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Effects of Alloying Elements on Thermal Desorption of Helium in Ni Alloys

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Background

- With the development of spallation target technology, interest in the behavior of helium in solids has increased

Damage and He production in 316 steel

	Irr. environment	Damage (dpa/y)	He (appm/y)
	Fusion neutrons	32.1	465
HFIR	Fission neutrons	36	2187
EBR-II	Fission neutrons	39.2	15.1
	SNS SB*	34	3000

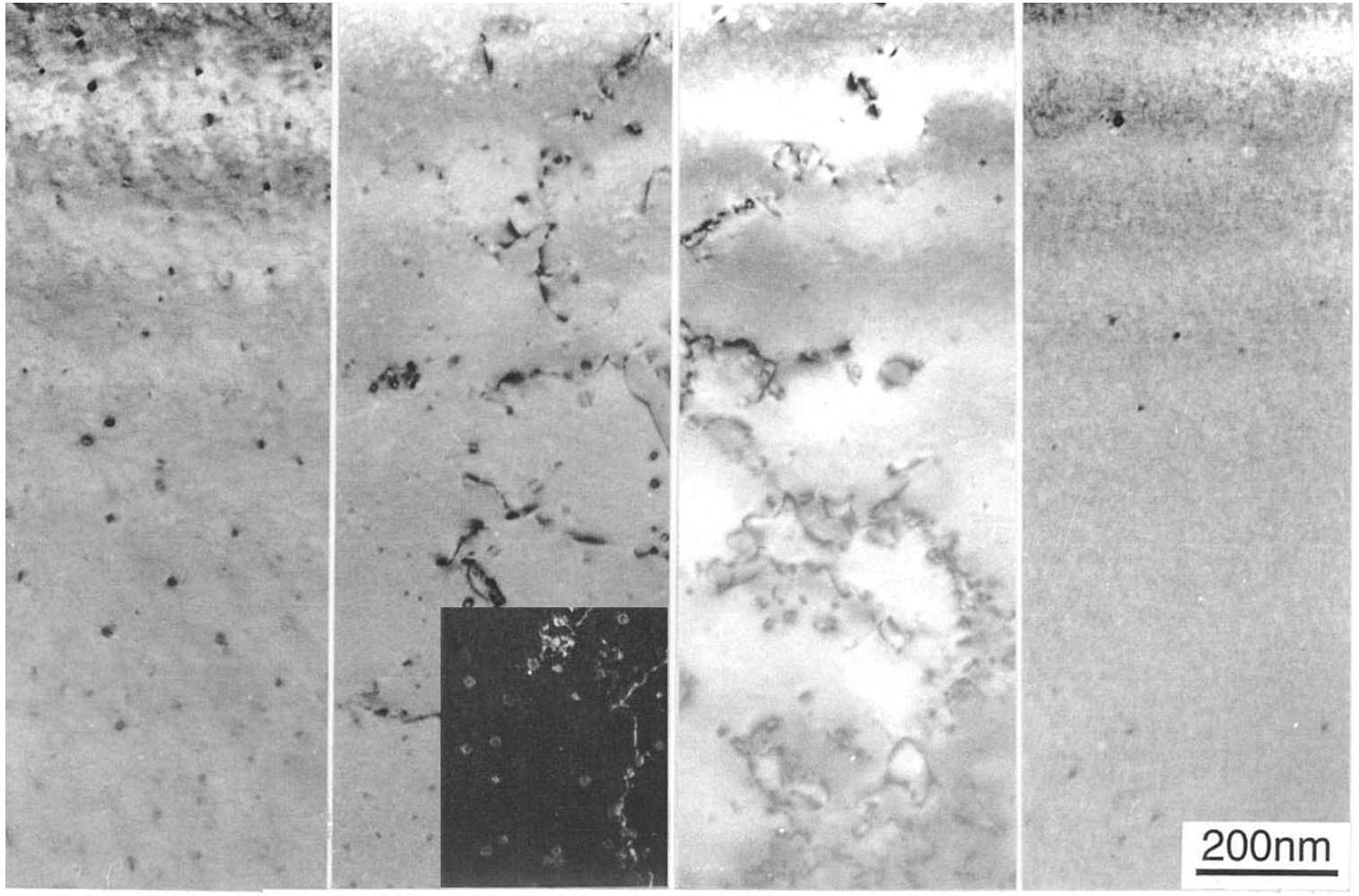
*:*JNM 377 (2008) 275*

✓ Promotion of dislocation loop
✓ Promotion of void swelling
✓ degradation of ductility and thermal conductivity

Object: find materials with low helium retention and/or better resistance to He bubble formation

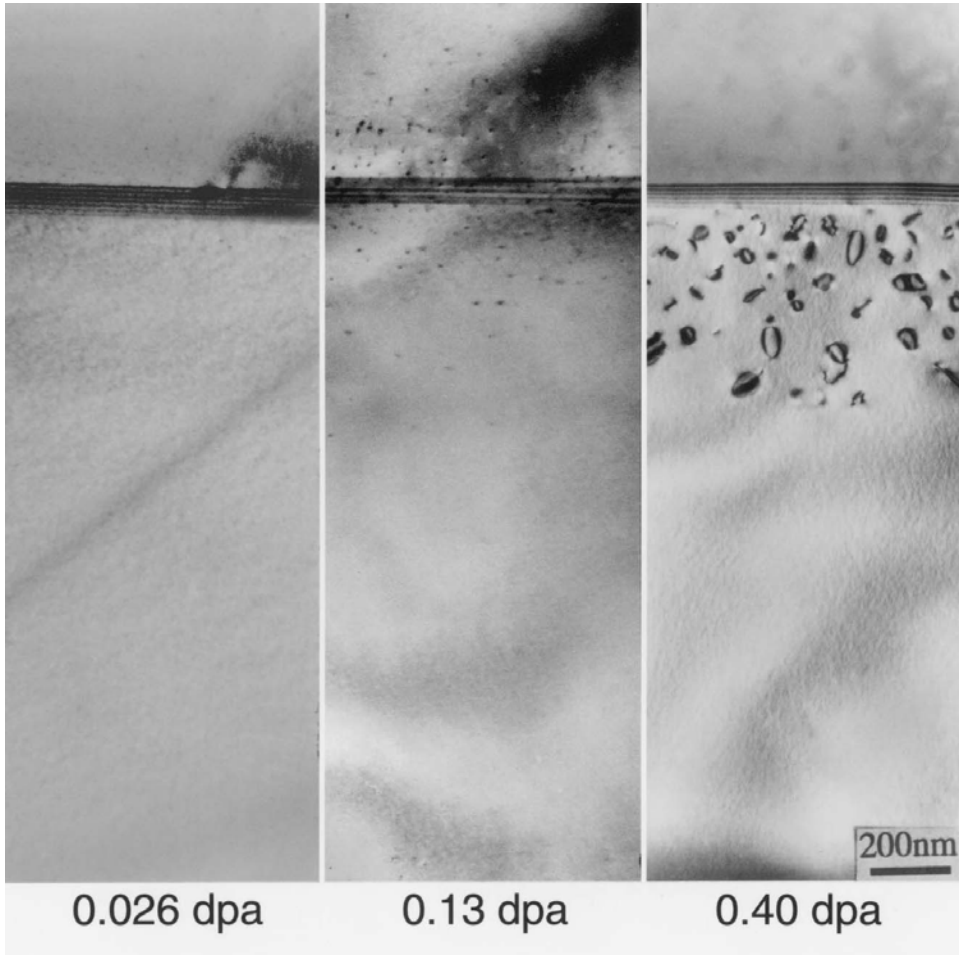
Effect of Alloying Elements on Void Formation in Ni

Neutron irradiation to 0.11dpa at 573K



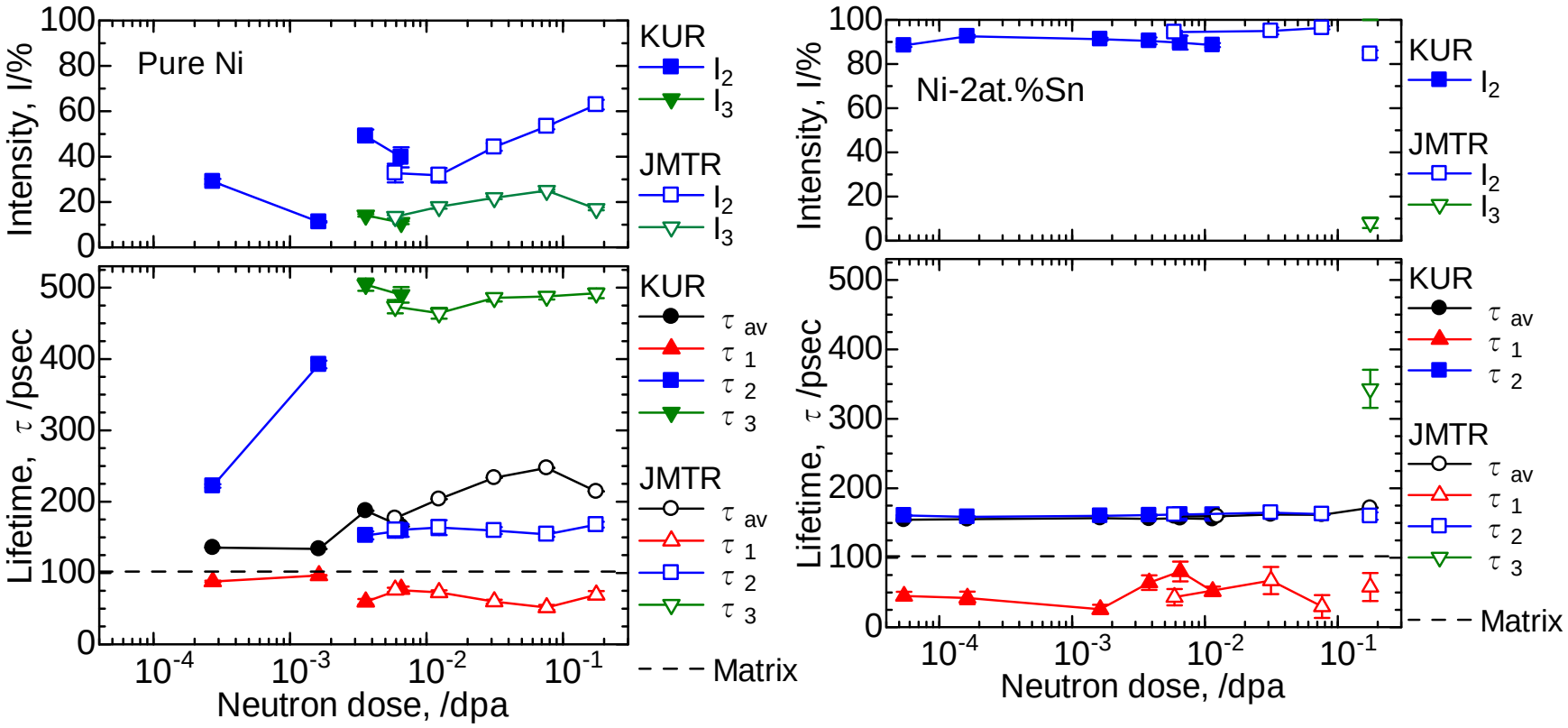
Ni-2at%Si	Ni	Ni-2at%Ge	Ni-2at%Sn
−5.81%		+14.76%	+74.08%

Dose dependence of microstructures in Ni-2Sn



Fission neutron irradiated Ni-2at%Sn at 573K

Positron Lifetime in Neutron Irradiated Ni and Ni-2Sn Alloys



Lifetime of 1V ~180 ps

Mechanism of Suppression Void Formation in Ni-Si and Ni-Sn Alloys

Ni-Si alloy

Interstitials will be trapped by undersized element Si easily. With increasing dose, a large amount of trapped interstitials and their clusters will be formed. They work as an effective site for the annihilation of freely migrating vacancies, and suppress the growth of microvoids .

Ni-Sn alloy

Largely oversized element Sn may trap interstitials and vacancies. As a result, the formation of interstitial-type dislocation loops and voids is suppressed due to the recombination of interstitials and vacancies at defect sinks of Sn.

Experimental Procedure

Materials：Ni、Ni-2Si、Ni-2Sn

Irradiation： Well annealed specimens were irradiated with 5 keV He^+ ions using a gun, in which mono-energetic He^+ ions were collimated and mass-analyzed ($5x10^{19}/m^2$)。

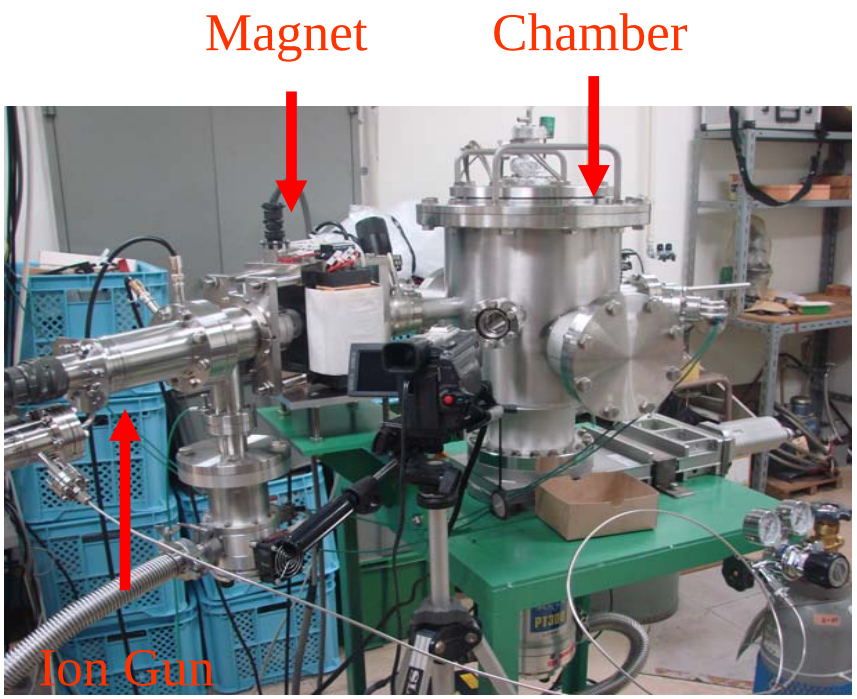
Temperature：723K

Post Irradiation Experiments：

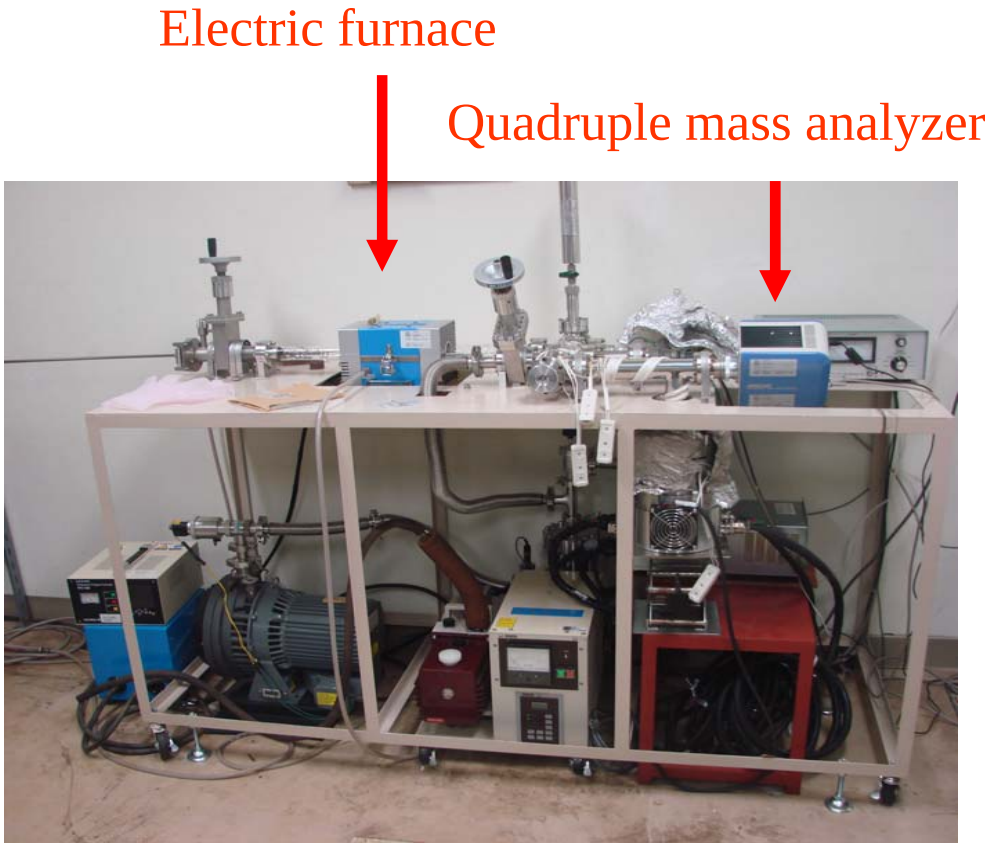
- helium thermal desorption ：thermal desorption spectroscopy (TDS) analysis
  Temperature：RT~1523K
  Ramping rate of the temperature ：1K/s

- TEM observation

Ion Injector with Low Energy and TDS



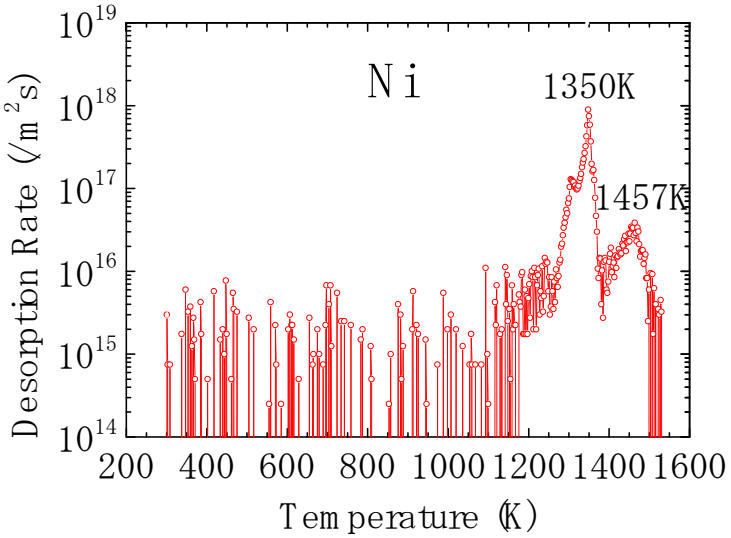
Ion Injector

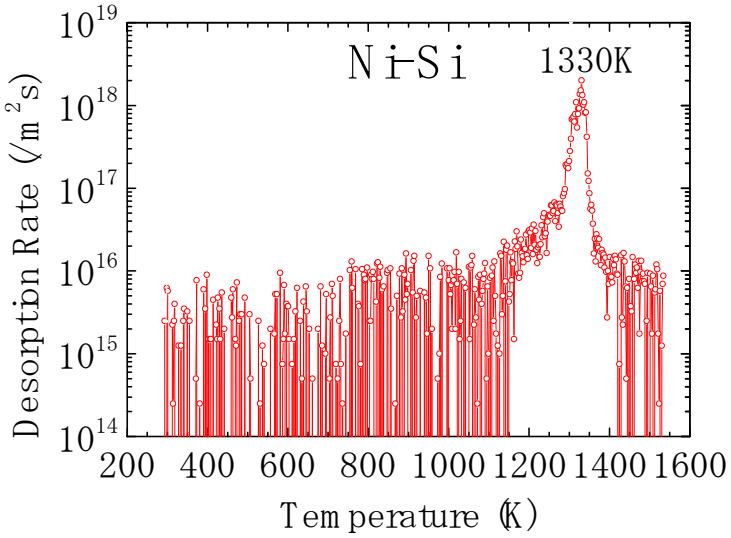


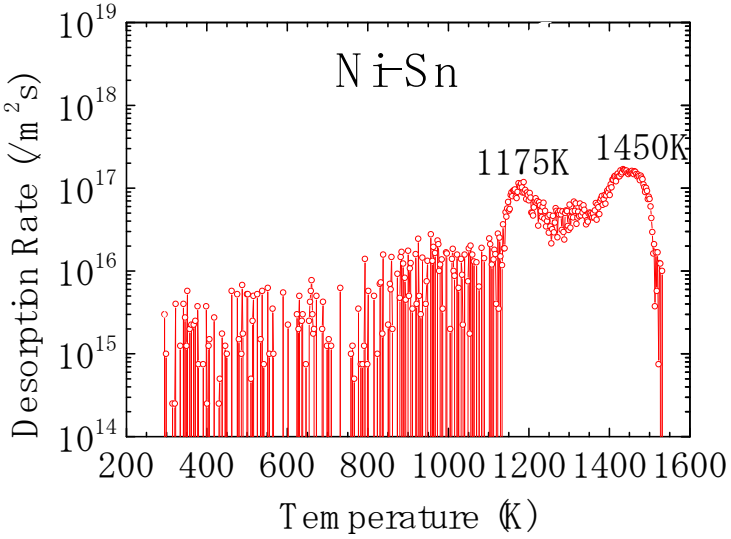
TDS

He Thermal Desorption in Ni, Ni-Si and Ni-Sn

irradiated by 5 keV He^+ ions to 5.0×10^{19} He^+/m^2 at 723 K

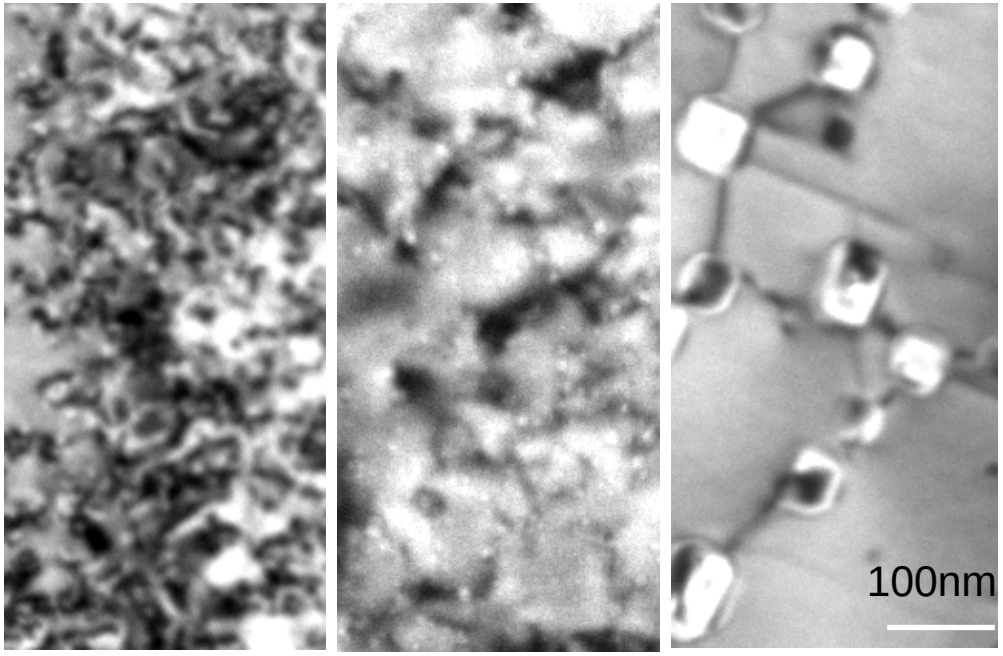






- He thermal desorption depends on alloying elements.

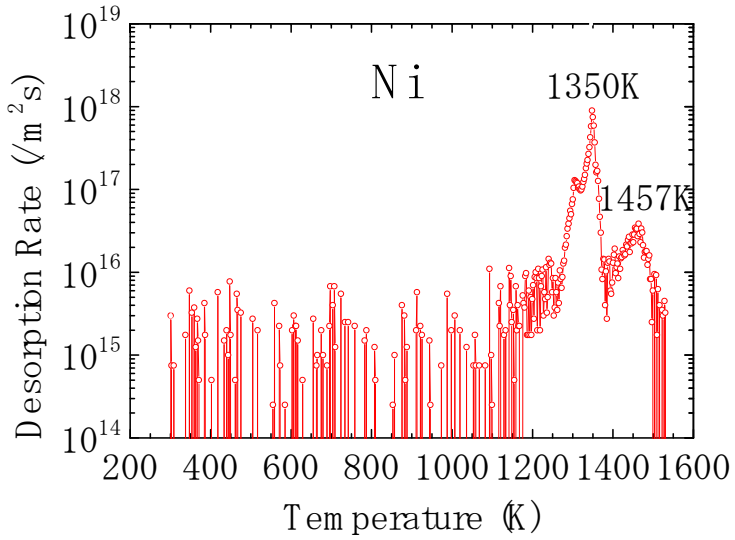
Microstructures in Helium Irradiated Ni



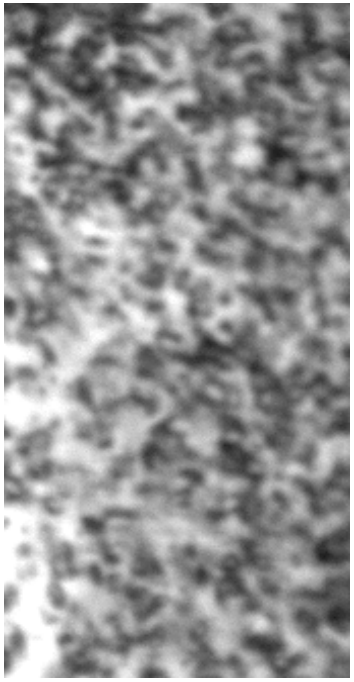
Irr. at 723K

Anneal at 1223K for 5 min

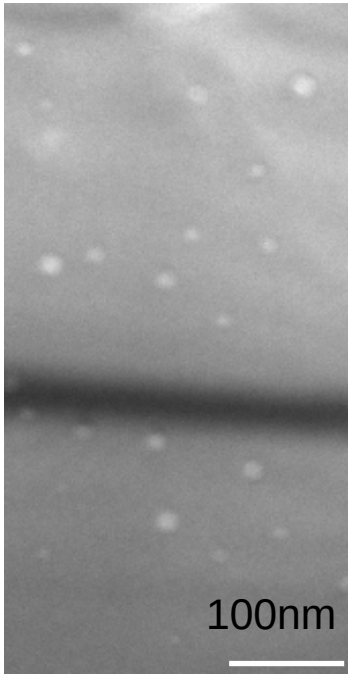
Subsequent annealing at 1373 K for 5 min



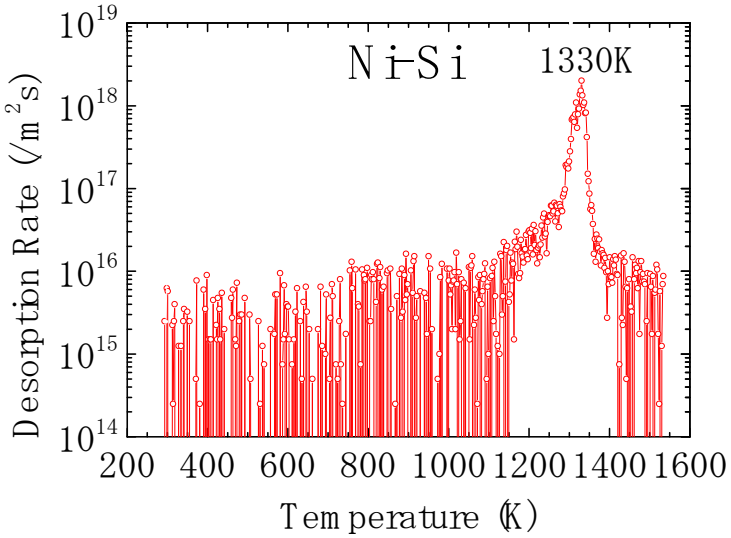
Microstructures in Helium Irradiated Ni-Si



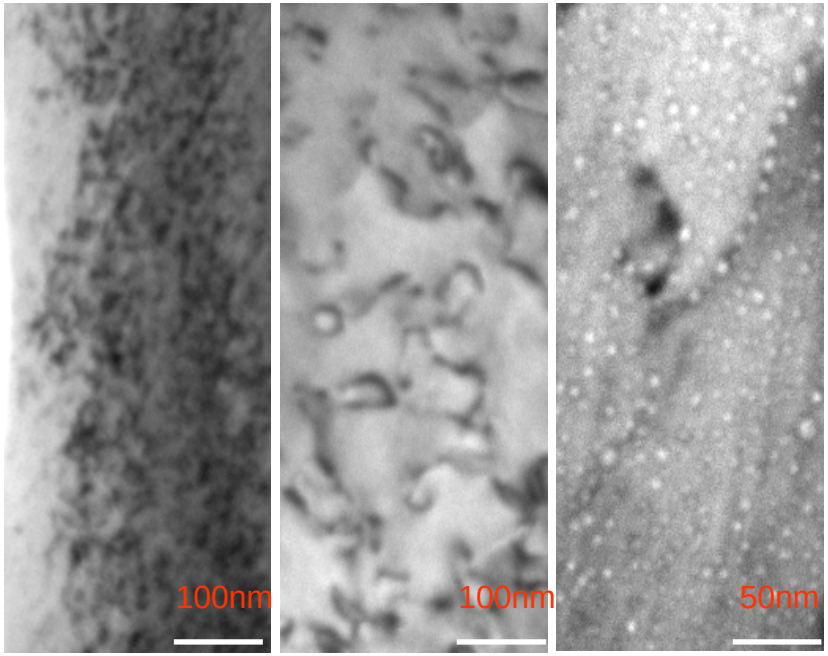
Irr. at 723K



Anneal at 1243K
for 5 min



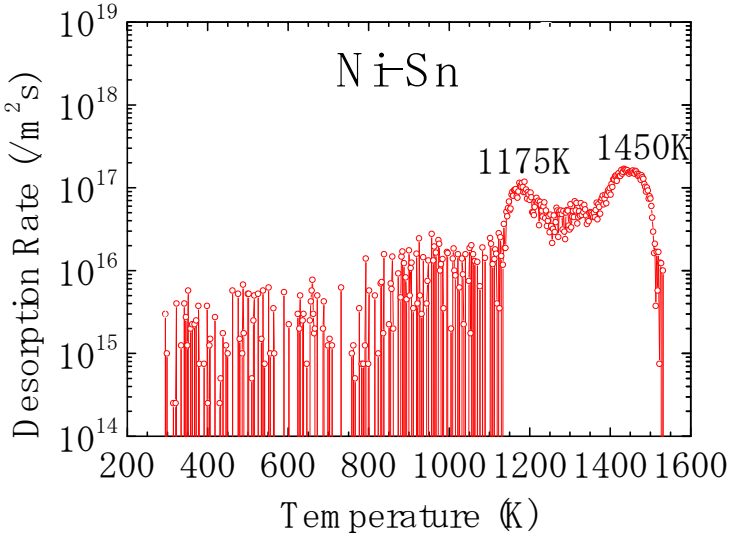
Microstructures in Helium Irradiated Ni-Sn



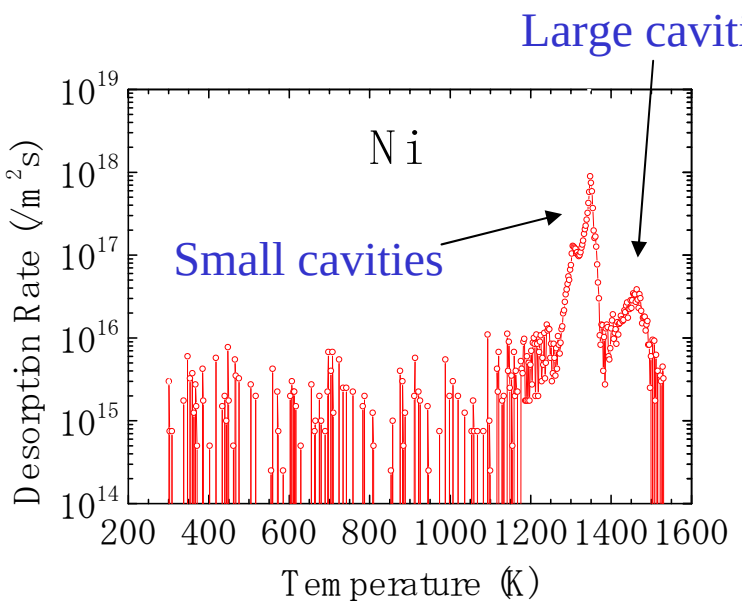
Irr. at 723K

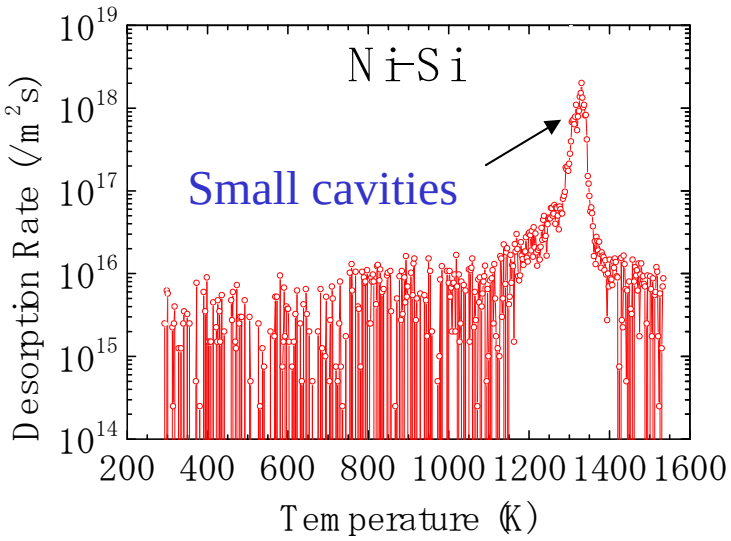
Anneal at 1103K for 5 min

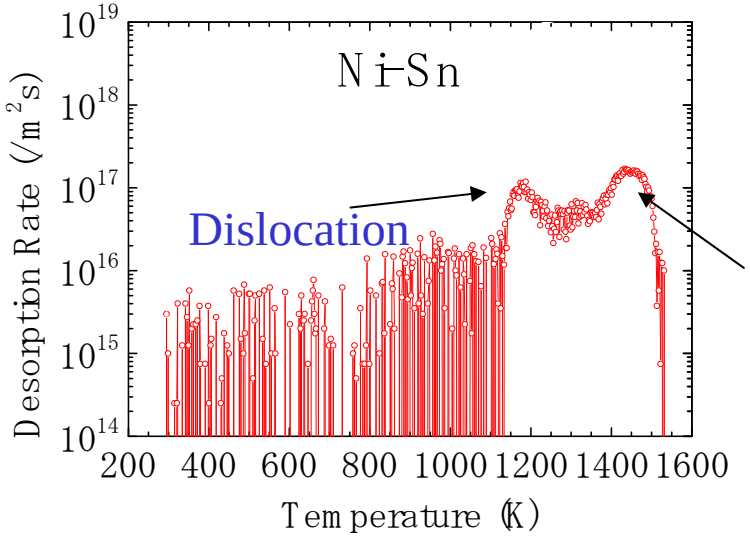
Subsequent annealing at 1323 K for 5 min



He Trapping Sites for Ni and Ni Alloys







Growth of cavities was suppressed in Ni-Si and Ni Sn alloys.

Conclusions

To investigate the effects of alloying elements Si and Sn on helium retension in Ni and its binary alloys, Ni, Ni-Si and Ni-Sn were irradiated by 5 keV-He ions at 723 K.

- The helium trapping sites were cavities in Ni and Ni-Si alloy, and both dislocations and cavities in Ni-Sn alloy.
- Compared with nucleation and growth of cavities in Ni, the addition of an Si or Sn alloying element suppressed the nucleation and growth of cavities.