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Influence of grain size and the presence of nano-oxides on the radiation resistance of a FeCrW alloy

M. Vrellou, C. Hatzoglou, B. Radiguet, A. Etienne, X. Sauvage, M.
Abramova, N. Enikeev, A. Mazilkin, J. Ivanisenko

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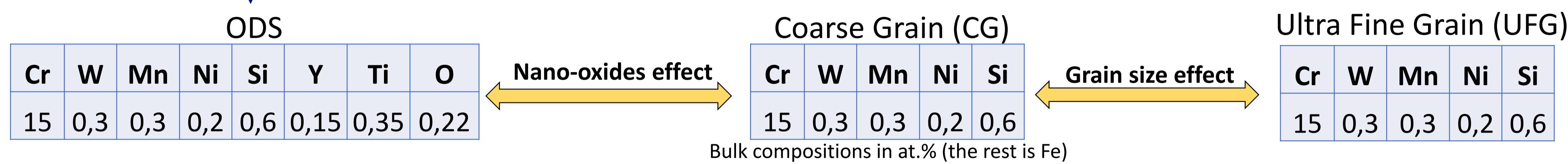
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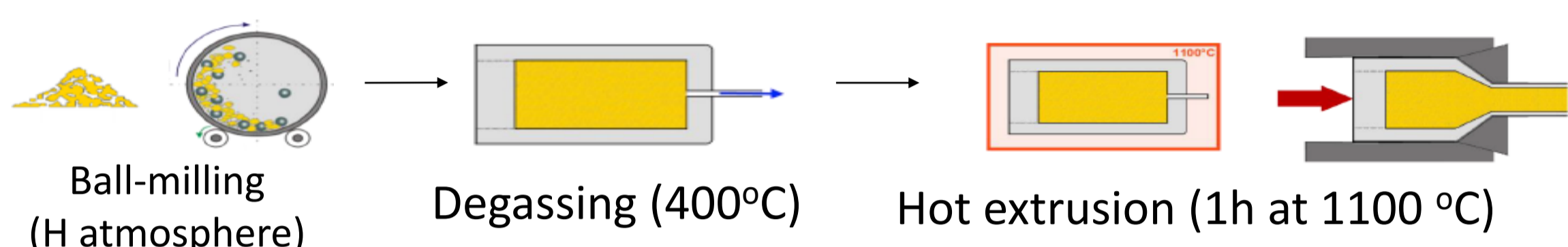
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Introduction

One of the most promising candidate materials for both nuclear fusion and Generation IV fission reactors is the class of oxide-dispersion strengthened (ODS) steels. The presence of uniformly dispersed nano-sized oxide particles provides an enhanced resistance to irradiation induced swelling by acting as nucleation sites for helium and as sinks for the irradiation-induced defects as well. While impeding dislocations movement has as result their high mechanical strength even at high-temperature.

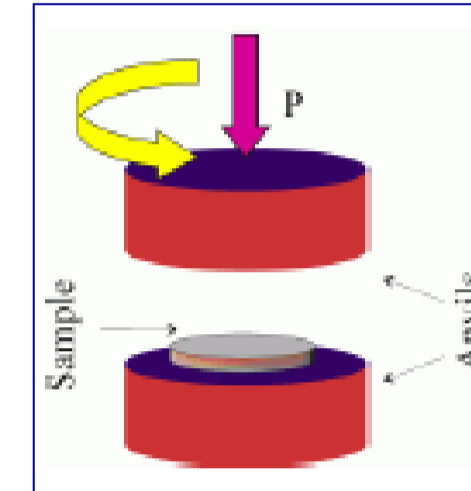


Fabrication of the ODS alloy from CG powder with mechanical alloying :



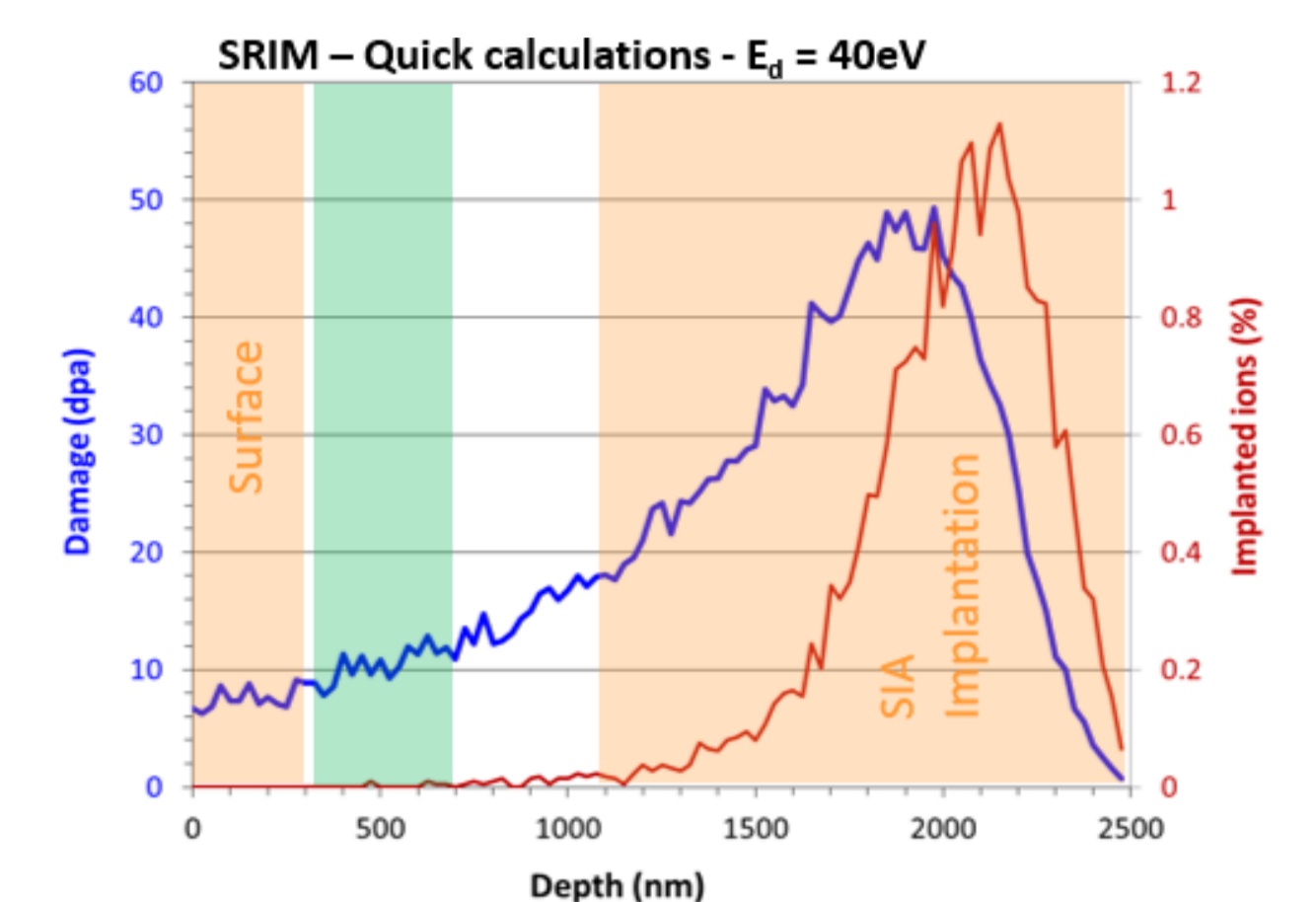
Fabrication of the UFG steel:

CG powder + High Pressure Torsion: P=6GPa, T=350oC, n=10 turns



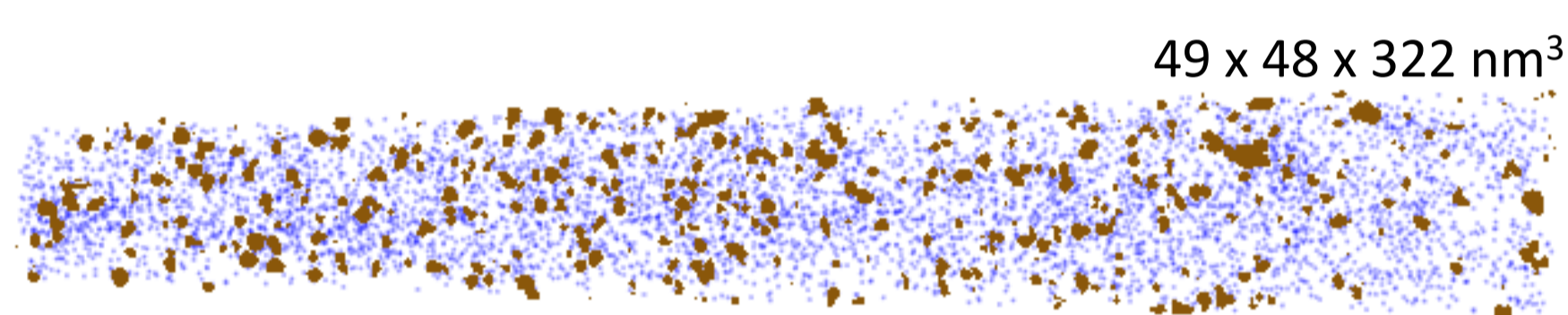
Irradiations performed in Epiméthée Accelerator in JANNUS Saclay with the following conditions :

- Ions : Fe⁵⁺ - 10MeV
- Flux : 7x10¹⁵ m⁻².s⁻¹ for 20h
- Fluence : 5.0x10²⁰m⁻²
- Temperature : 400°C



ODS

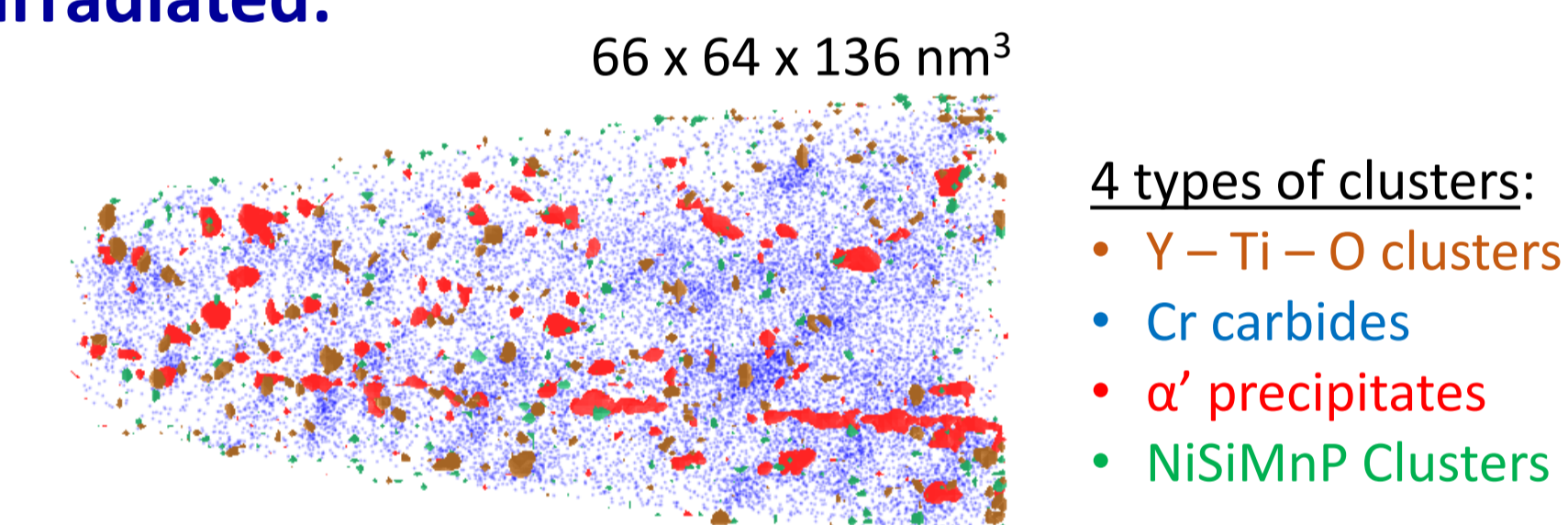
Unirradiated:



- Y - Ti - O clusters
- C
- Grain size: 0,44 µm

	ρ (m ⁻³)	<Size> (nm)
Y Ti O	(8,1±0,3) x 10 ²³	1,3±0,1

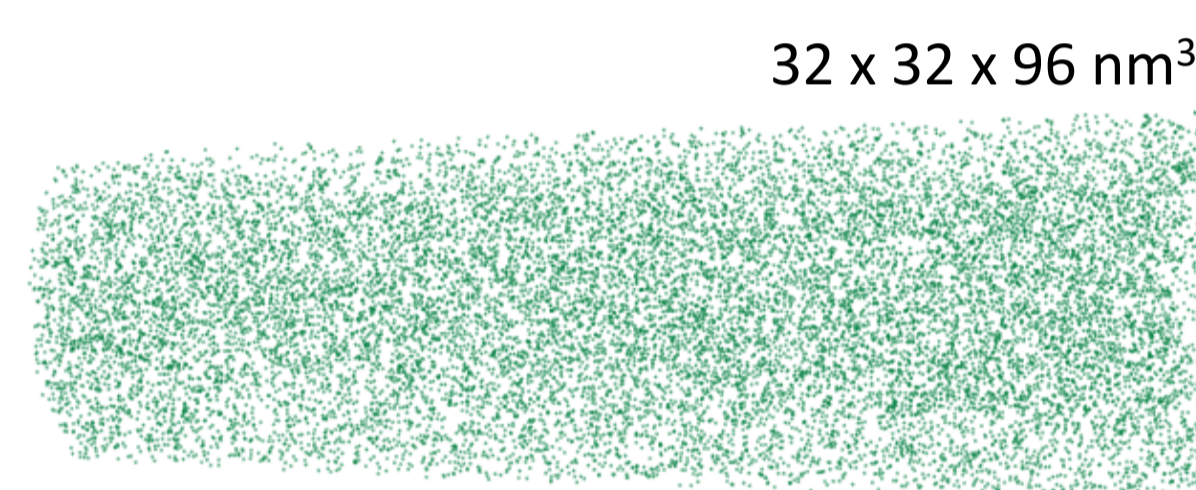
Irradiated:



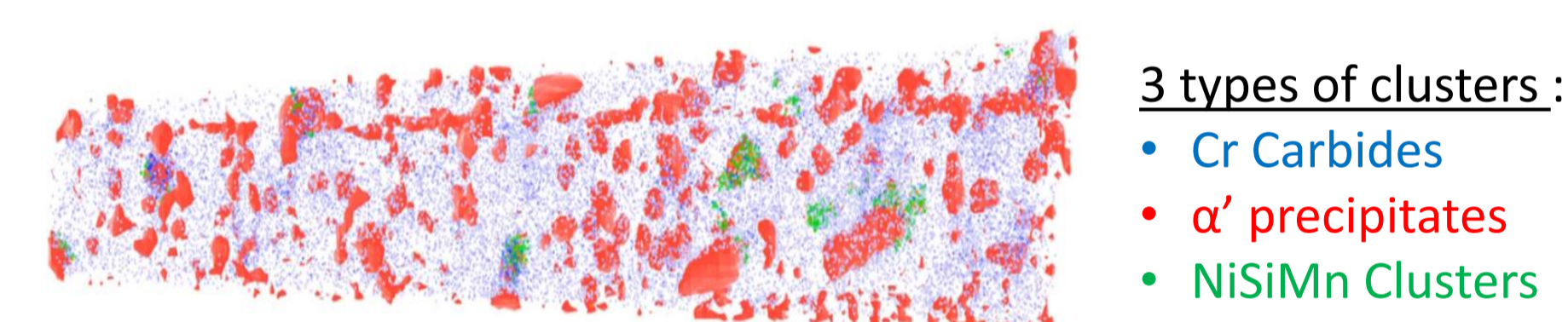
	ρ (m ⁻³)	<Size> (nm)
Y Ti O	(7,3±0,4) x 10 ²³	<edge> 1,6±0,1
C	(2,6±0,2) x 10 ²³	<D> 3,8±0,4
Cr	(8,4±0,4) x 10 ²³	<D> 5,4±0,2
NiSiMnP	(1,2±0,1) x 10 ²³	<D> 3,8±0,4

Coarse Grain

Unirradiated:



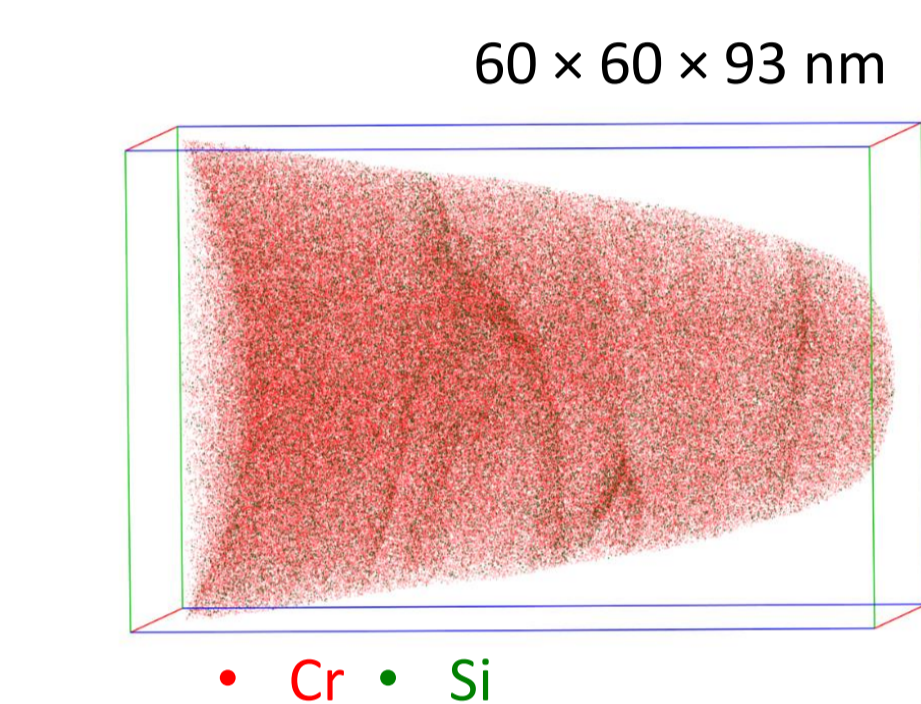
Irradiated:



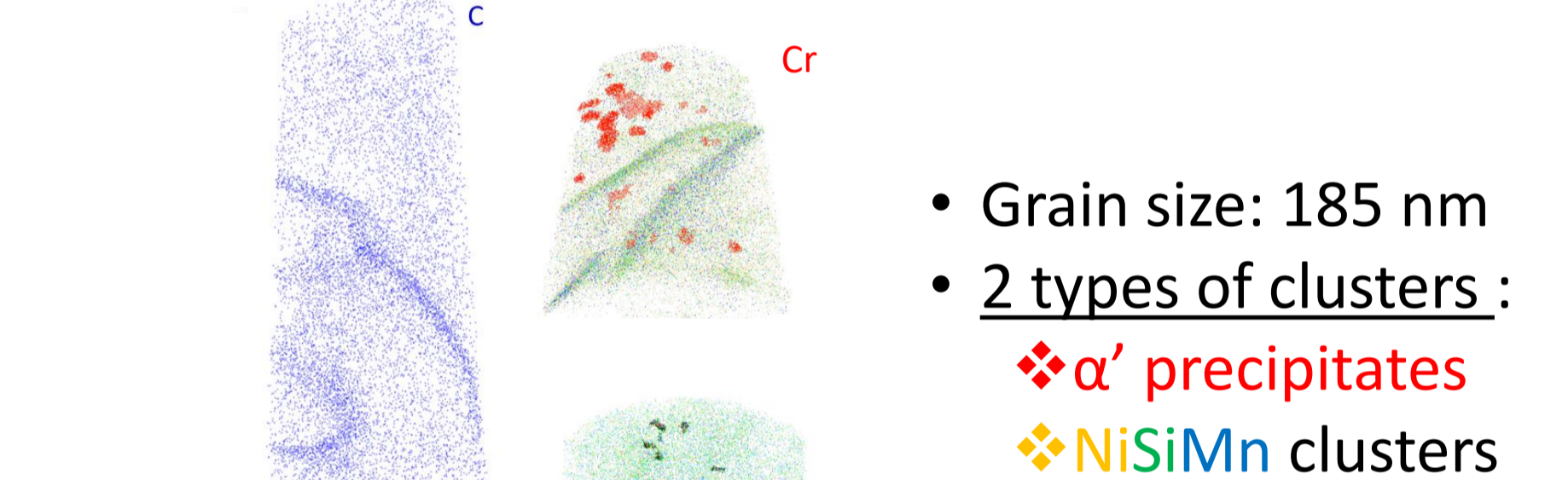
	ρ (m ⁻³)	Size <D> (nm)
C	(27±3) x 10 ²²	3,2±1,2
Cr	(161±7) x 10 ²²	2,8±1
NiSiMn	(23,9±3) x 10 ²²	2,4±0,8

Ultra Fine Grain

Unirradiated:



Irradiated:

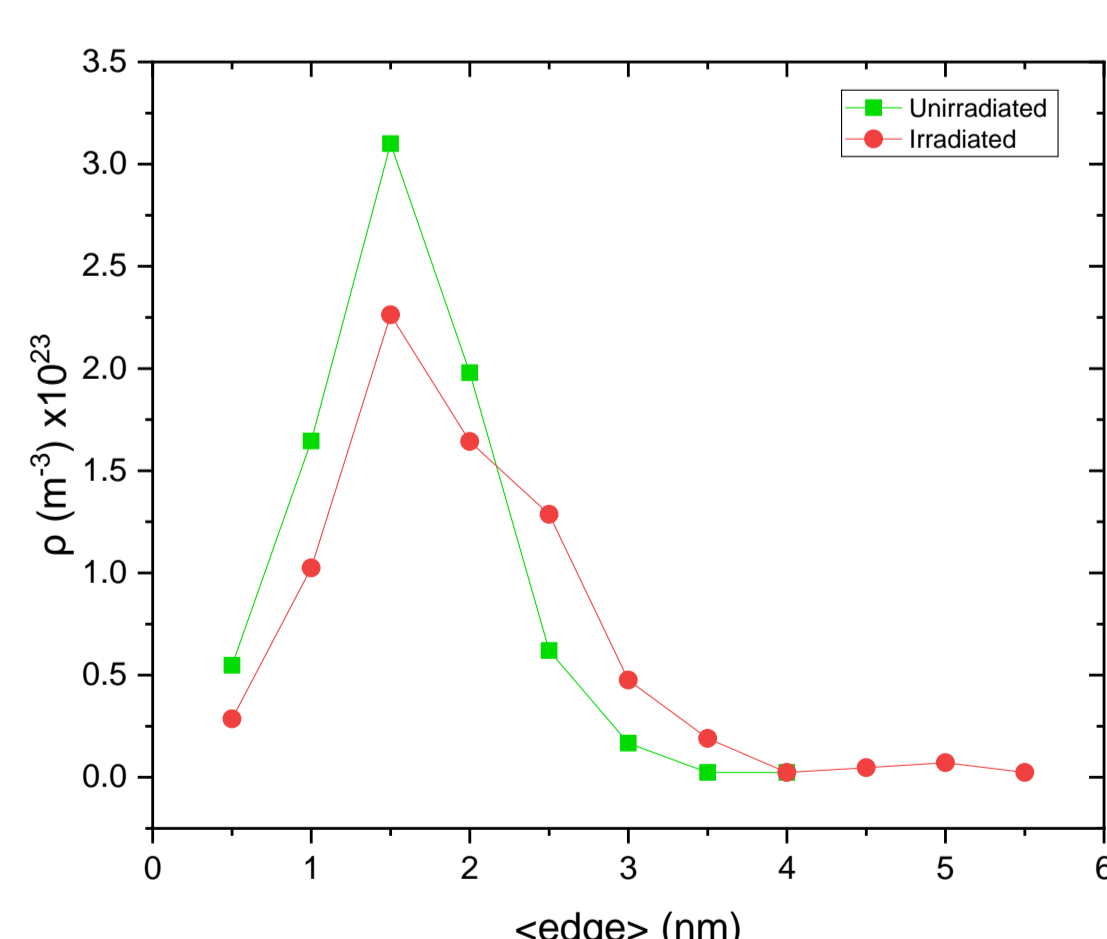


- Grain size: 185 nm
- 2 types of clusters:

Discussion

Stability of nano-oxides → slight coarsening

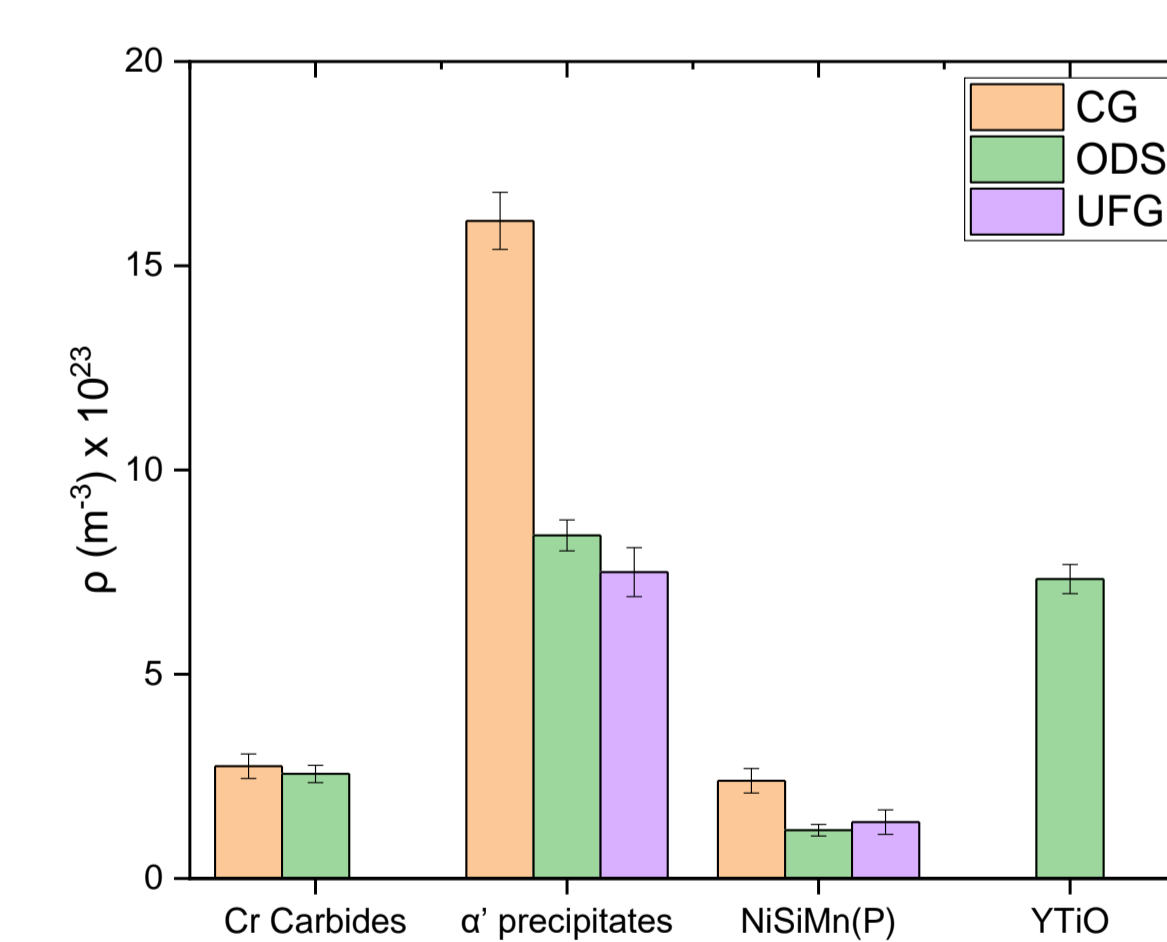
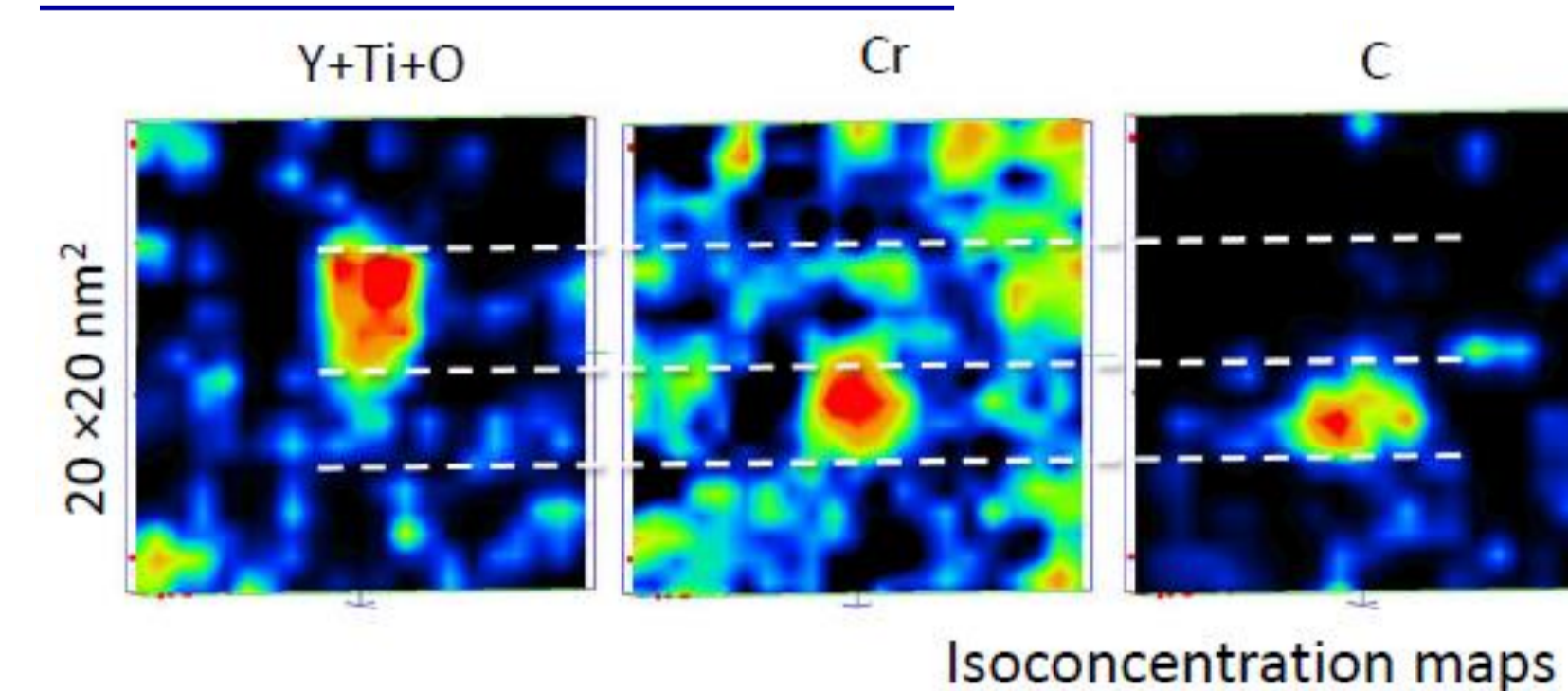
(Y Ti O)	ρ (m ⁻³)	<Size> (nm)	fv%
Unirradiated	(8,1±0,3) x 10 ²³	1,3±0,1	0,11
Irradiated	(7,3±0,4) x 10 ²³	1,6±0,1	0,07



Formation of clusters:

1. **Cr Carbides** : Due to C contamination during irradiation
2. **α' precipitates** : Due to Radiation Enhanced Diffusion
3. **NiSiMn(P)** : Unexpected family of clusters, possible mechanism: Radiation Induced Segregation at different sinks

Localisation of Cr carbides :



Grain size effect.

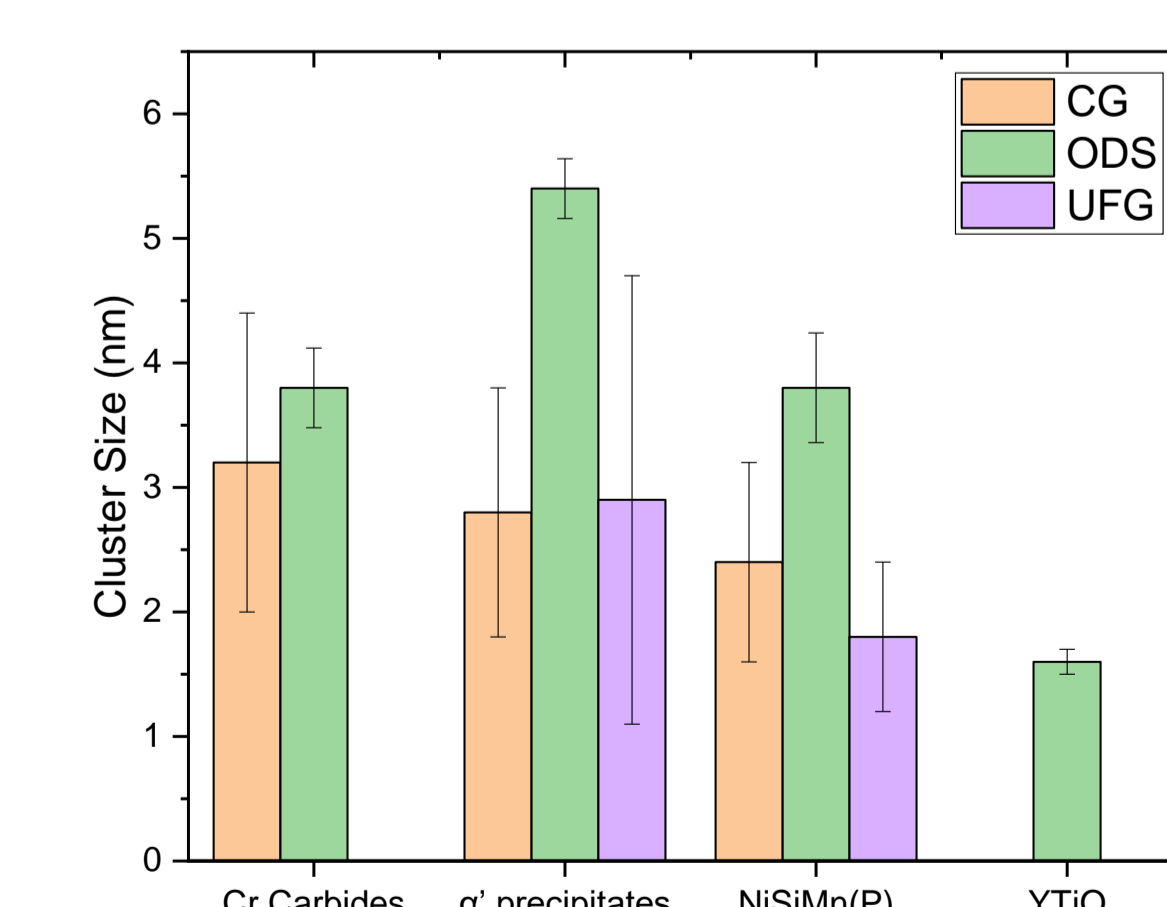
CG vs UFG :

- Absence of Cr Carbides for the UFG
- No grain size effect (for ρ or cluster size) for the α' precipitates
- Slight grain size effect for the Ni family clusters

Effect of nano-oxides :

CG vs ODS :

- Largest cluster size → ODS
- Highest cluster number density → CG



Conclusion

- ✓ **Stability of nano-oxides & slight coarsening after irradiation**

After irradiation: Cr carbides, α' precipitates and NiSiMn(P) clusters

→ Not efficient resistance after irradiation

Acknowledgments

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