Radiation-induced segregation and precipitation of rhenium in tungsten

Hong-Bo Zhou*, Yu-Hao Li, Guang-Hong Lu

School of Physics, Beihang University, Beijing 100191, China

Tungsten (W) is one of the most promising candidates for plasma facing materials (PFMs) in future fusion reactors. Rhenium (Re) is not only the typical alloying elements but also the main productions of transmutation in W-PFMs. More importantly, Re will aggregate and precipitate in W under high energy radiation, which substantially enhance the radiation hardening and embrittlement, leading to the great concerns for the life-limiting of W-PFMs. So far, the formation mechanism of Re-rich clusters in W remains to be fully elucidated.

We have systemically investigated the synergistic evolution of Re and irradiation defects in W under different temperatures and irradiation doses using object Kinetic Monte Carlo method. Our results revealed the underlying mechanism for the transition of Re effect on W from beneficial to harmful during the Re-defects evolution with the increasing of irradiation dose[1-3], in which temperature always plays a critical role. On the one hand, Re will significantly promote the defect annihilation at low irradiation dose and high temperature, thereby effectively reducing their sizes and number densities. This is due to the formation of stable Re-SIAs complexes that can be eliminated by the mobile vacancy-type defects, whereas the transition of the migration pattern of SIAs only plays a weak role on the defect recombination in W-Re system. On the other hand, with the increasing of irradiation dose, Re will aggregate to form Re-rich clusters or even precipitates. Interestingly, the formation mechanism of Re-rich clusters is also dependent on temperature[2]. At low temperatures, the interstitial-mediated mechanism plays a crucial role in the Re-rich cluster formation[4,5], while at high temperatures, both SIA-type and vacancy-type defects will act as the transport carriers of Re to promote their clustering. Accordingly, the critical conditions for the transition of Re from beneficial to harmful and the formation of Re-rich clusters at different temperatures and irradiation doses are given with the help of the phase diagram. Our work presents the temperature dependence of the synergy of Re and irradiation defects in W in fusion-relevant environment, which provides a good reference for the development of radiation-resistant materials and the prediction of W performance in fusion reactors.

References

1. Li, Y. H.; Zhou, H. B.; Lu; G. H.; *et al*. *Acta Materialia* **2019**, *181*, 110-123.
2. Li, Y. H.; Yue, F. Y.; Zhou, H. B.; *et al*. *Journal of Materials Science & Technology* **2023**,*145*, 221-234
3. Yang, T. R.; Li, Y. H.; Zhou, H. B.; *et al*. *Scripta Materialia* **2023**, *235*, 115624
4. Li, Y. H.; Zhou, H. B.; Lu; G. H.; *et al*. *Nuclear Fusion*, **2017**, *57*, 046006.
5. Zhang, B.; Li, Y. H.; Zhou, H. B.; *et al*. *Journal of Nuclear Materials* **2020**, *528*, 151867.