Investigation of the interaction between gliding dislocations and irradiation induced loops in zirconium alloys

**Industrial background**

Zr-alloys: Cladding tube of the nuclear fuel in PWR
- First containment barrier against the dissemination of radioactive elements

► Necessity to understand and predict the effects of neutron radiation on the microstructure and on the mechanical properties.

**Effect of irradiation on the deformation mechanisms**

*Basal channeling (easy slip system after irradiation)*

(Transverse tensile test and internal pressure tests at 350°C on a recrystallized Zr-4 cladding tube)

Dislocation glide in prismatic plane mainly
- Reversal of the easy slip system!
- Dislocation channeling mechanism!

► Why is there such a change of the easy slip system?
► How does the dislocation channeling mechanism operate in irradiated zirconium alloys?

*Prismatic channeling (when basal slip not well orientated)*

(Axial tensile test at 350°C on a recrystallized Zr alloy cladding)

Dislocation channeling in the basal plane only.

**In situ TEM observations of dislocation – loop interaction on ion irradiated specimens**

Material: recrystallized Zr-4 rolled sheet, grain size 5 μm

Ion irradiation:
- Ions: Zr +
- ARAMIS facility at CSNSM/IN2P3-Orsay
- Irradiation dose = 0.5 dpa (or 1 dpa)
- Temperature = 500°C (or 350°C)
- Energy = 2 MeV and 0.6 MeV

**Experimental results after 1 dpa at 350°C**

- Clearing of loops by edge dislocations gliding in the prismatic plane in the case of a high loop density (1 dpa at 350°C)
- Creation of cleared bands in the prismatic plane

**Experimental results after 0.5 dpa at 500°C**

- Annihilation of a loop incorporated as a super-jog in an edge dislocation gliding in the prismatic plane in the case of a low loop density (0.5 dpa at 500°C)

**TEM observations after mechanical testing on neutron irradiated specimens**

- Basal channeling (easy slip system after irradiation)
- Prismatic channeling (when basal slip not well orientated)
- Only few remaining loops in the channel
- Nearly full clearing in the basal plane
- Easy basal channeling

**In situ TEM observations of dislocation – loop interaction on ion irradiated specimens**

- Ion irradiation: recrystallized Zr-4 rolled sheet, grain size 5 μm
- ARAMIS facility at CSNSM/IN2P3-Orsay
- Irradiation dose = 0.5 dpa (or 1 dpa)
- Temperature = 500°C (or 350°C)
- Energy = 2 MeV and 0.6 MeV

- TEM observation after in situ testing