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Dislocation channel formation process in neutron irradiated vanadium alloys using confocal laser microscopy

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Experimental Procedure

Specimens

V-(3-5)Cr-(3-5)Ti : HFIR-11J （ 300ºC, 5dpa)

Procedure

Tensile tests

Test Temperature : RT, Strain rate ： 3.33×10^{-4}/s(0.1mm/min)

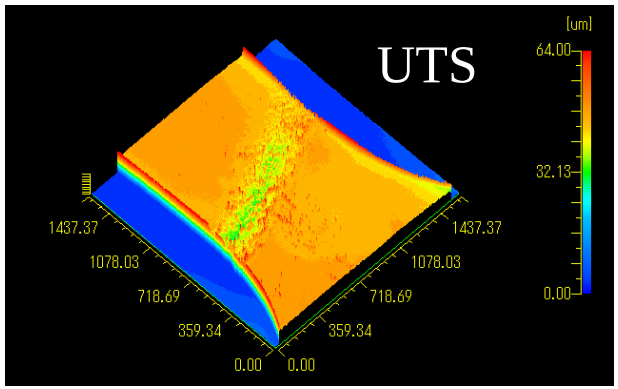
SEM equipped with a tensile-testing machine

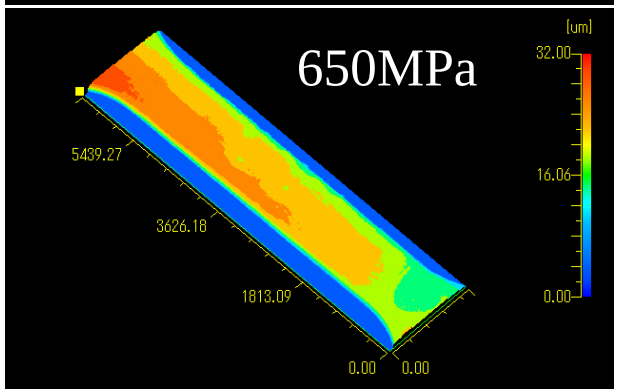
Cofocal laser microscope HD-100D （ Lasertec Co.Ltd ）

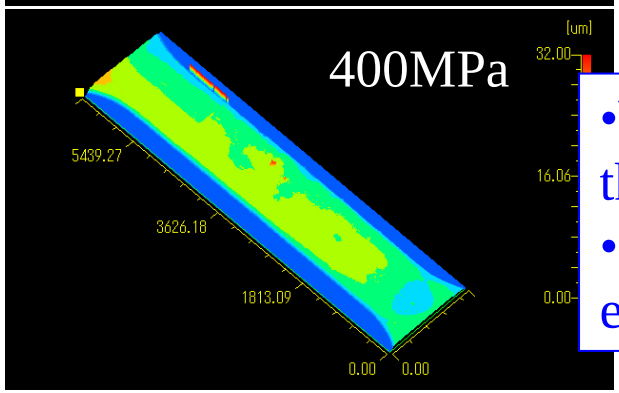
Reaching UTS, released to the lord to zero.
Processing the deformed area to a TEM sample.

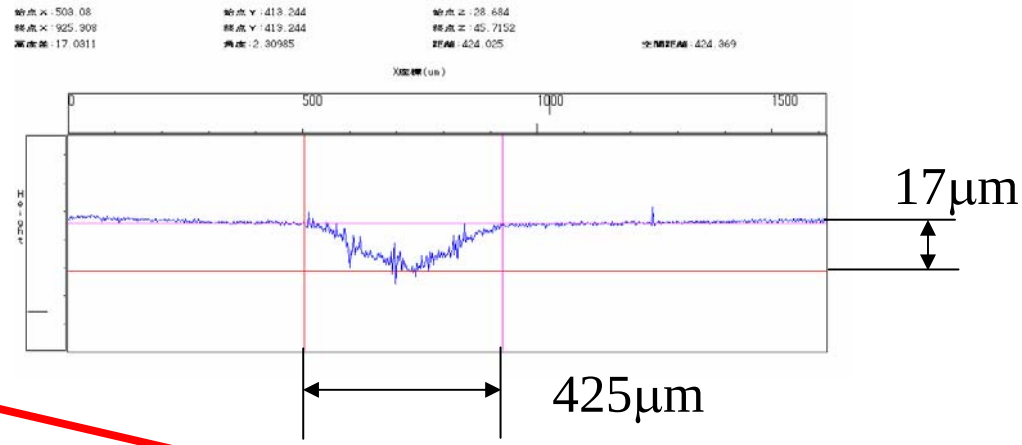
TEM observation JEM-2010

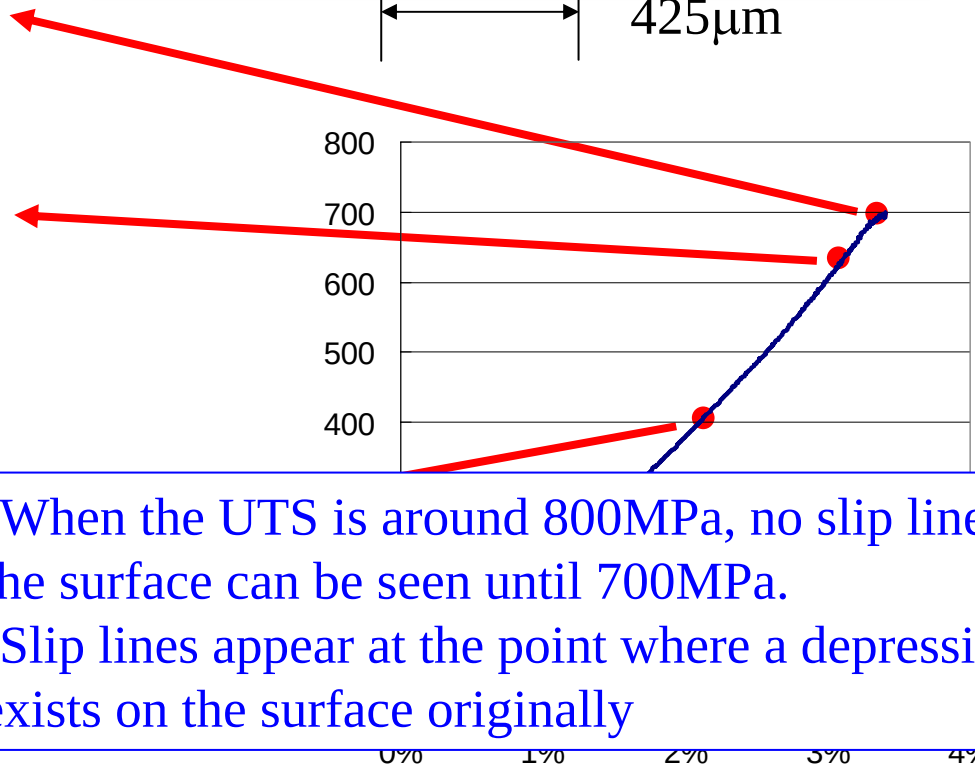
Changes of surface roughness due to tensile tests





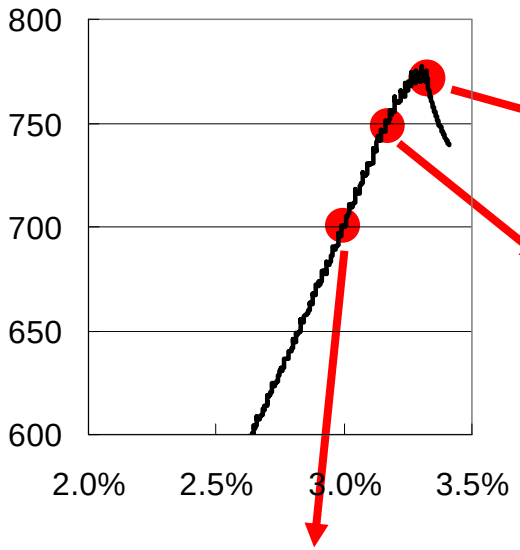


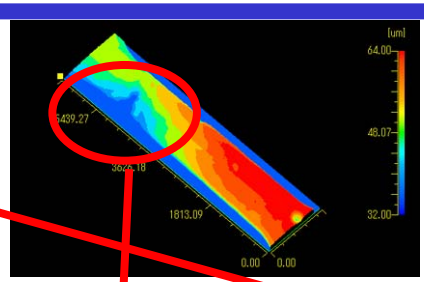


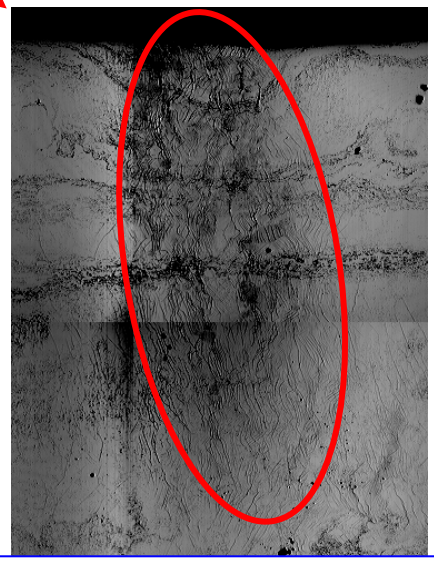


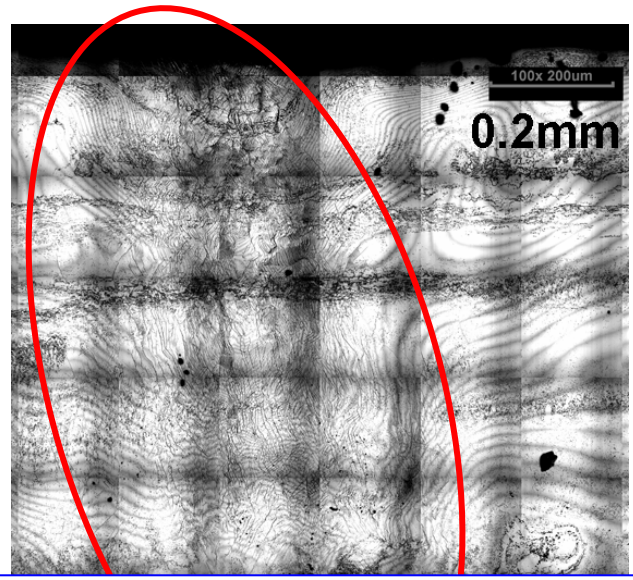
- When the UTS is around 800MPa, no slip lines on the surface can be seen until 700MPa.
- Slip lines appear at the point where a depression exists on the surface originally

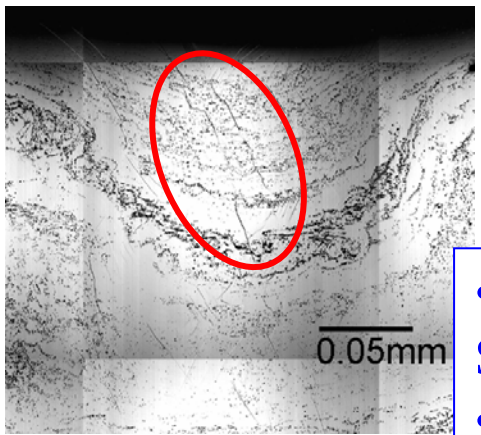
Changes of surface elevation in a tensile test





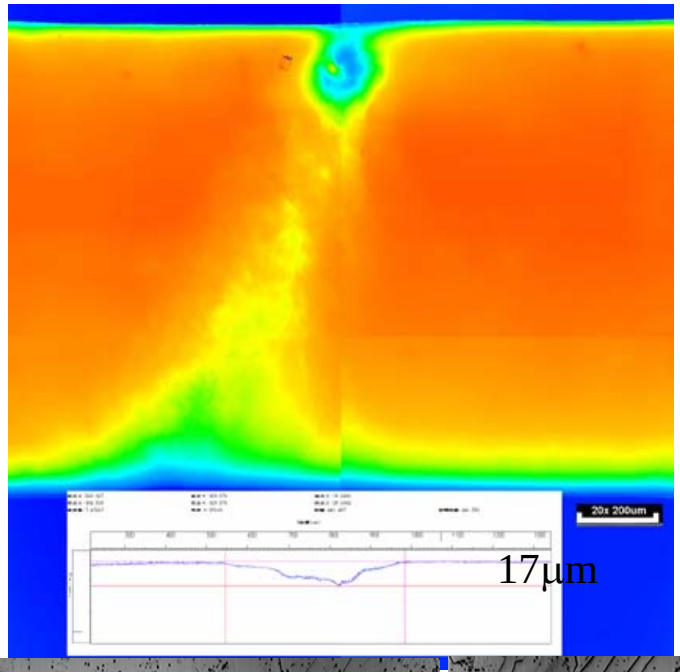


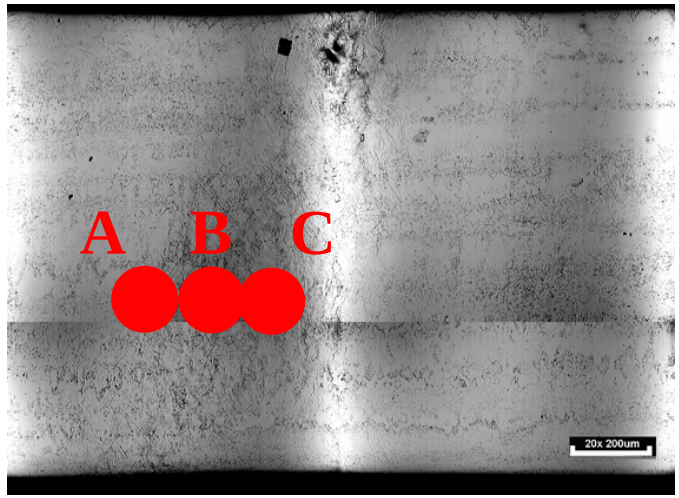


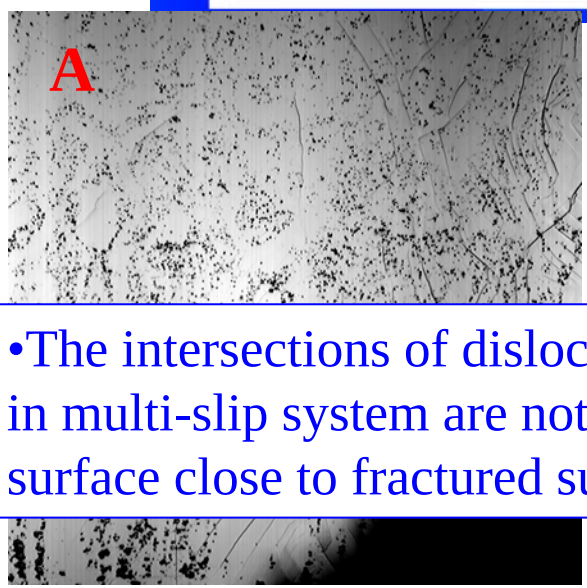


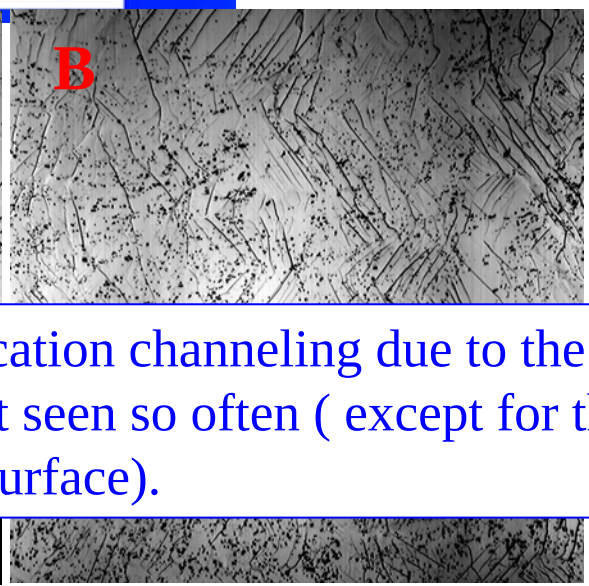
- The slip lines traverse the entire specimen, when the SS-curve deviates from the straight line.
- The deformation only proceeds in the area where slip lines initially propagate and it lead to fracture there.

Measurement of surface elevation around the deformed area at UTS



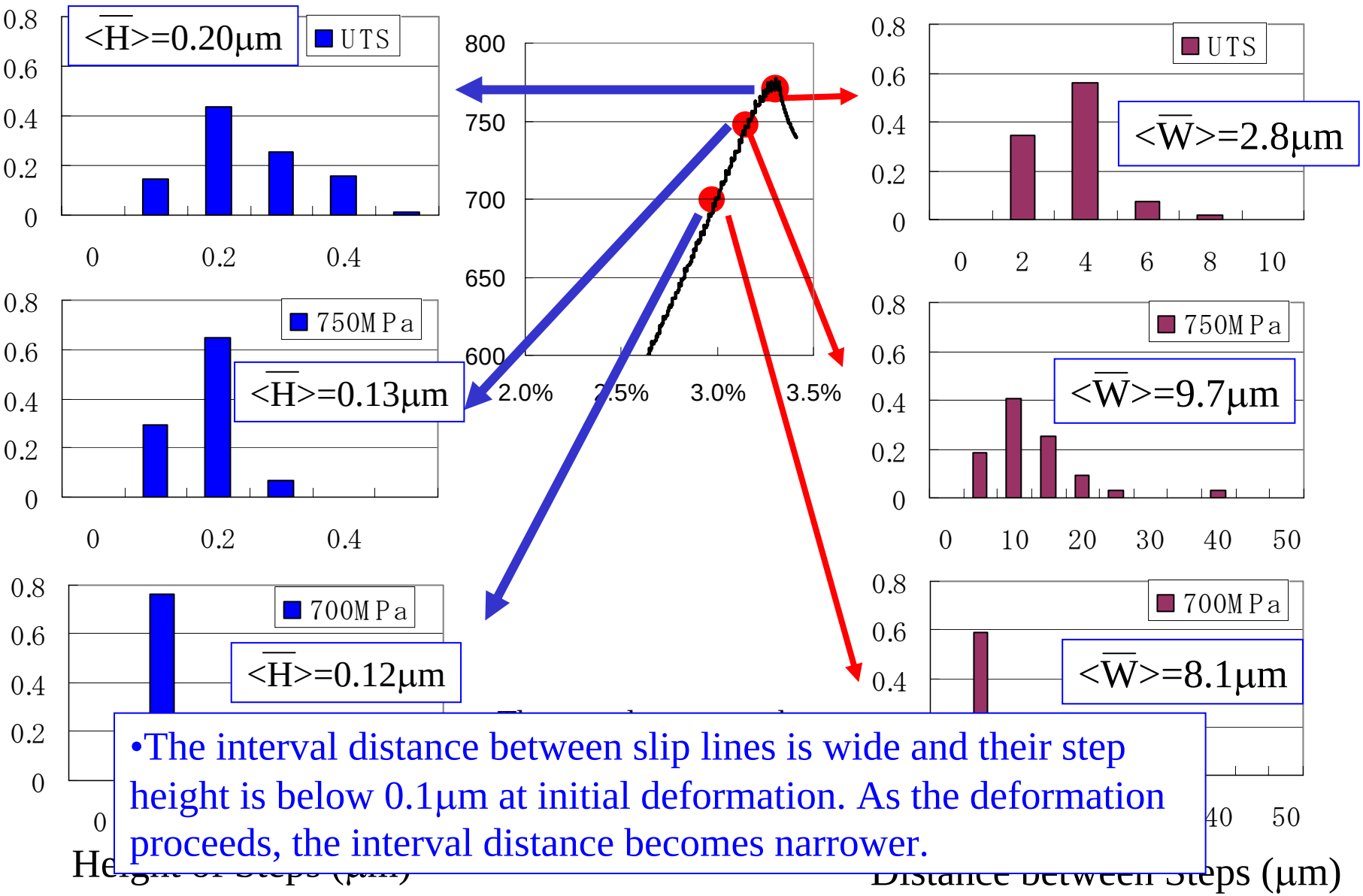






•The intersections of dislocation channeling due to the deformation in multi-slip system are not seen so often (except for the lateral surface close to fractured surface).

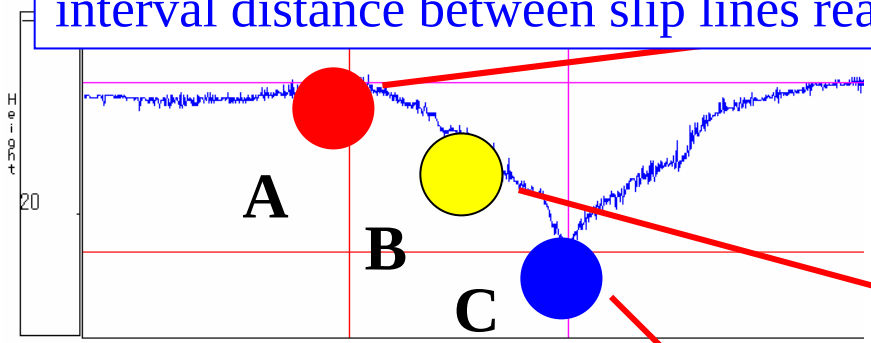
Measurement of the interval between slip lines and the step height of slip line

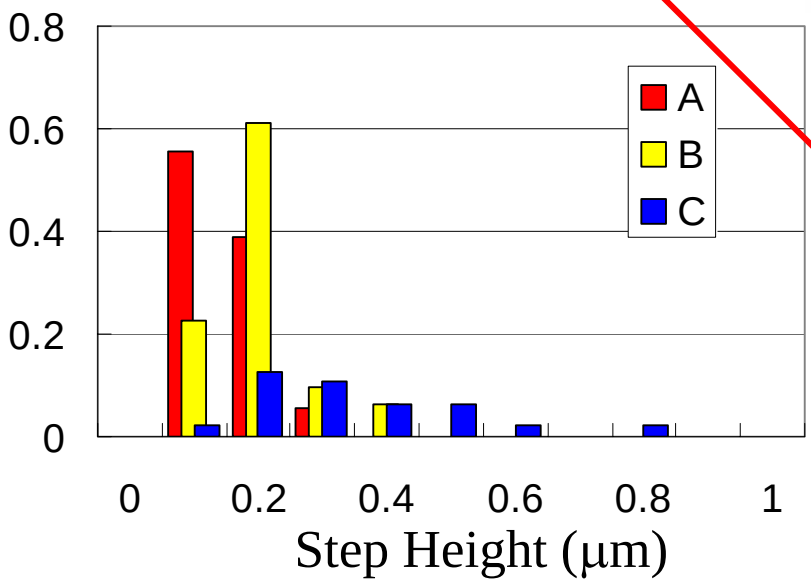


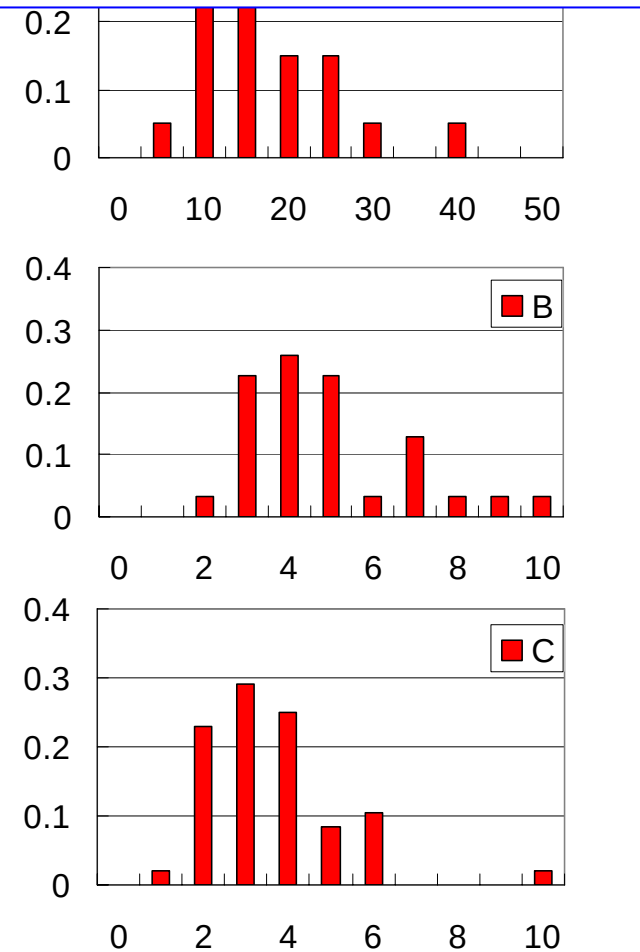
- The interval distance between slip lines is wide and their step height is below 0.1μm at initial deformation. As the deformation proceeds, the interval distance becomes narrower.

Areal dependence of the interval distance and the step height of slip line at UTS

•There is a trend the step heights of slip lines become larger when the interval distance between slip lines reaches to a certain level (≈3-4μm).

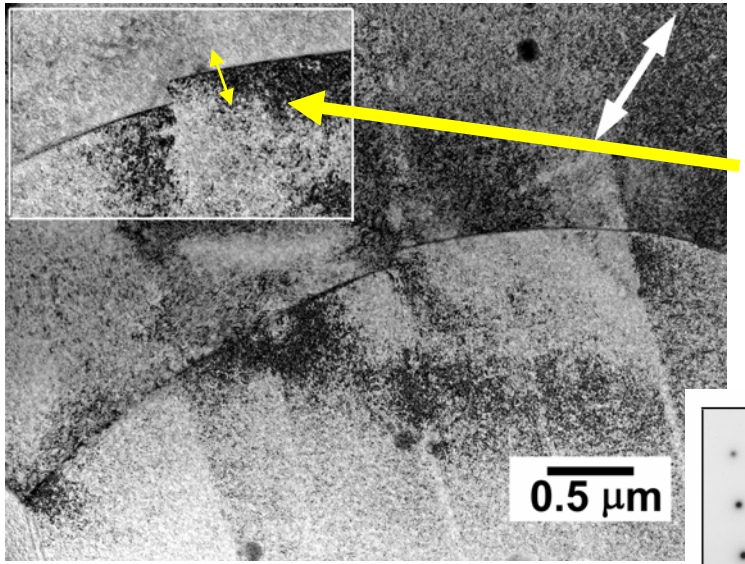




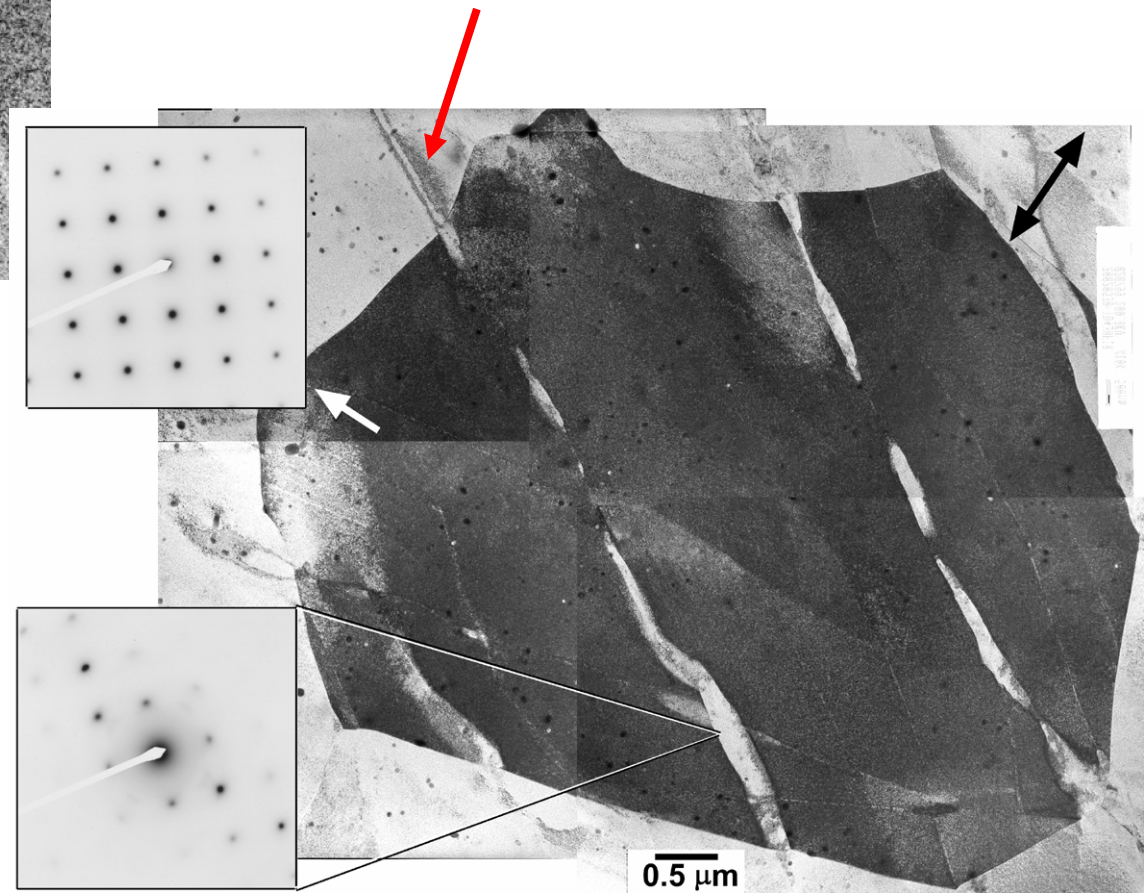


<H>	0.11→0.15→0.29 μm
<W>	14.8→ 4.5→ 3.2 μm

TEM observation of dislocation channeling (1)



•Dislocation channels traverse straightly across grains. The heights of steps on the grain boundary produced by dislocation channels are about 0.1μm.



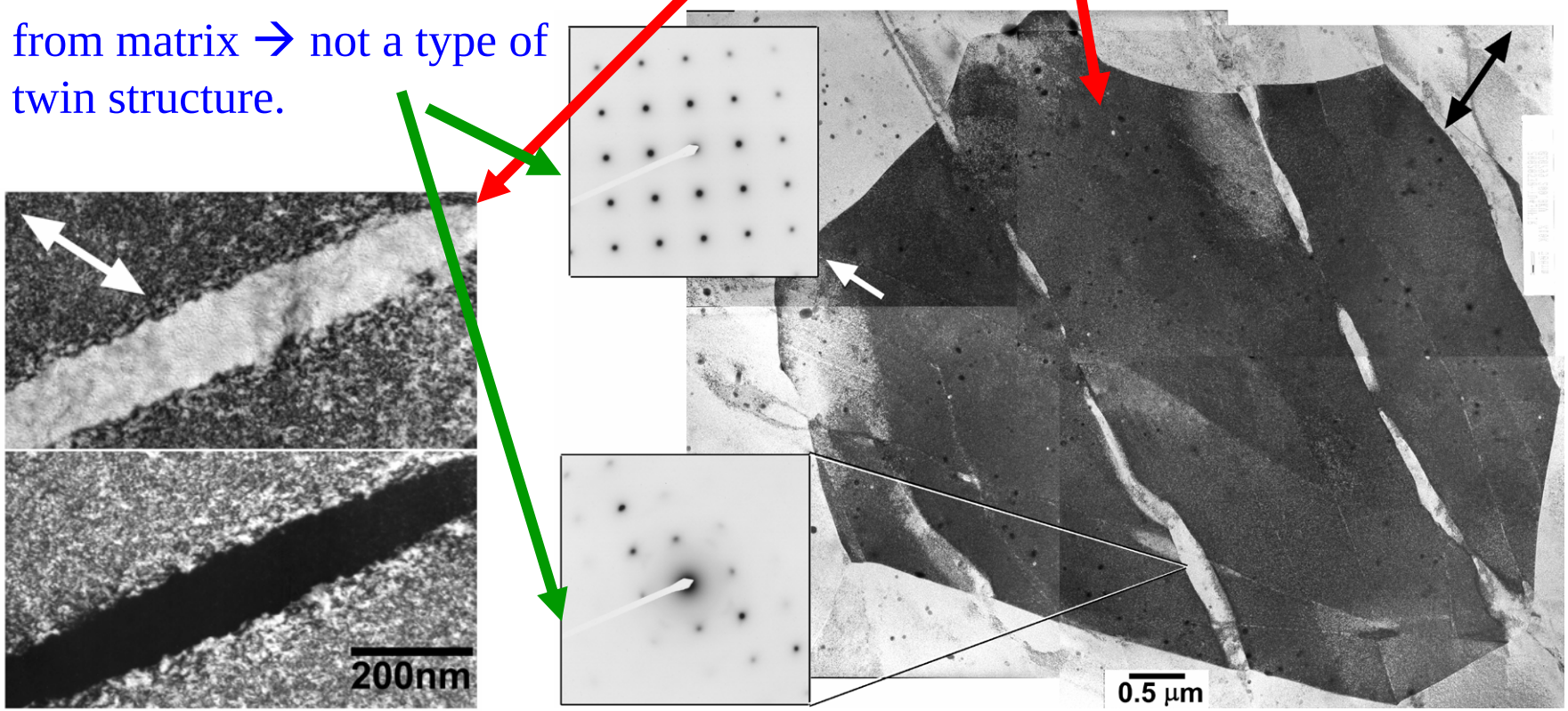
TEM observation of dislocation channeling (2)

•No dislocation lines and networks inside the dislocation channels.

•The inside of dislocation channel rotates to 10° from matrix → not a type of twin structure.

•Few dislocation channels on secondary or multi-slip systems in a grain.

•No dislocation line on the interface between the dislocation channel and the matrix.



A previous study for dislocation formation in Zircaloy

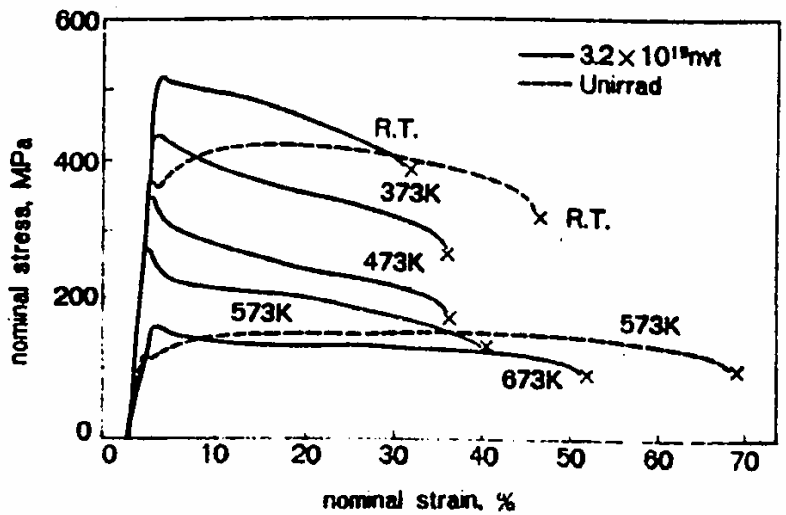


Fig. 1. Variation of stress–strain curves with temperature, for annealed transverse Zircaloy-2 specimens unirradiated and irradiated to 3.2×10^{19} n/cm^2 ($E > 1$ MeV) at about 423 K.

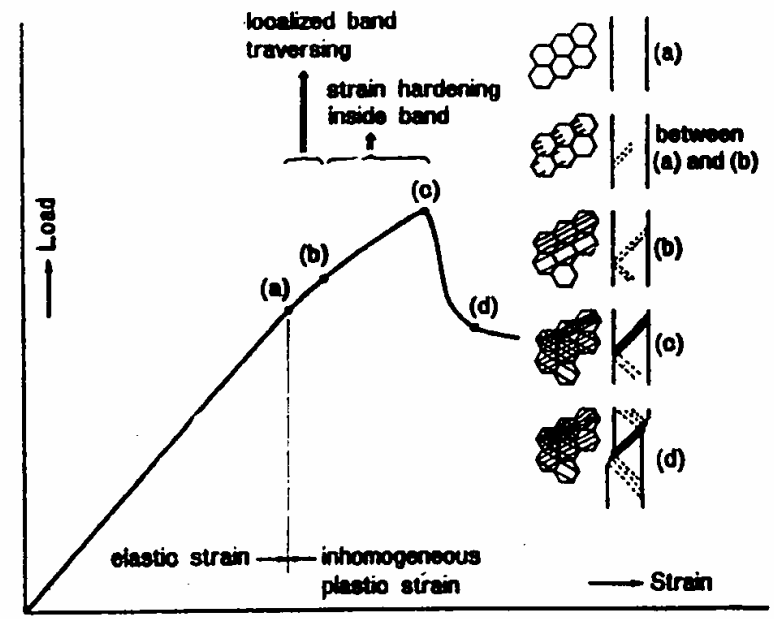
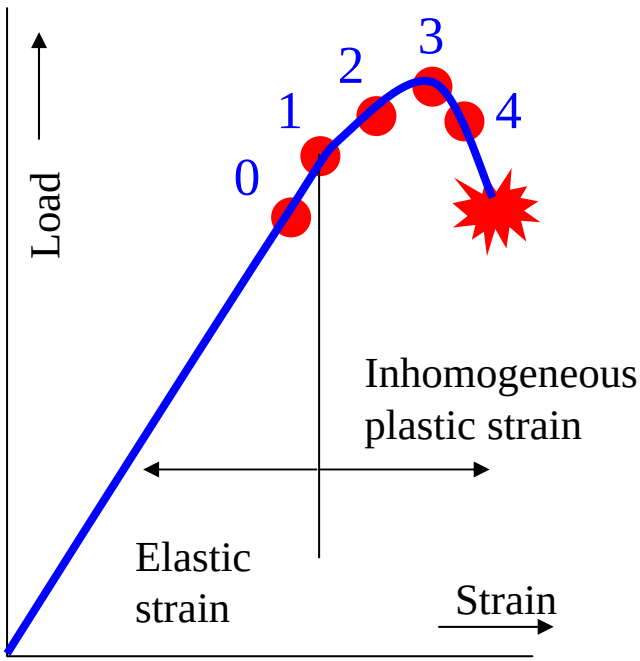


Fig. 8. Schematic diagram illustrating several stages of localized band development during deformation.

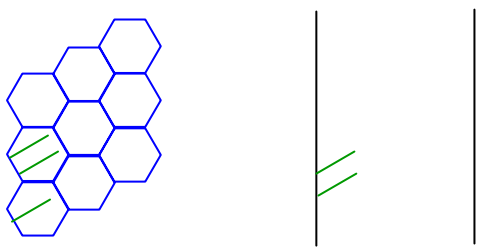
- A similar behavior with V-alloys until UTS.
- No detailed description about the morphology of dislocation channels.
- Dislocation channels on secondary and multi-slip systems proceed the subsequent ductility after UTS in a Zry.

The inhomogenious deformation behavior of neutron irradiated ZIRCALOY-2
T.Onchi, H.Kayano and Y.Higashiguchi, J.Nucl.Mater., 88 (1980) 226

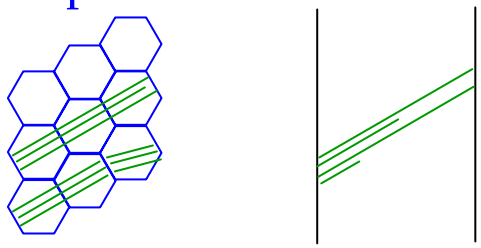
The formation process of dislocation channeling in neutron irradiated V-Cr-Ti alloys



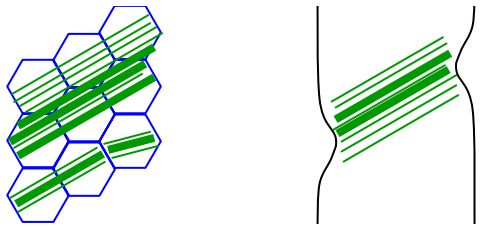
1. The formation of dislocation channel



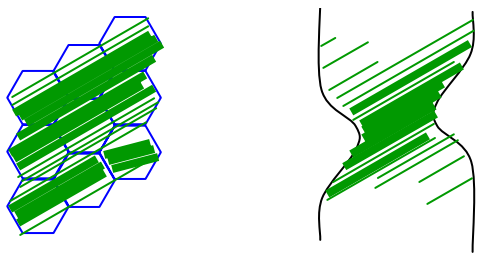
2. The propagation of slip band traversing the entire specimens



3. Multiplication and growth of dislocation channel proceed around the center of slip band



4. The formation of necking due to the channel deformation → lead to fracture



Summary

The formation process of dislocation channeling was investigated by the research of the tensile behavior and microstructure in neutron irradiated V-Cr-Ti alloys in HFIR at 300° C

- Slip bands consisted of dislocation channels are formed above the yield point (>700MPa).
- As the deformation proceeds, the density of slip lines increases initially and subsequently the width of dislocation channel increases.
- Since the primary slip system of dislocation channeling works until the necking behavior of the specimens, the V-Cr-Ti alloys are fractured without the deformation due to dislocation channeling formation of multi-slip systems.