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Impact properties of 9Cr tempered martensitic steels and MA957 ODS alloy irradiated in a spallation environment up to 24 dpa

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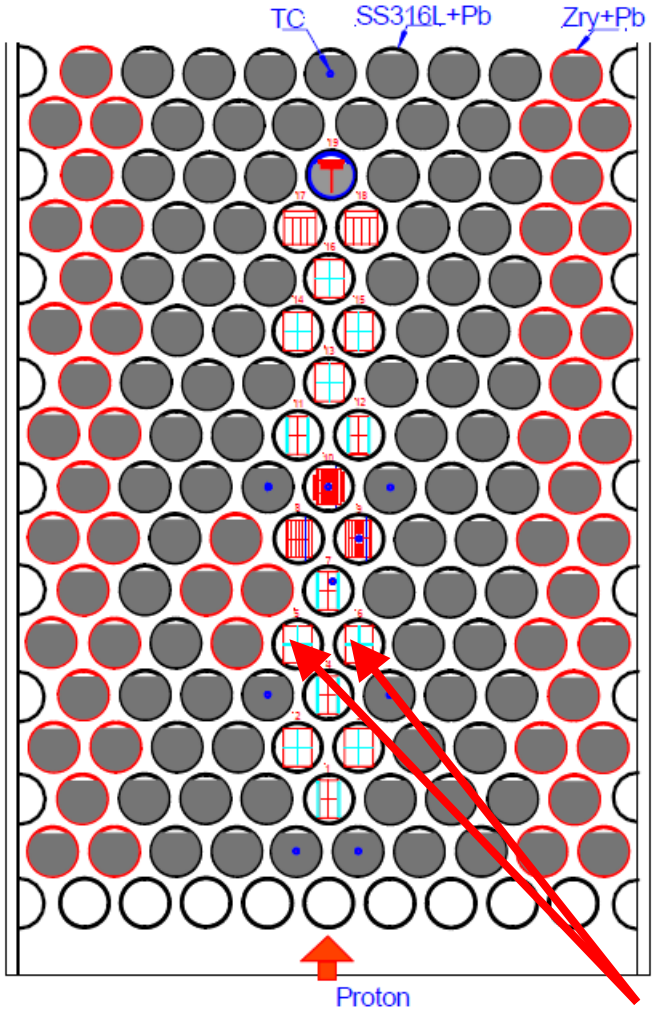
Outline

- Materials and irradiation conditions
- 9Cr-1Mo martensitic steels:
  - Tensile data/microstructure
  - Impact properties
- MA957 ODS:
  - Tensile properties
  - Impact properties
- Conclusion

Comparison with BOR60 data



Materials, irradiation conditions

- Materials :

  - T91 (9Cr1Mo V Nb), N (1 h @1050° C &T (1h @750° C)

  - T92 (9Cr2WMoV), N (0.5 h @1060° C &T (1h @780° C)

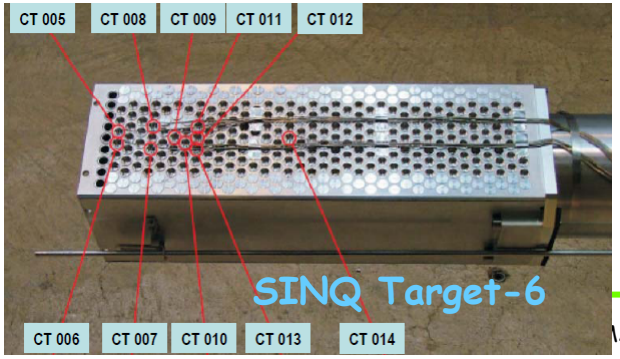
  - MA957 ODS (Fe-14Cr-1Ti-0.3 Mo-0.25 Y_2O_3), hot extruded

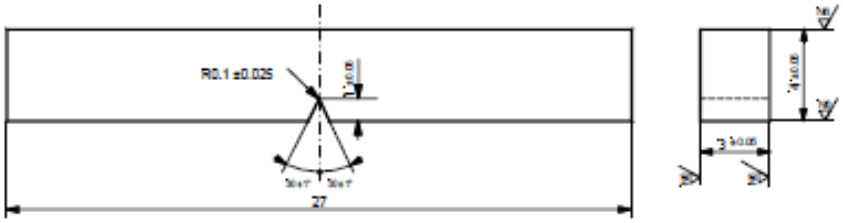
- Subsize Charpy specimens (rods 5 & 6)

- Doses 11 & 24 dpa (~ 0.13 % He)

- (average) Temperature range: 200-350°C

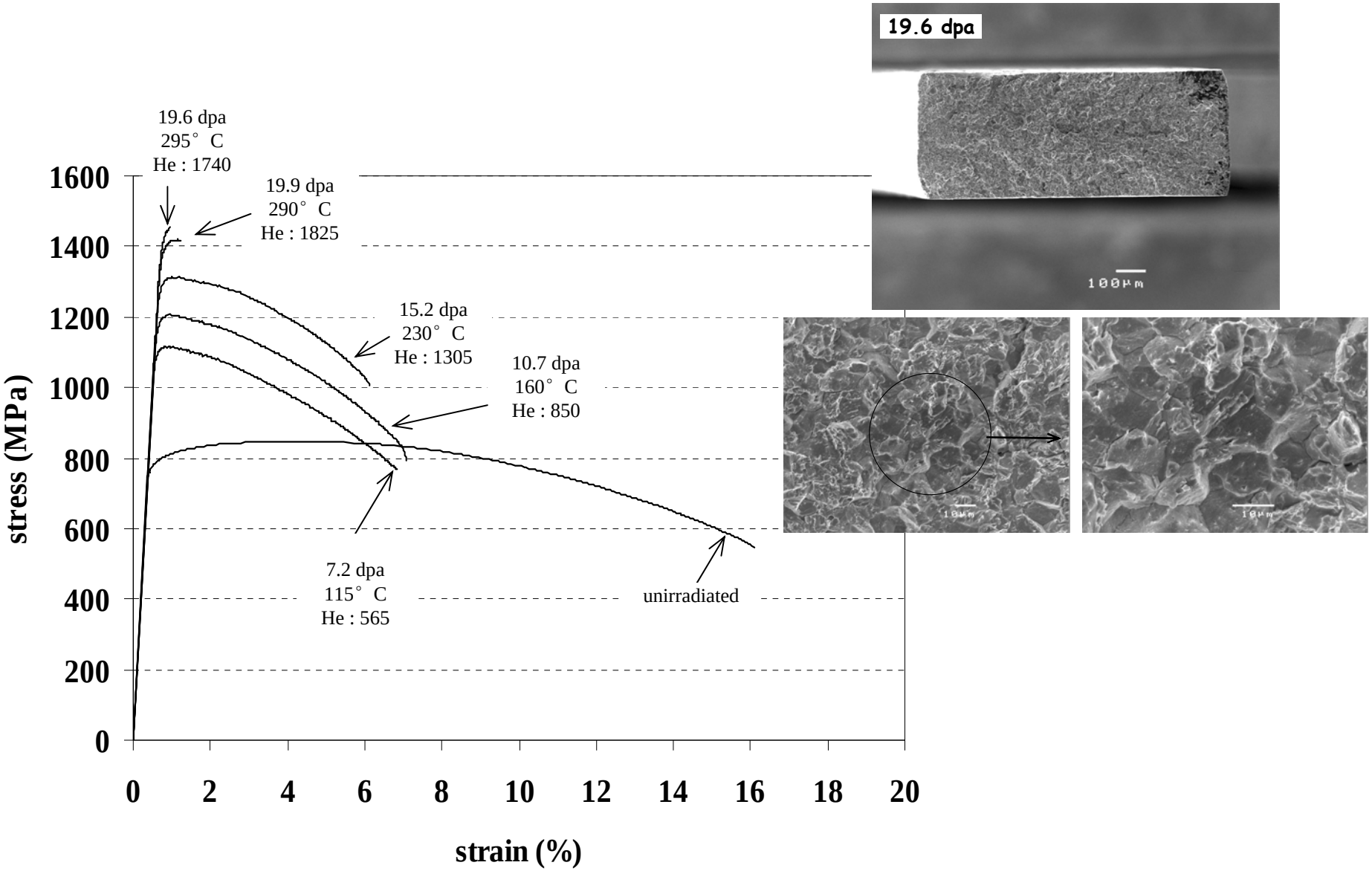
- Two temperature « excursions » (over-focussed beam)



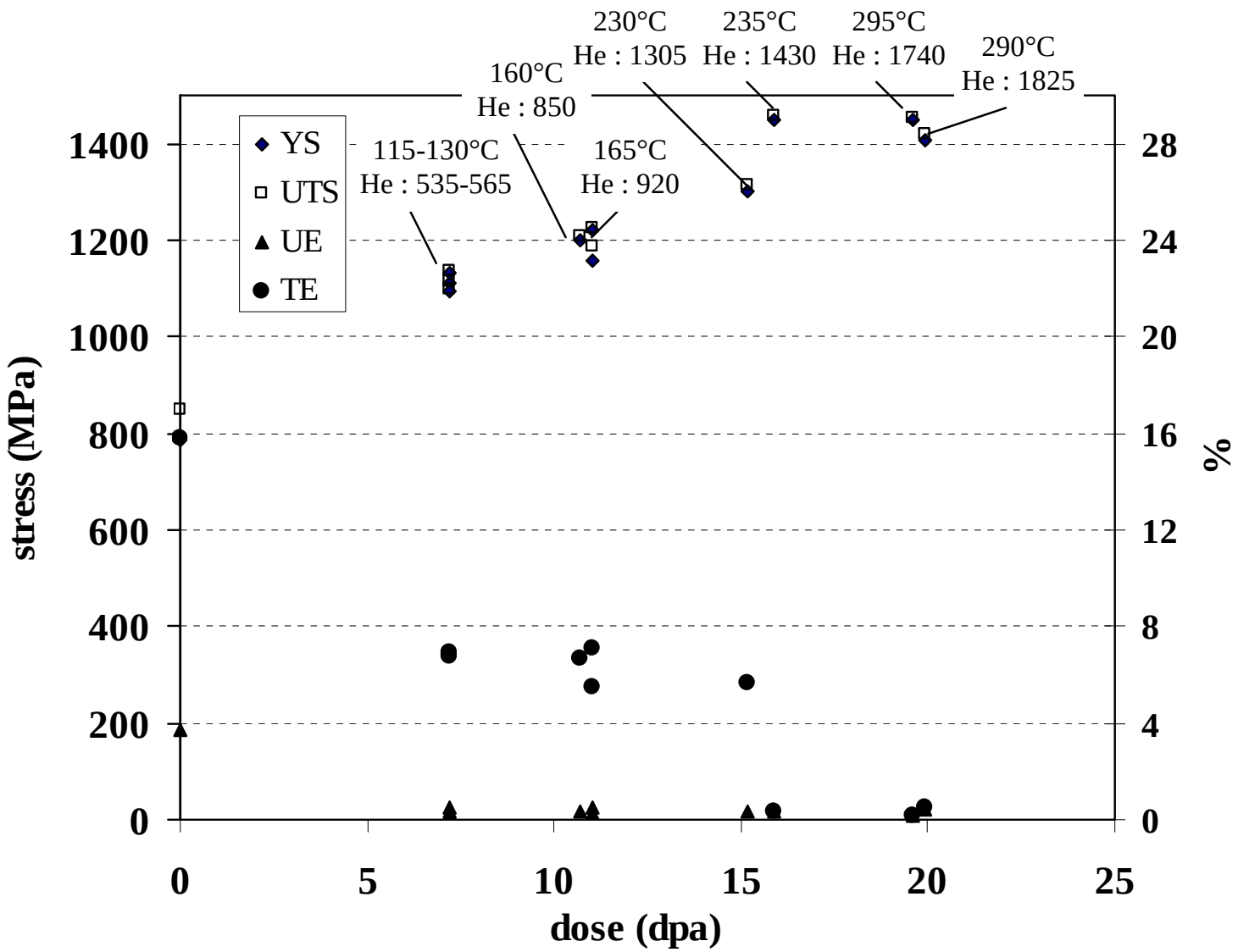


Subsize Charpy 27x4x3 mm3

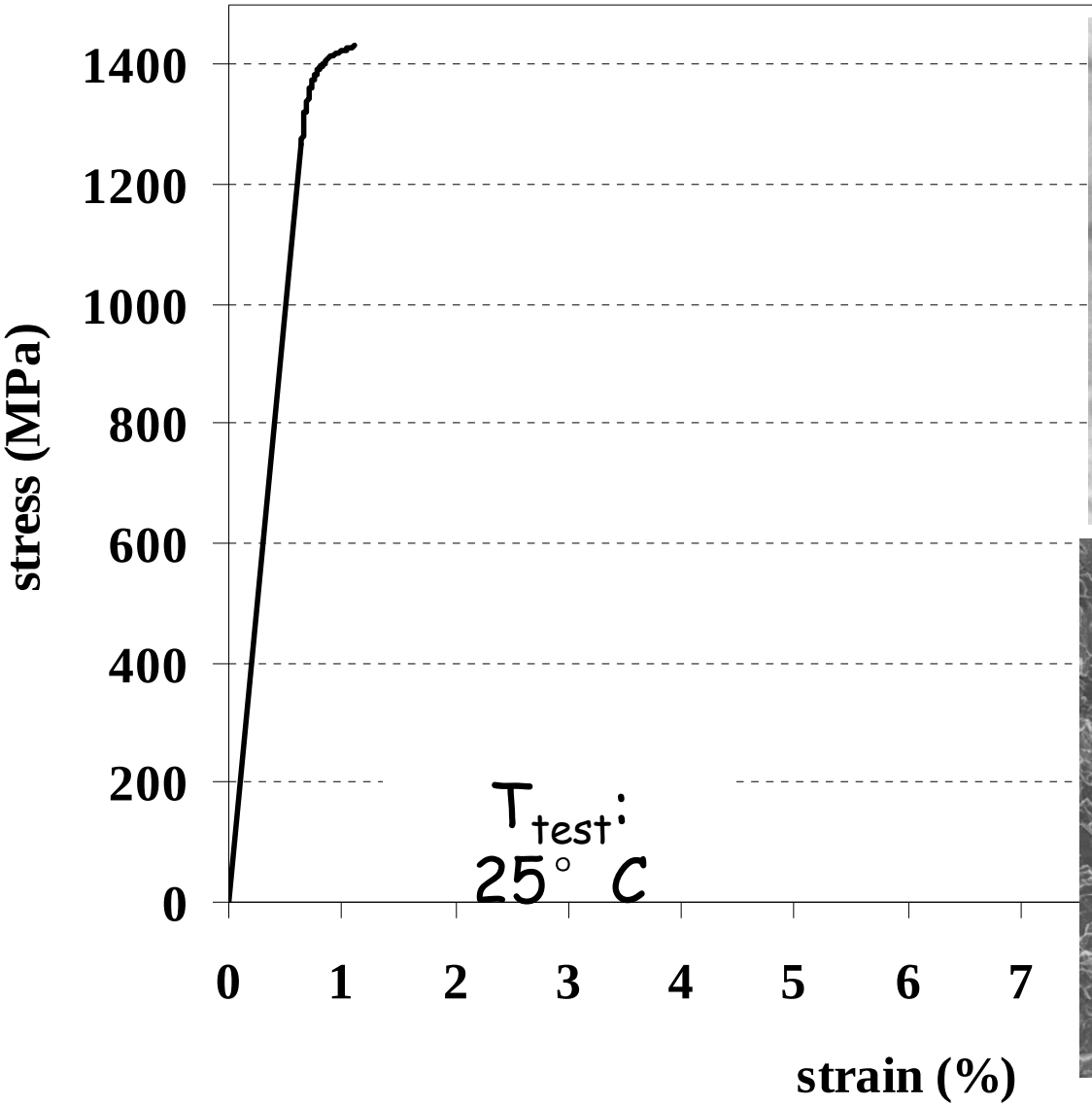
Examples of tensile curves (T91 tested at RT)

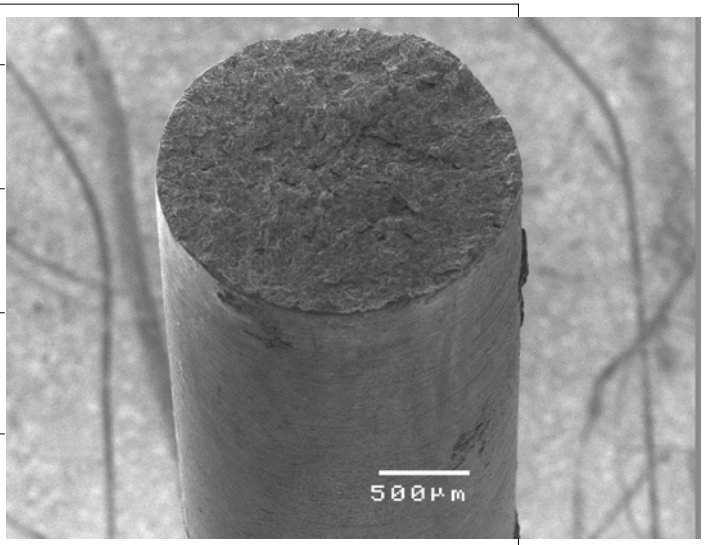


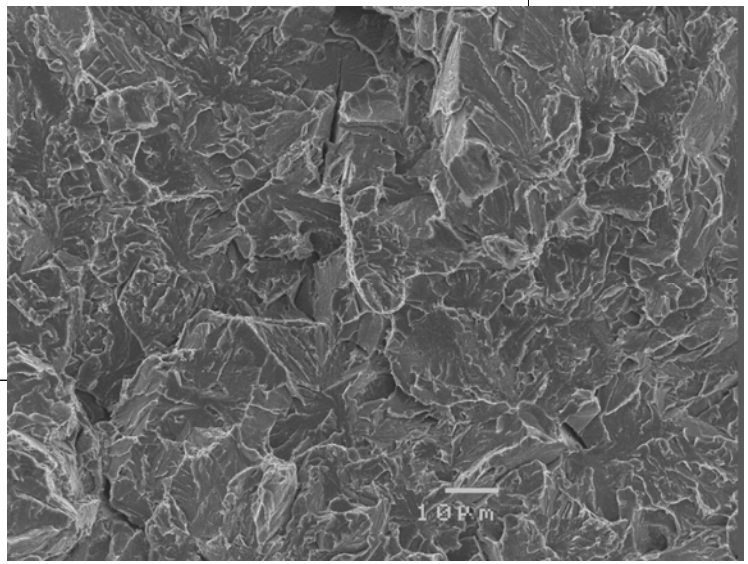
Evolution of Tensile properties/dpa (T91, RT)



T91 irradiated in BOR60 (325° C) to ~78 dpa

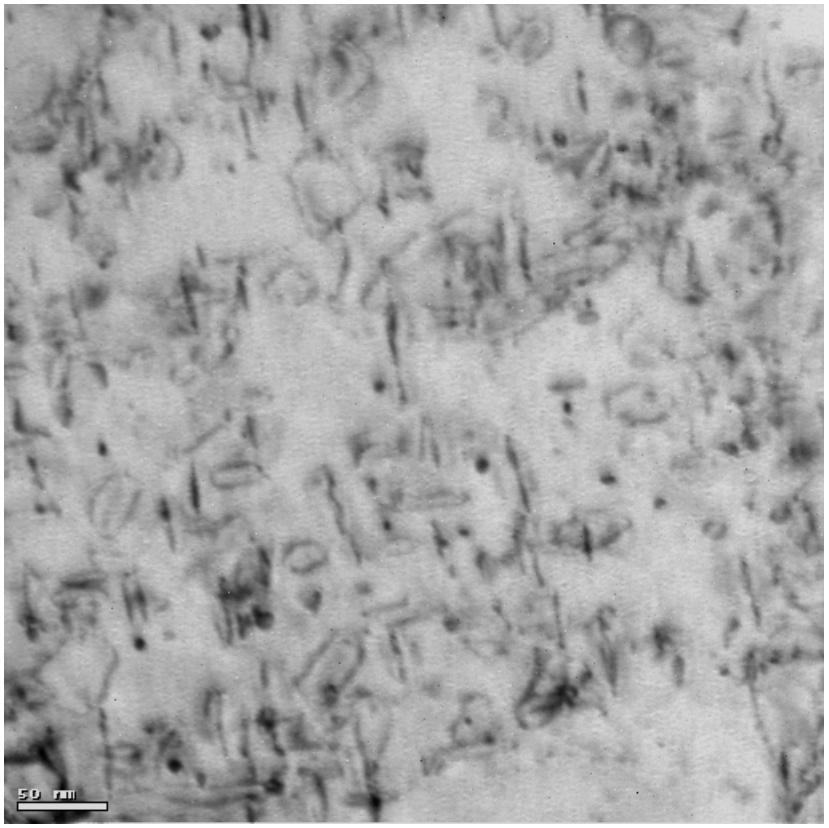


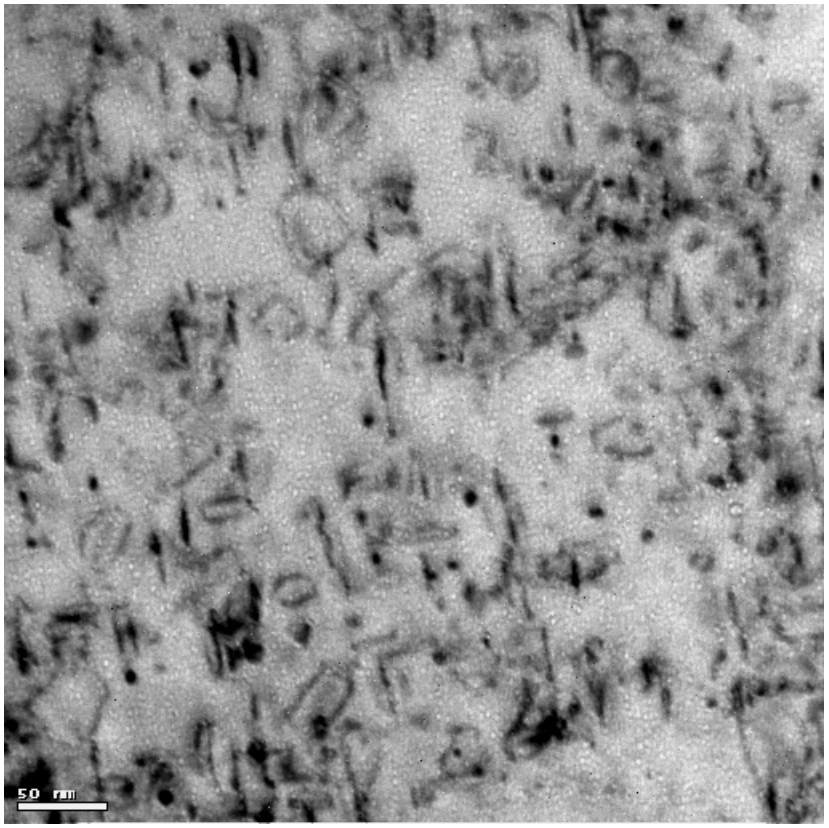




9Cr1Mo: Microstructure (TEM)- STIP II irradiation

306° C average T_{irr}, 18 dpa 1580 appm He

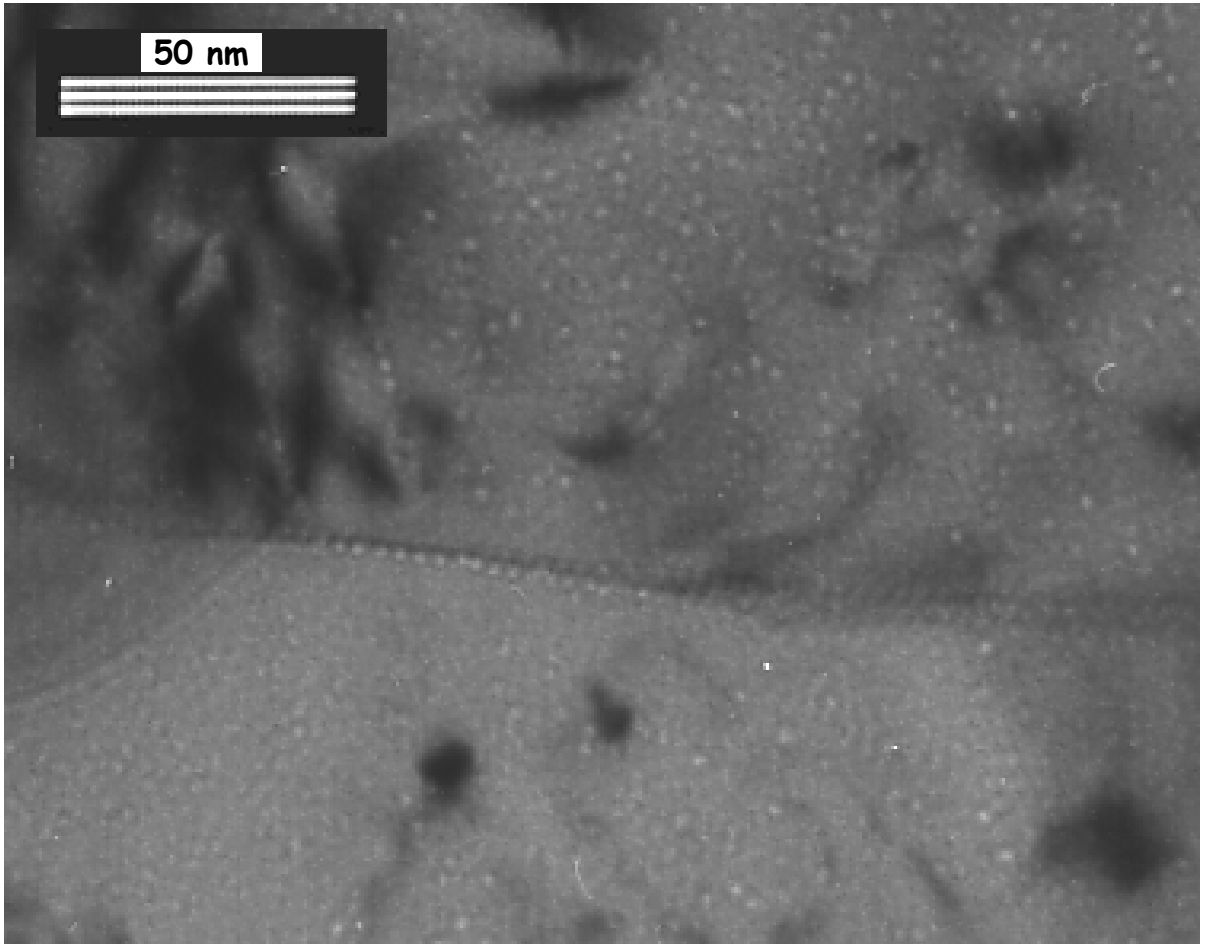




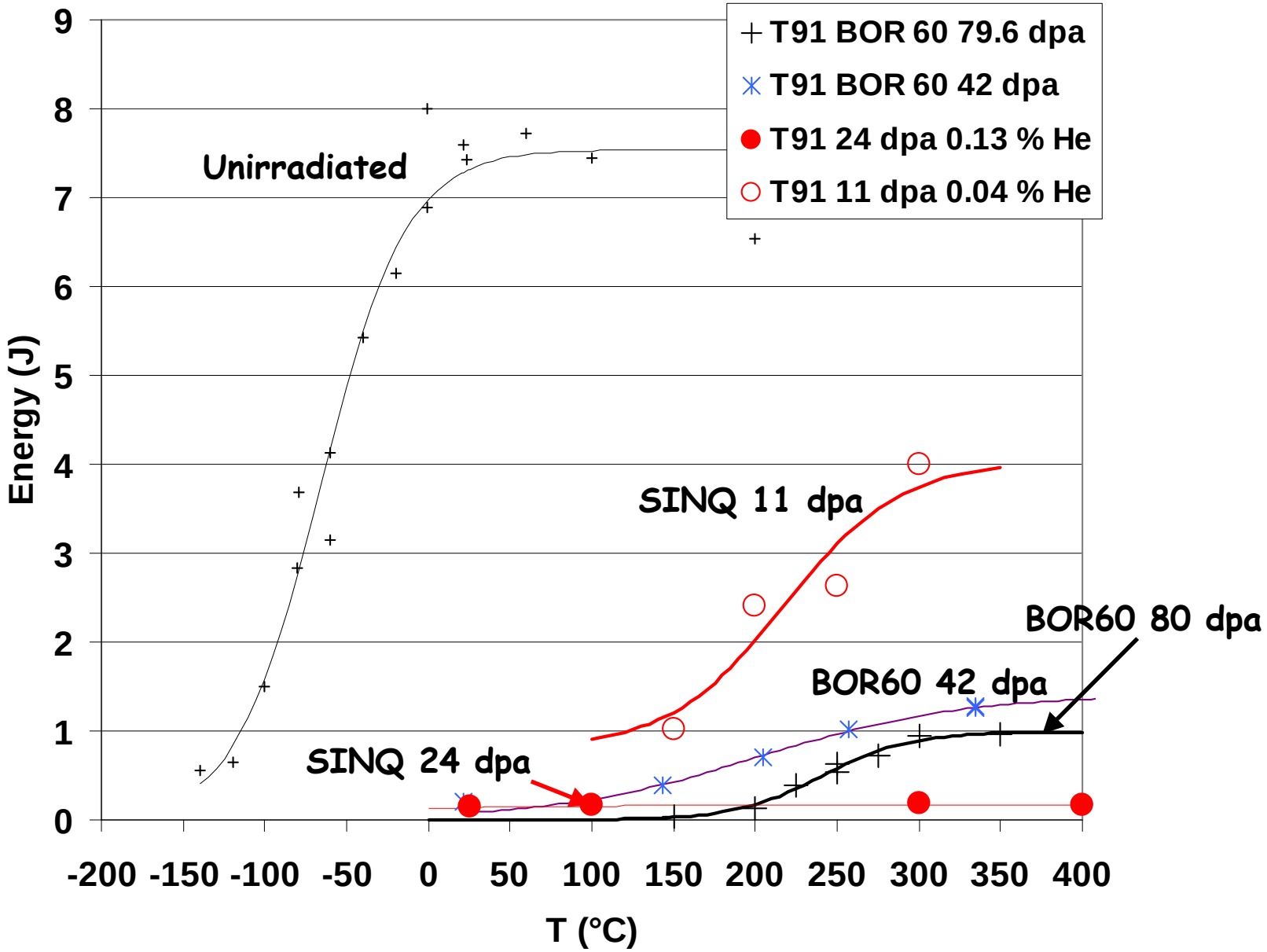
g= (011), B = [100]

Defocus: -2500 nm

9Cr1Mo : Bubbles at GB



T91: Impact Properties



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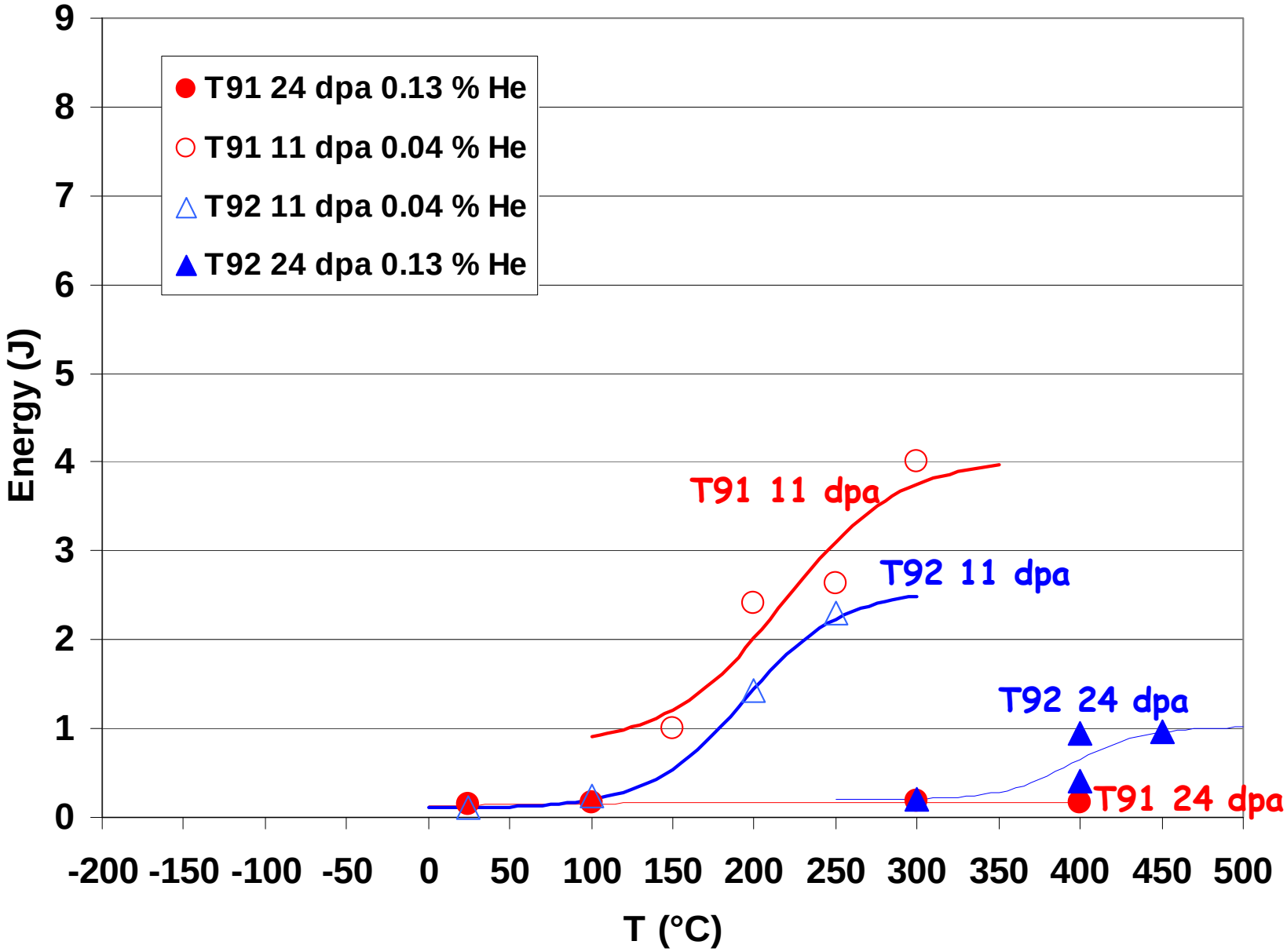
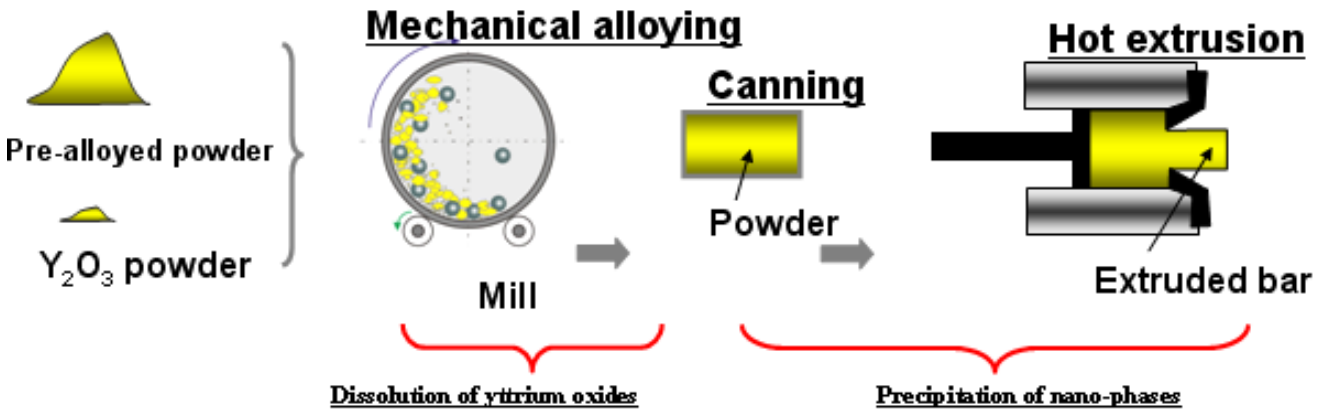
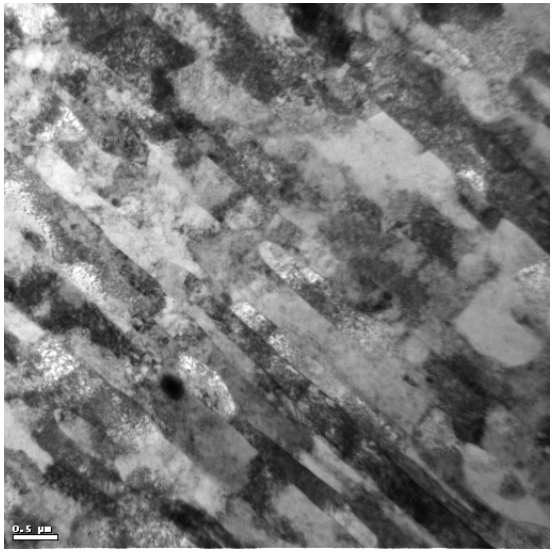
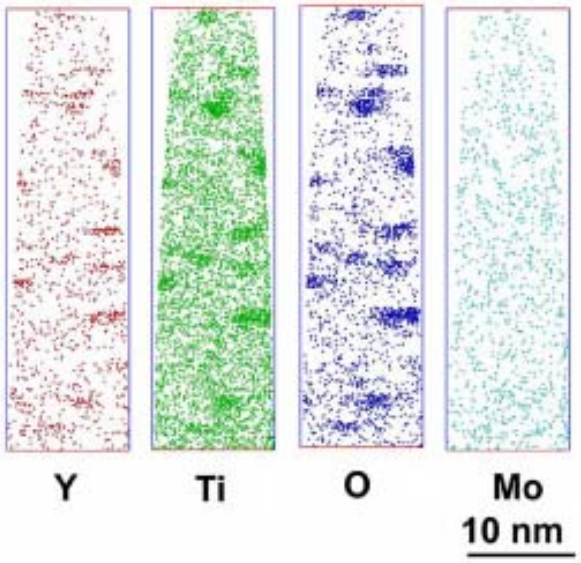
Comparison T91/T92



MA957 (14Cr-1Ti-0.3Mo-0.25Y_2O_3): a Nanostructured ODS alloy







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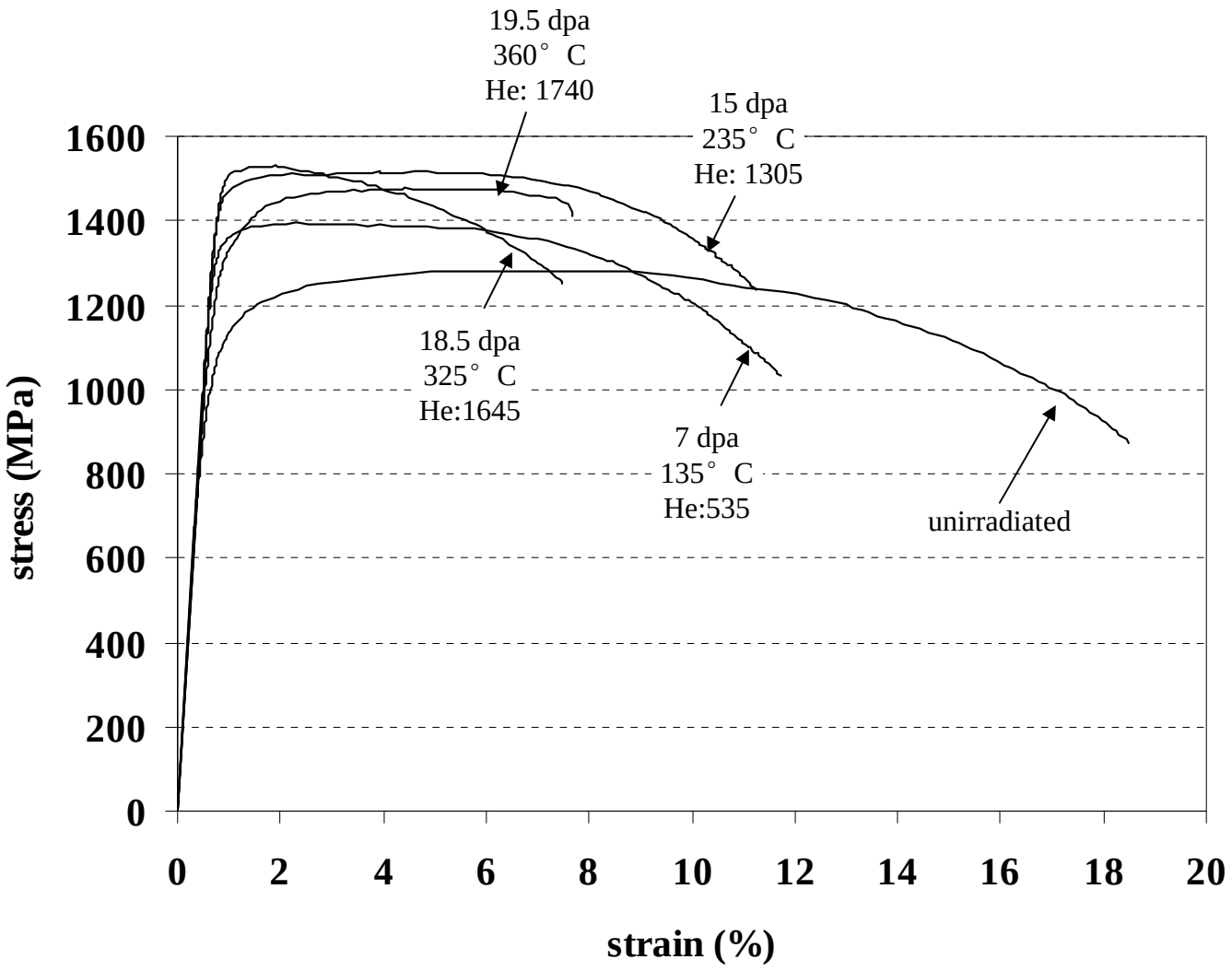
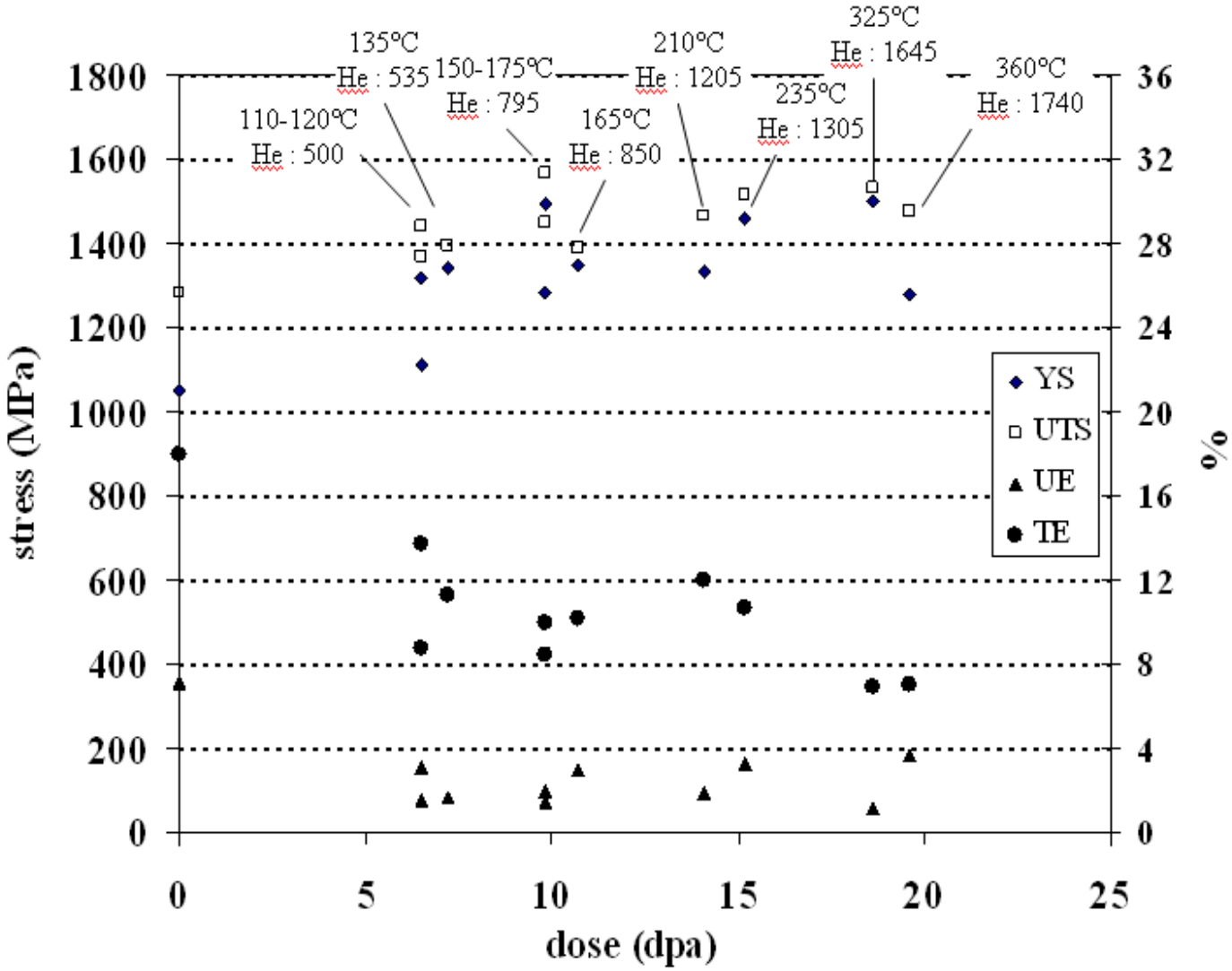
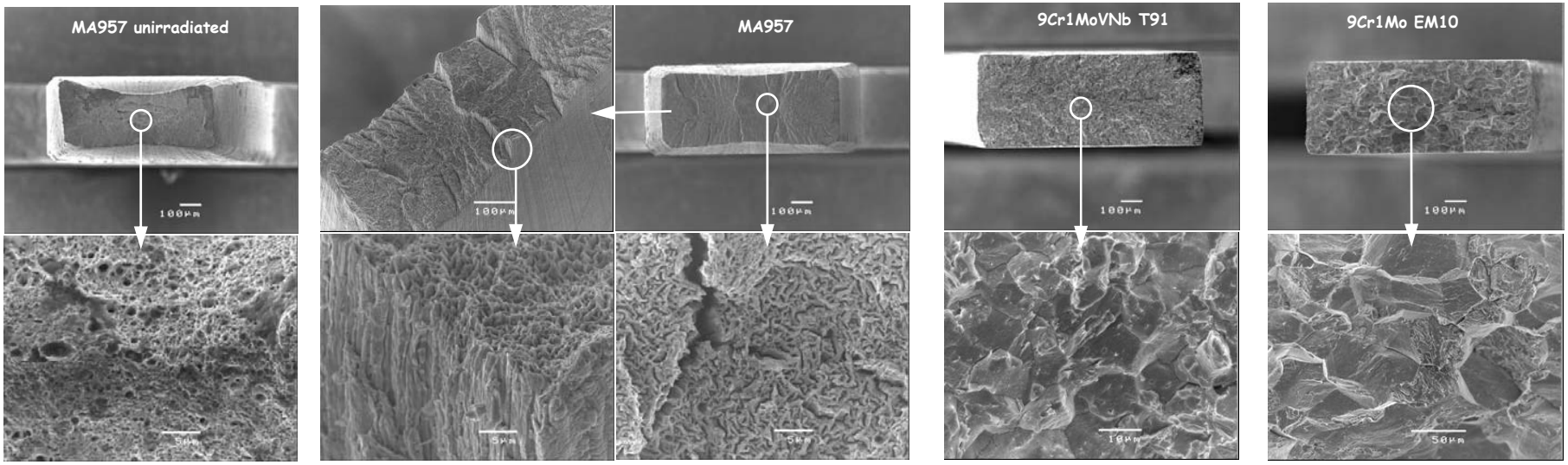
Examples of tensile curves (MA957 tested at RT)



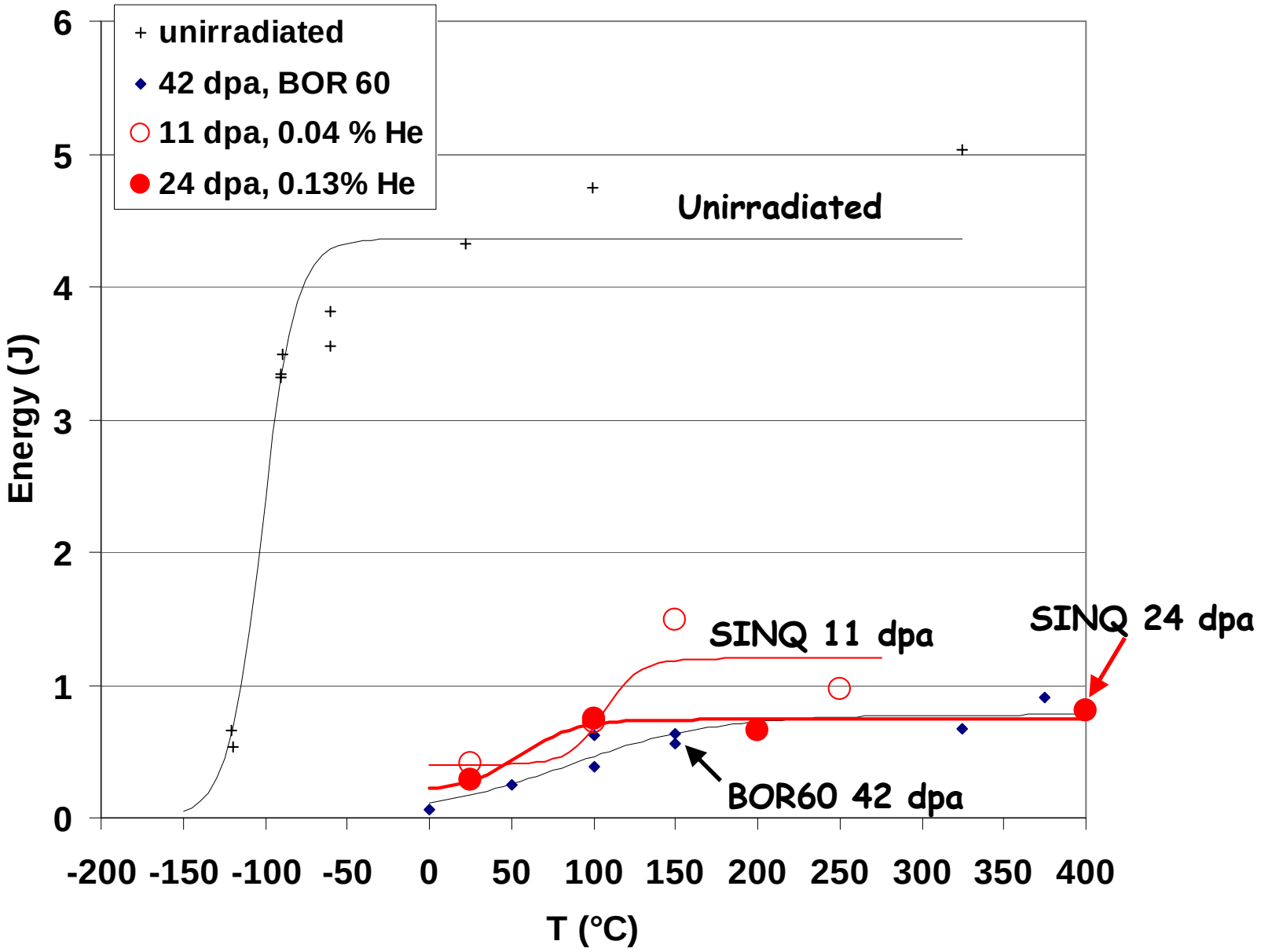
Evolution of Tensile properties/dpa (MA957, RT)



Fracture surfaces: MA957 & 9Cr-1Mo irradiated to ~19 dpa at ~300° C



MA957: Impact Properties



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Summary/Conclusion

The mechanical properties of two 9%Cr steels and a 14%Cr ODS were investigated after irradiation in SINQ to doses up to 24 dpa:

- In tensile tests, T91 displayed high hardening and brittle, intergranular fracture mode for doses above ~16 dpa, which is probably partly due to a high helium content (no intergranular fracture was observed in T91 irradiated to 80 dpa with fission neutrons).
- The impact behaviour was drastically degraded by the irradiation in a spallation environment: at 24 dpa (0.13 at% He), T91 exhibited a brittle behaviour up to at least 400° C; T92 impact properties after irradiation in SINQ were similar to those of T91.
- By contrast, MA957 in the hot extruded condition, retained significant ductility up to the max dose when tensile tested at RT.
- Irradiation in spallation conditions of MA957 induced a large shift of DBTT/decrease of upper shelf energy; However, the degradation of impact properties was much less than in the case of 9Cr martensitic steels.