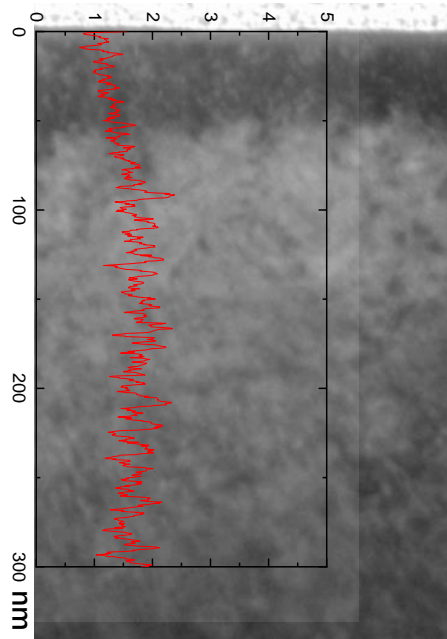
1273 K



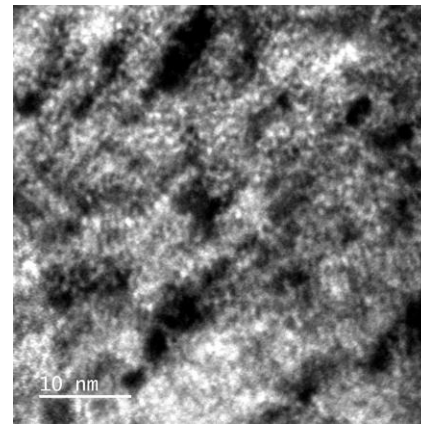
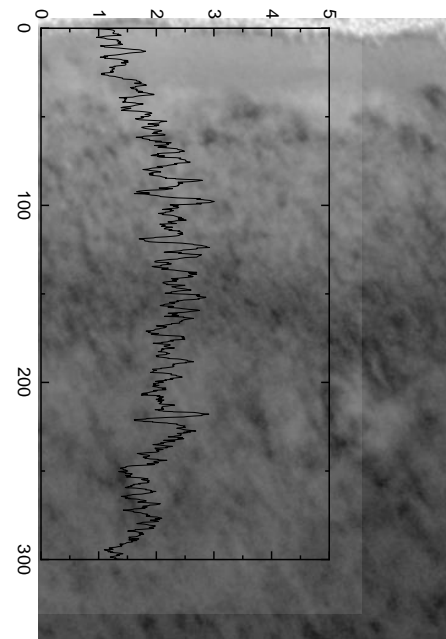
# 1. He in Ta series RHEA



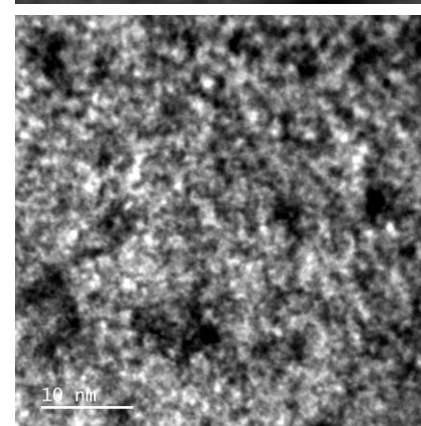
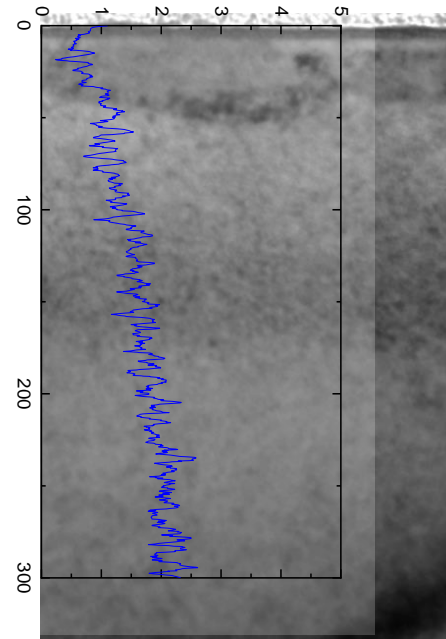
He concentration  $\times 10^{13}$  ions/nm/cm<sup>2</sup>



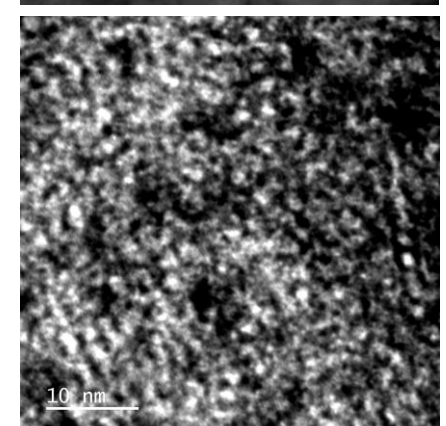
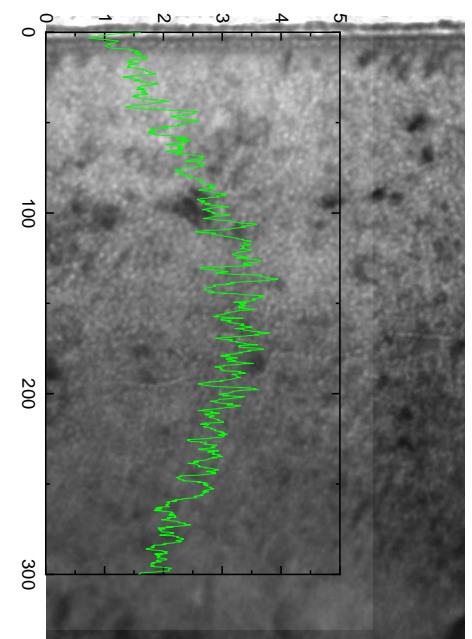
R1 Average size 0.95 nm



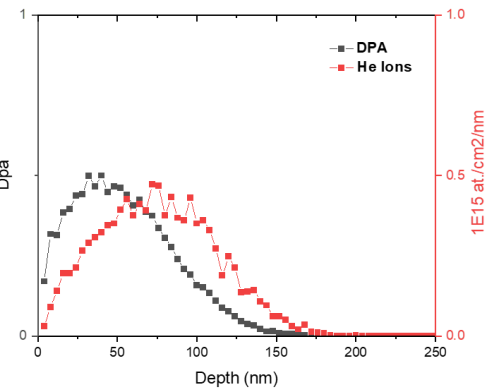
R2 0.92 nm



R3 0.97 nm



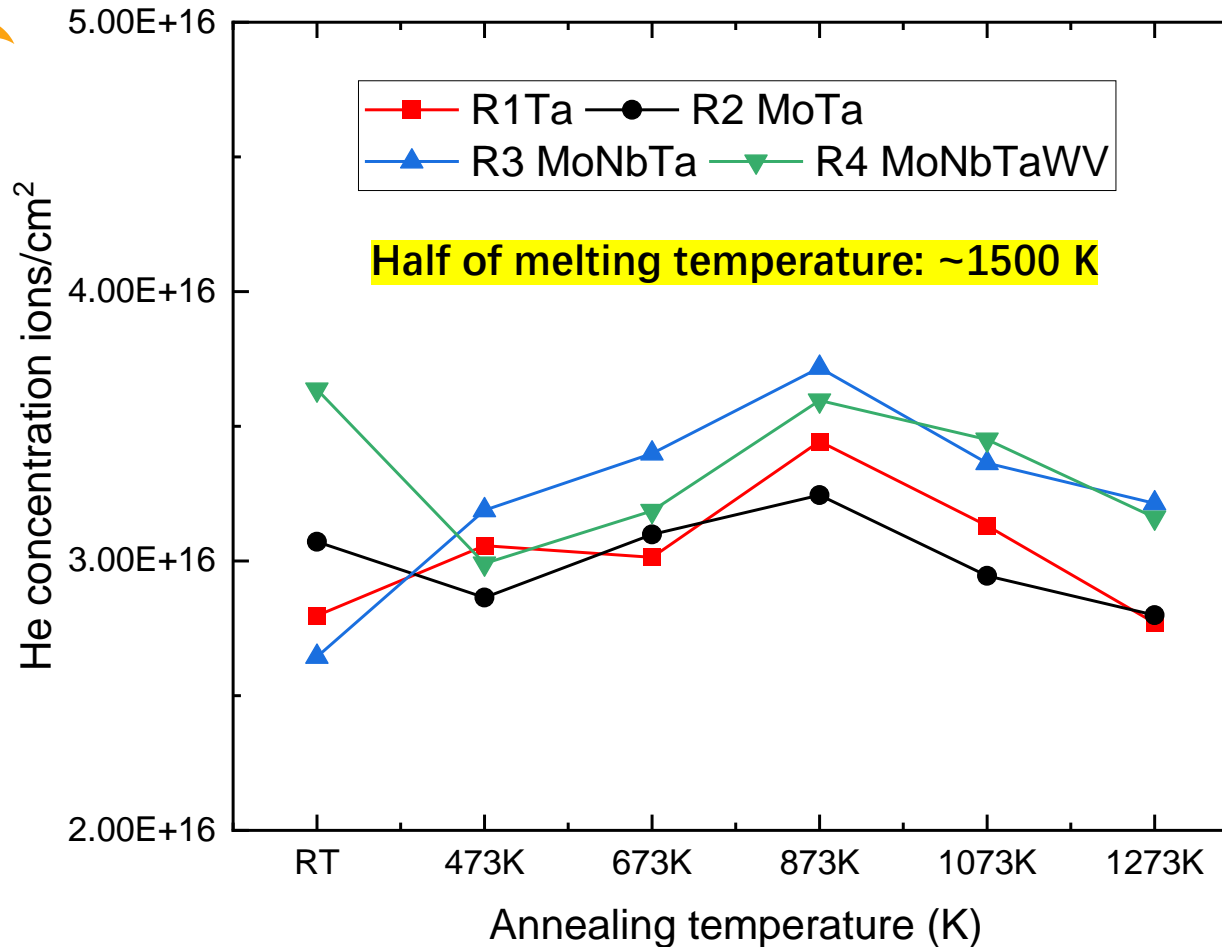
R4 1.16 nm



SRIM simulation of 25 keV He in Ta

TEM BF image of He cavities depth distribution

# 1. He in Ta series RHEA



- MoNbTaWV has a larger helium concentration after RT implantation.
- The helium concentration increases until the temperature reaches 873K, after which it decreases.
- Apparently, R1, R2 have fast decreasing rate than R3, R4. Higher annealing temperatures is needed to observe a clear tendency.

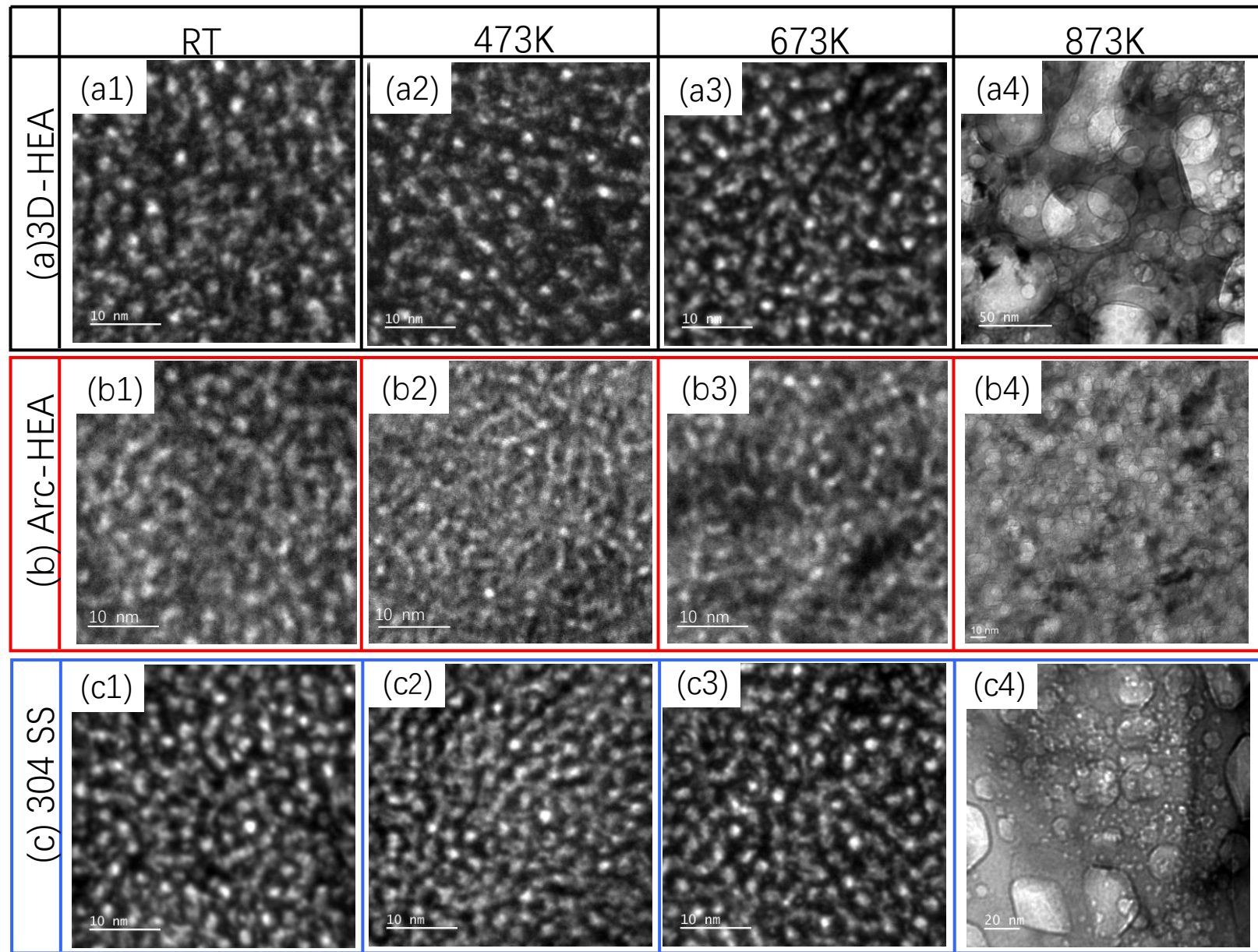
ERDA measurement of total He concentration from 0-300nm depth after annealing

# Discussion: Comparison with FCC HEA



Samples: Arc-melted and 3D printed Cantor HEAs (FeMnCrCoNi), 304 steel as reference. FCC, large crystal (around 100  $\mu\text{m}$ )

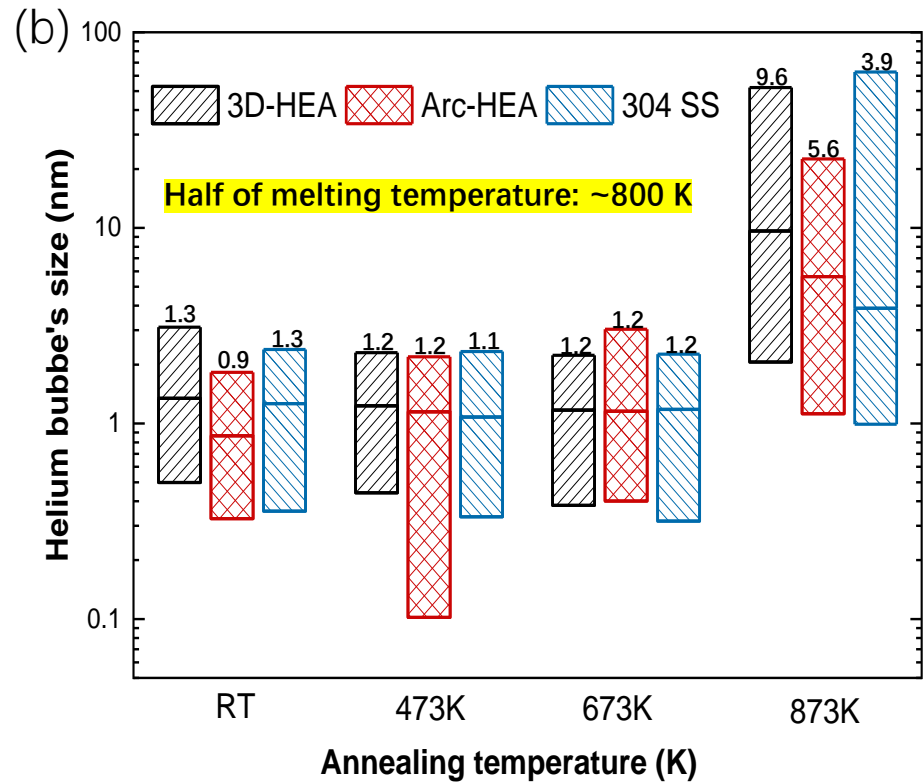
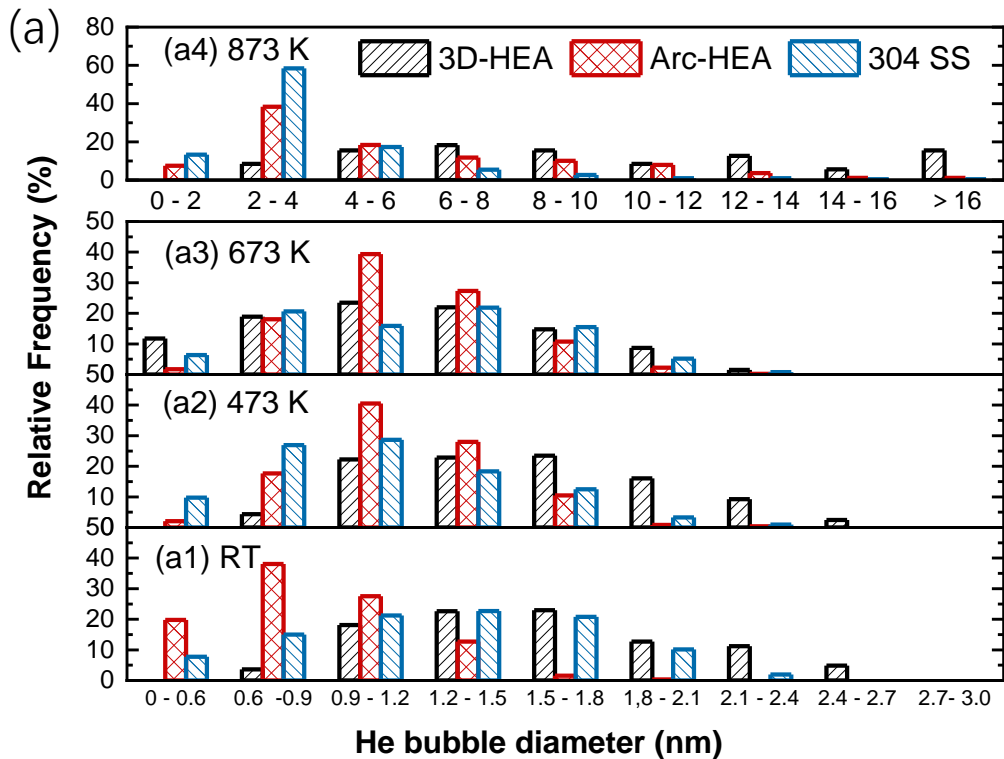
Irradiation:  $1\text{E}16$  3 MeV Ni and  $5\text{E}17$  500 keV He (ions/cm $^2$ ), room temperature



Annealing after irradiation RT – 873 K, 1h



# Discussion: Comparison with FCC HEA

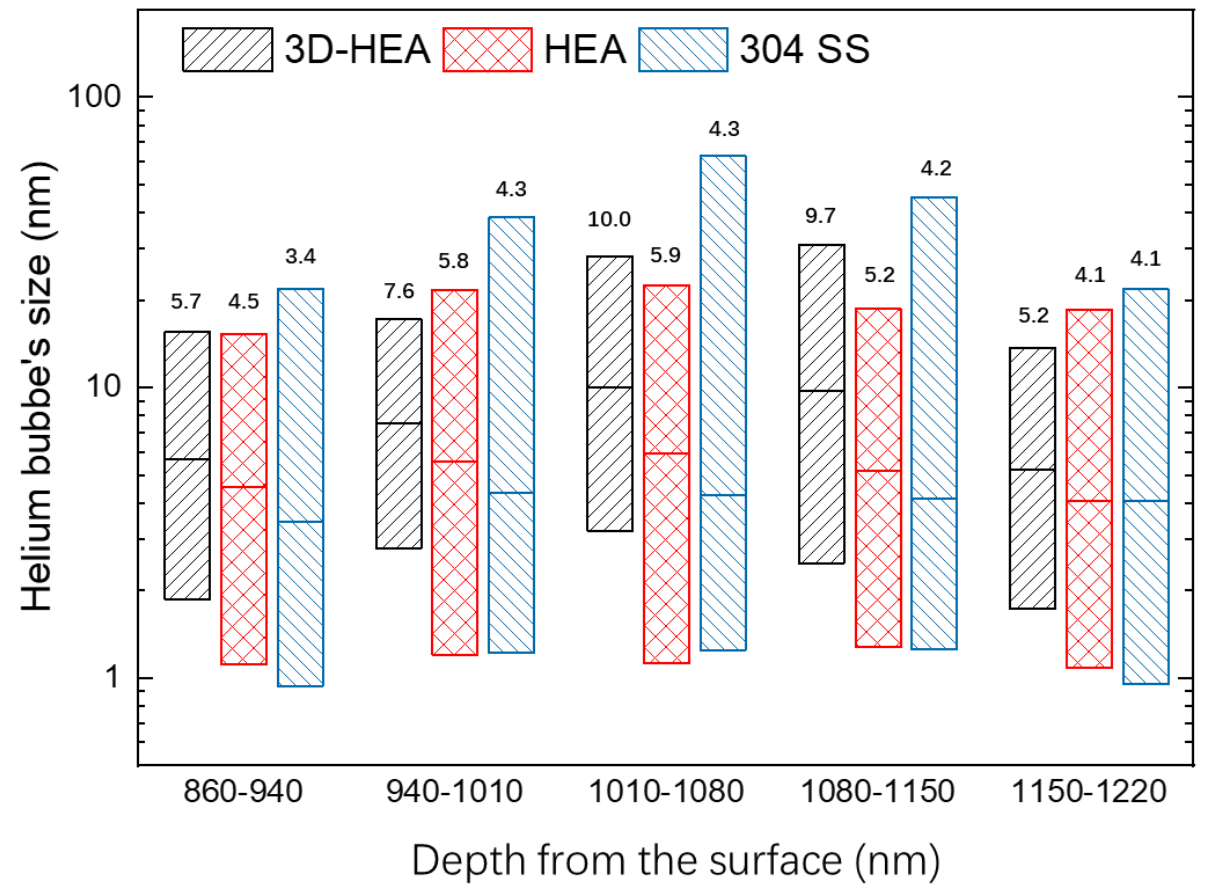
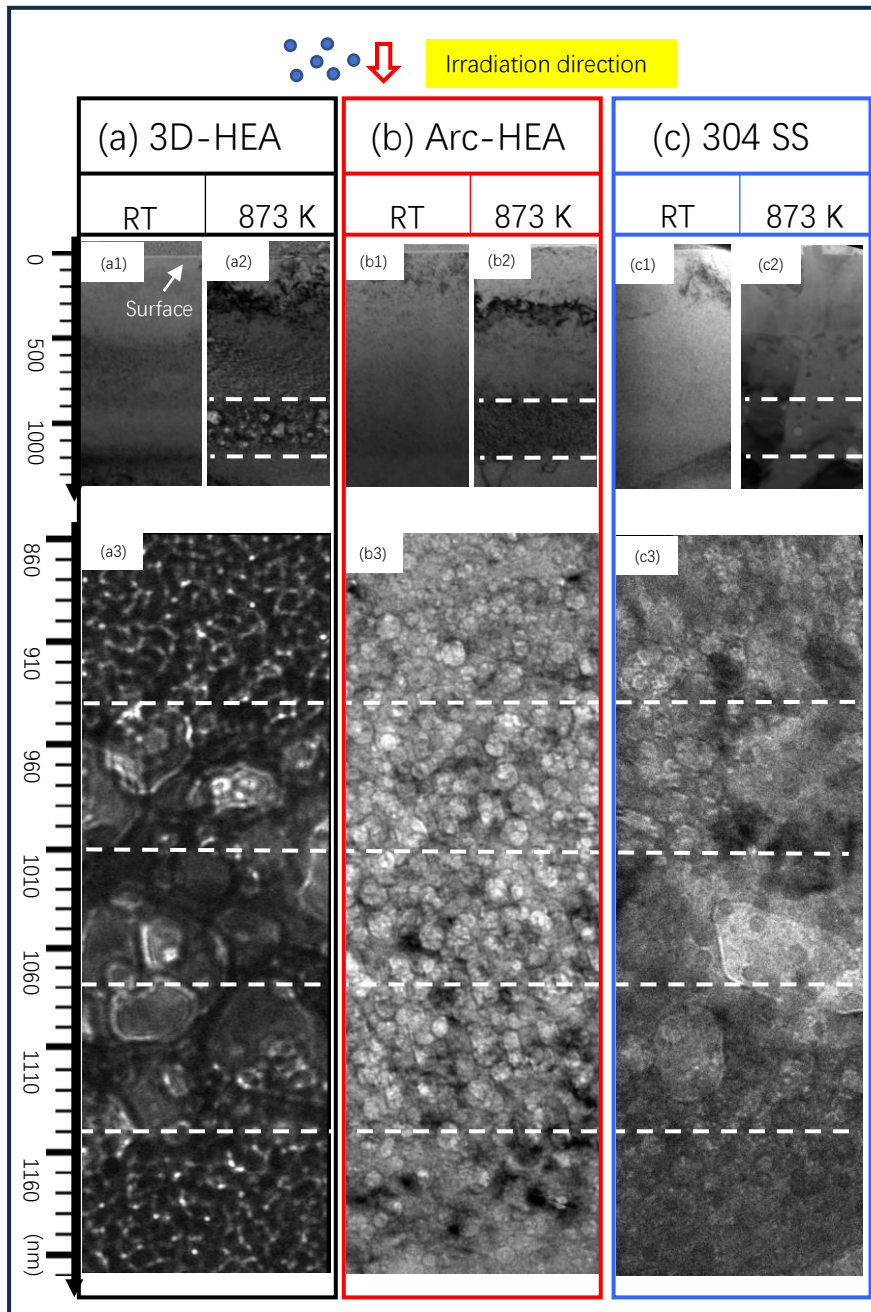


Size distributions (a) and average sizes (b) of He cavities





# Depth profile after 873k annealing



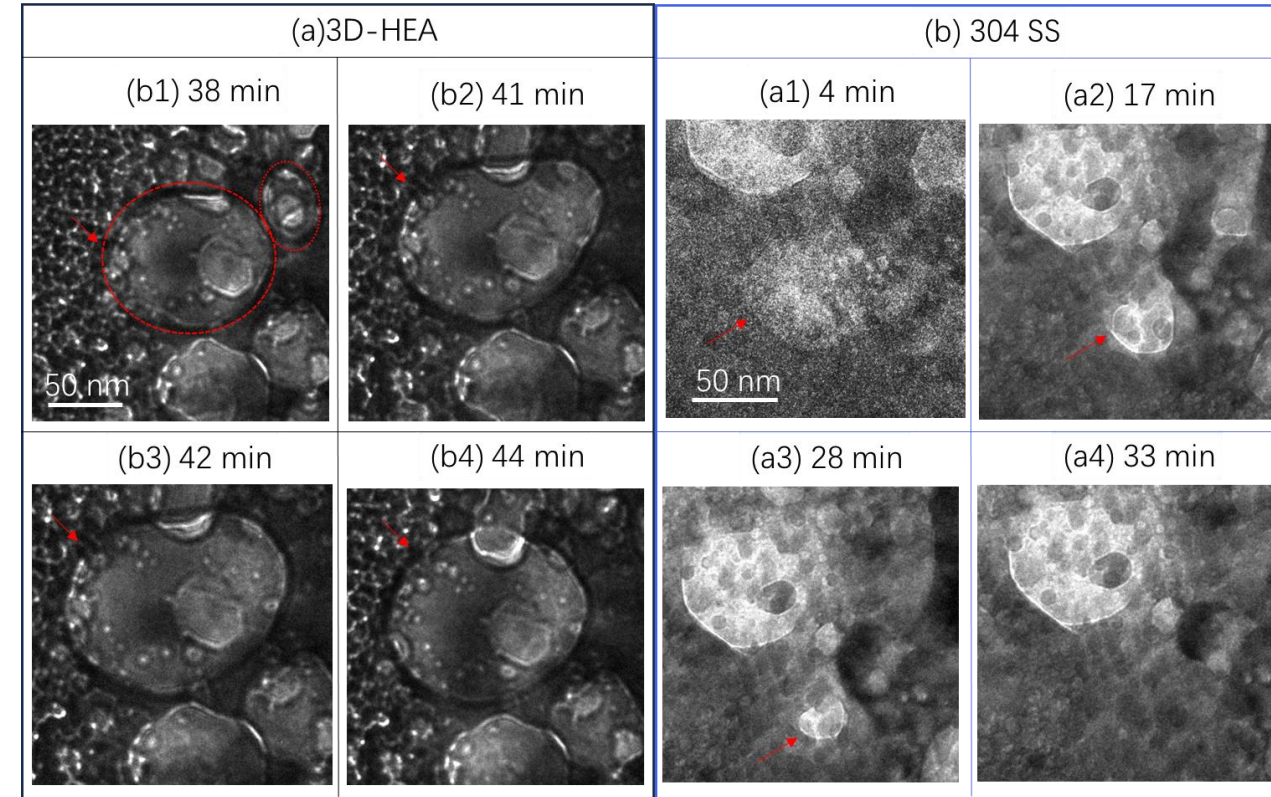
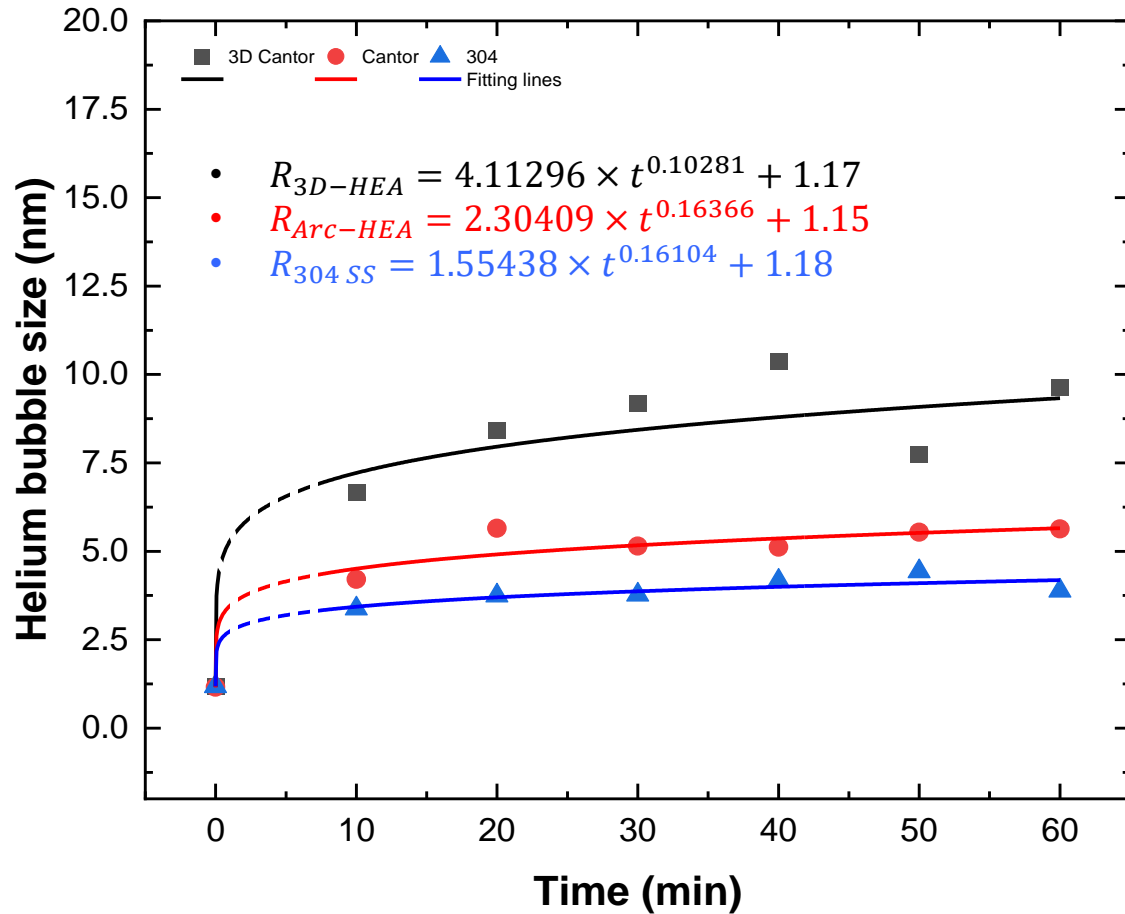
Top: He bubble size distributions and depth profiles in 3D-HEA, Arc-HEA and 304 SS. Each bar shows maximum, average and minimum value, and the average value is indicated on the top.

Left : TEM BF image: 3D-HEA (a), Arc-HEA (b) and 304 SS (c) as-irradiated and after sequential 873K annealing. Each of the damage areas is divided into 5 blocks as show in (a3-c3).



# Discussion: Comparison with FCC HEA

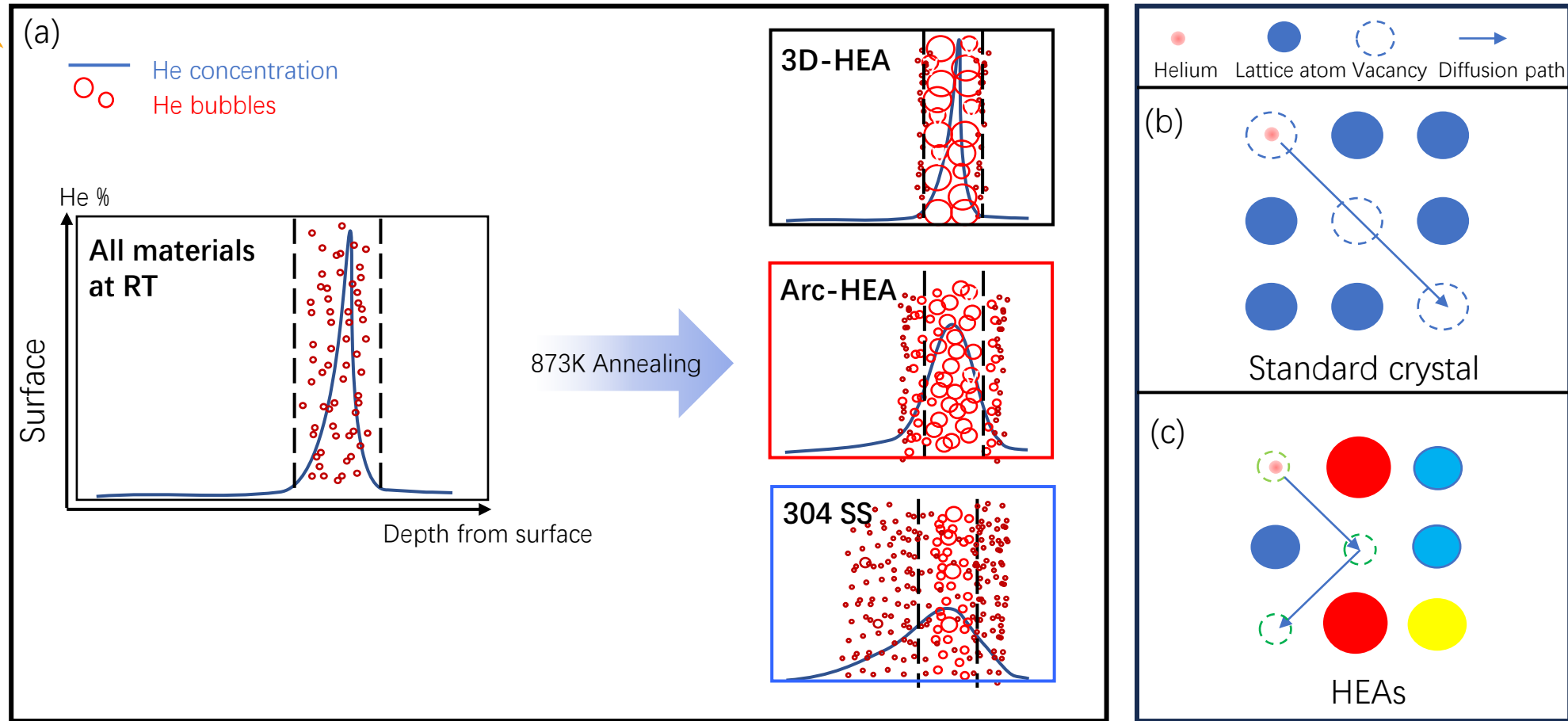
## In-situ TEM and annealing at 873k, 1h



Left: Average He bubbles size as a function of annealing time during in-situ annealing of 3D-HEA, Arc-HEA and 304 SS. The empirical formula from Ref. [1] is fitted to the data for reference.

Right: TEM BF images illustrating two He bubble growth processes: (a) the coalescence process as observed in 3D-HEA, and (b) Ostwald Ripening (OR) as observed in 304 SS

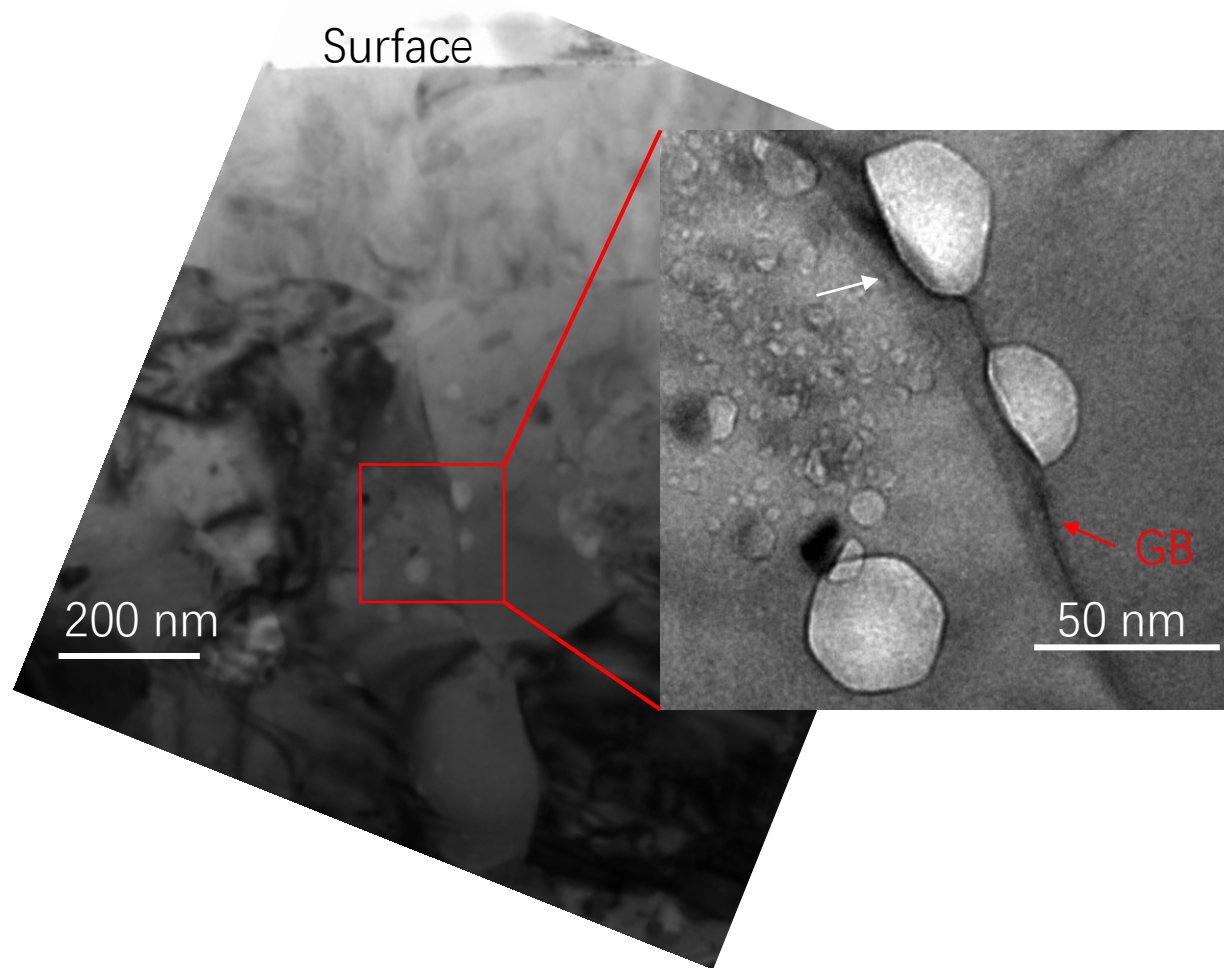
# Discussion: Comparison with FCC HEA



Sketch of He diffusion in FCC HEA

- In inhomogeneous implantation, the size of helium cavities depends on the local helium concentration.
- Sluggish diffusion leads to high local helium concentrations, resulting in larger cavities.
- Sluggish diffusion may be related to **random diffusion paths** in HEA, which is affected by the **diversity of migration energies**

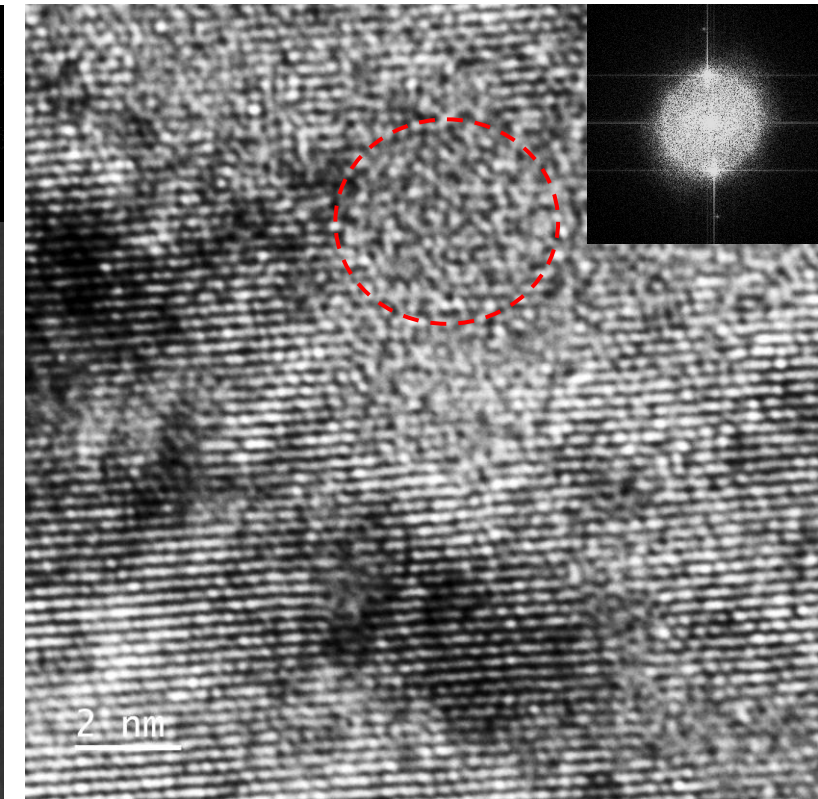
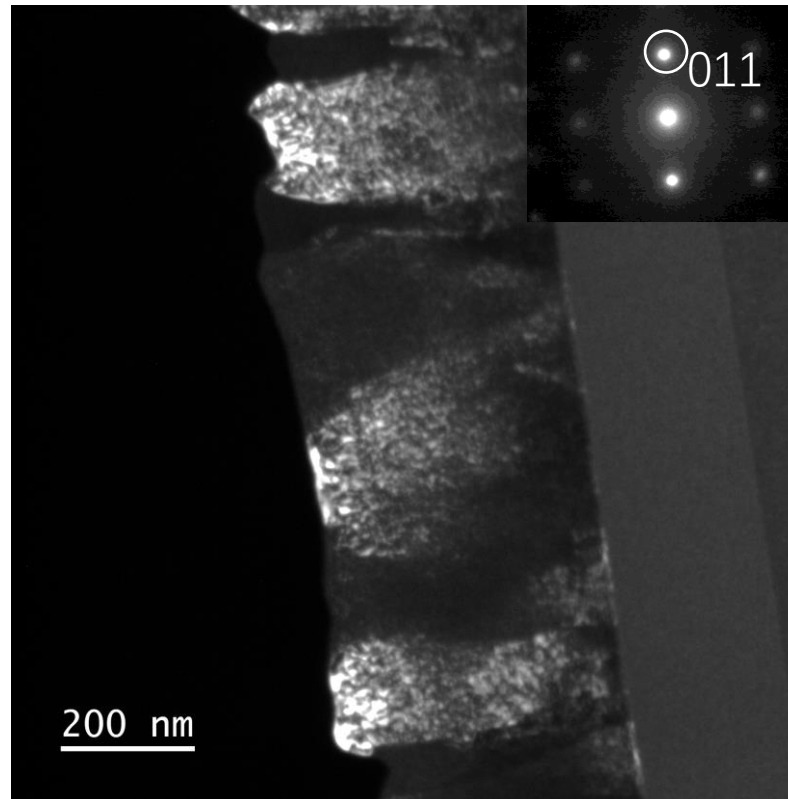
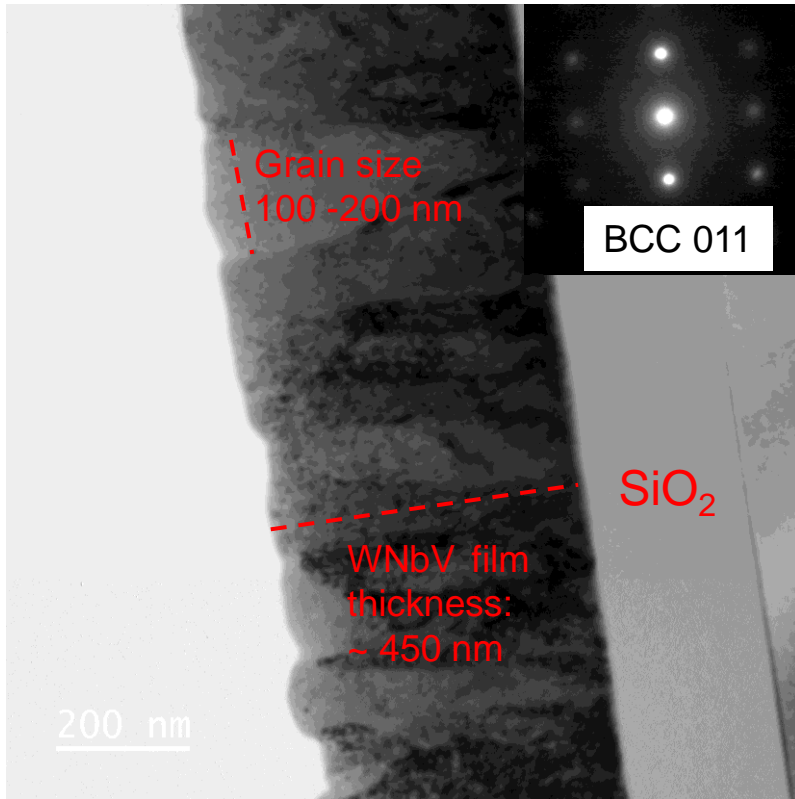
## Discussion: Comparison with FCC HEA



Long-range diffusion lead to helium cavities growing at grain boundary in 304 SS.



## 2. RHEA thin film synthesis: WNbV



Cross-sectional TEM BF image

Cross-sectional TEM DF image

HRTEM image

- The WNbV thin film with a primary BCC matrix was successfully synthesized (by Spyros) using magnetron sputtering.
- It contains many amorphous domains. High-temperature annealing is needed to homogenize the crystal structure and increase the grain size.



Next step:

1. Fixing the high temperature oven!
2. Annealing up to 1600 K and TEM characterization
3. WV thin film samples?

**Thank you for your attention!**