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ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Materials Conference 2024
July 22-26, 2024, Geneva, Switzerland

MAX PLANCK INSTITUTE FOR SUSTAINABLE MATERIALS

Designing high Cr-alloy Eurofer with advanced properties by cryogenic processing for fusion

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Geneva, July 23rd 2024

SURFACE SCIENCE FOR FUTURE MATERIALS
SURFACES

Content

- Future Energy Sector
- Metallic Materials
- Cryogenic treatment
- Eurofer97
- Conclusions

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About me

Patricia. Credit: Patricia Jovičević-Klug.

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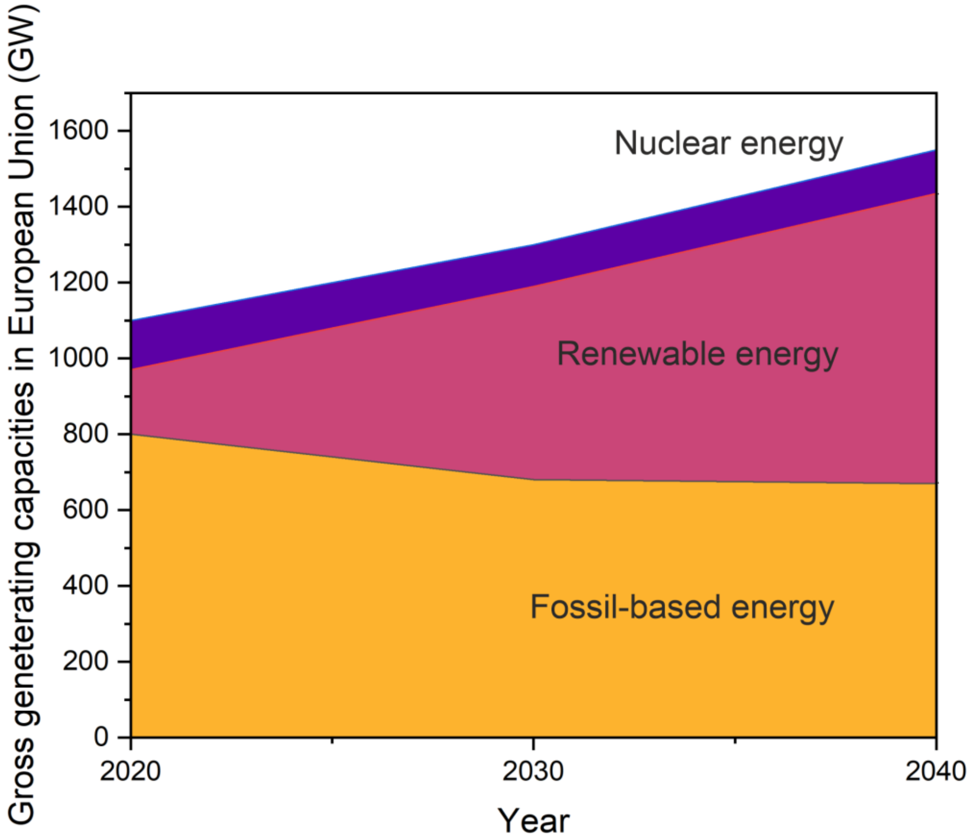
- ➢ 2024-2026: PostDoc in Alternative Materials used for Fusion awareded by Marie Skłodowska-Curie Actions (Germany)
- ➢ 2024: Group Leader of Surface Science for Future Materials
- ➢ 2023-2024: PostDoc in Materials used for Energy Sector awareded by Alexander von Humboldt Fellowship (Germany)
- ➢ 2022: PhD in Nanosciences and Nanotechnologies (Slovenia)

Future Energy Sector and Metallic Materials



Jovičević-Klug et al. 2024.

Ferrous alloys	Non-ferrous alloys
➢ Austenitic stainless steel	➢ Zr-based alloys
➢ Cast austentic stainless steels	➢ Ni-based alloys
➢ Martensitic stainless steels	➢ ODS alloys ➢ ODS ferritic alloy
➢ Duplex steels	➢ W-based alloys
➢ Low-alloyed steels	➢ Cu-based alloys
➢ Ferritic steels	➢ Pb-Al-based alloys
➢ Bainitic steels	➢ HEA
➢ RAFM steels (Eurofer, CLAM etc.)	➢ Mo-based alloys
➢ Ferritic steels	➢ Nb-based alloys
	➢ V-based alloys

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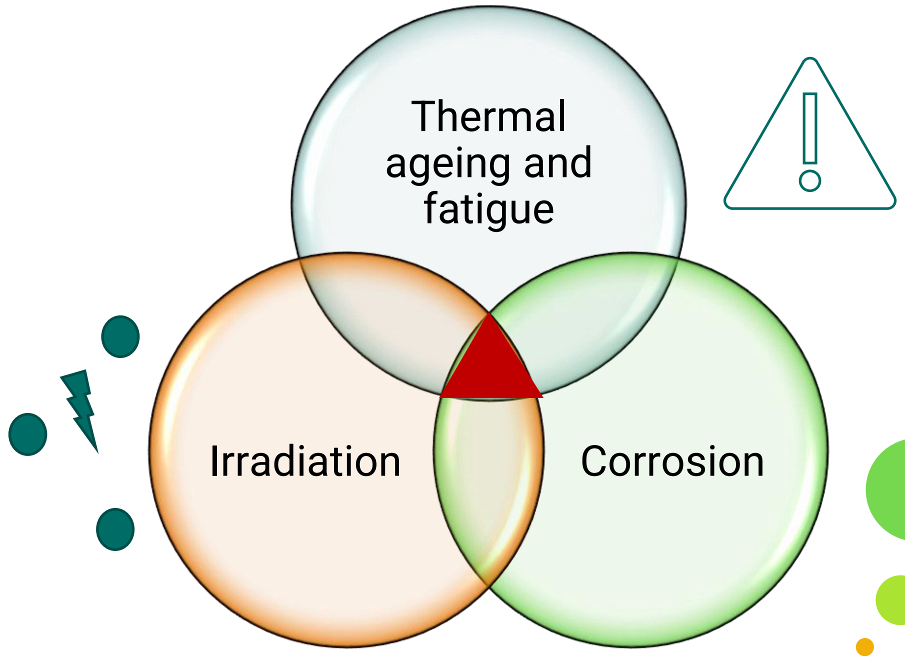
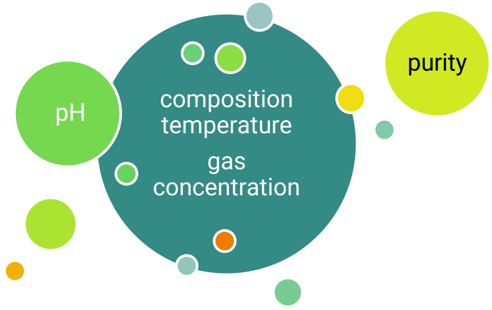
Fusion and Challenges of Materials

Metals (ferrous and non-ferrous alloys):

- high-energy particles
- high temperatures
- pressure changes
- highly corrosive environments





Options

- tailoring microstructure
- coatings
- nitriding etc.
- CRYOGENIC PROCESSING

Cryogenic processing (treatment)

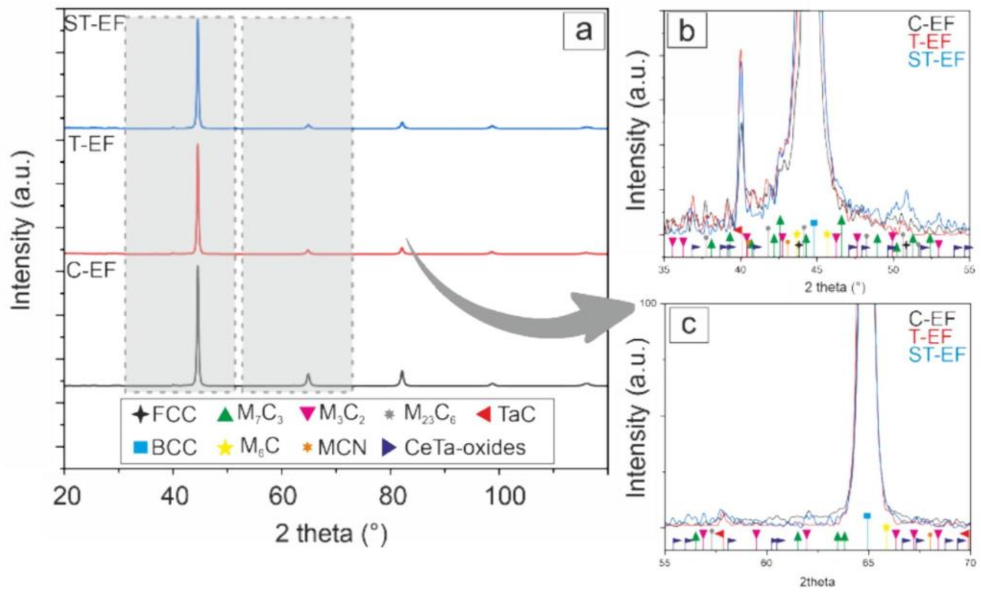
Cryogenic treatment

Conventional cryogenic treatment	Shallow cryogenic treatment	Deep cryogenic treatment
(273 K) – (193 K)	(193 K) – (123 K)	below 123 K

- increases tool life
- Improves mechanical properties (5-50%)
- improves corrosion and wear resistance (up to 30%) etc.
- cuts operating costs

Study of Eurofer97

Sample group	Heat processing		
	Hardening	CP	Tempering
EF-CHT	Ta = 1237 K/ 0.5 h, Q rate ~ 10 s from 1073 K to 773 K	–	Tt = 823 K / 2 h
CRYO (T-EF, ST-EF)	Ta = 1237 K/ 0.5 h Q rate ~ 10 s from 1073 K to 773 K	DCT 24 h / 77 K	Tt = 823 K / 2 h



	C-EF	T-EF
BCC phase	88.4	88.6
FCC phase	1.2	0.1
M_7C_3	3.5	4
M_3C_2	1.9	1.7
M_6C	1.7	1.1
$M_{23}C_6$	1	1.6
TaC	0.3	0.5
MCN	0.6	0.6

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Jovičević-Klug et al. 2024.

Study of Eurofer97

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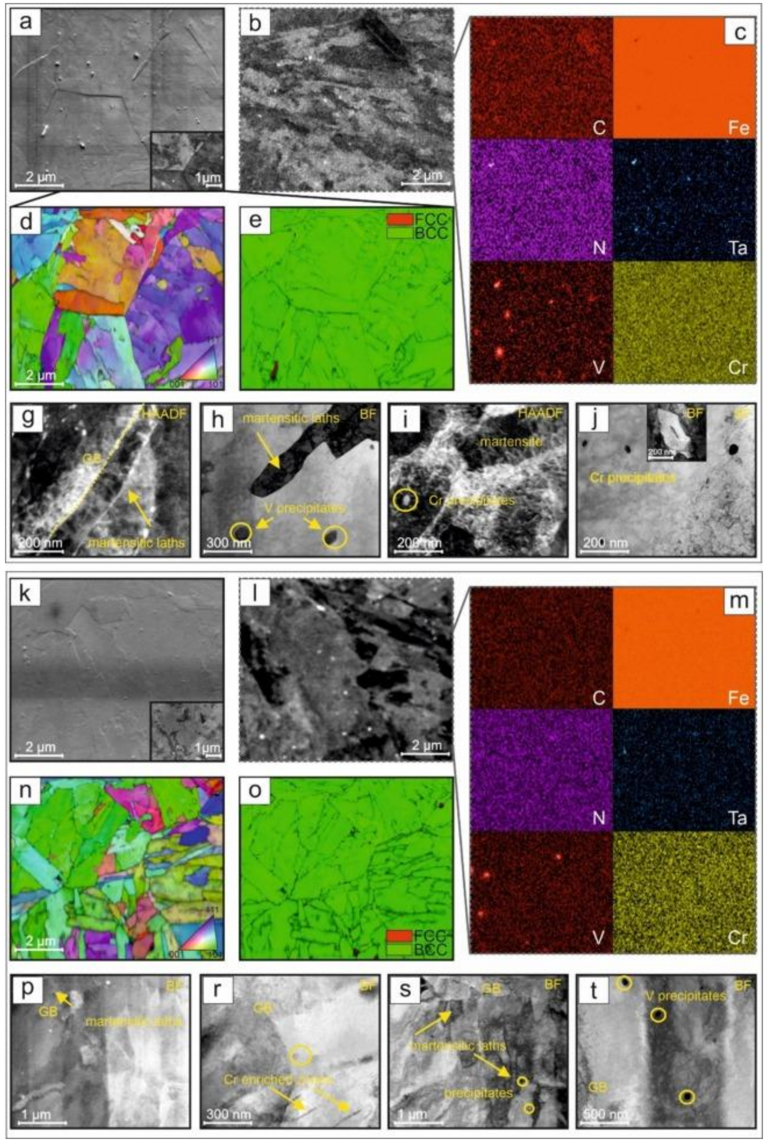

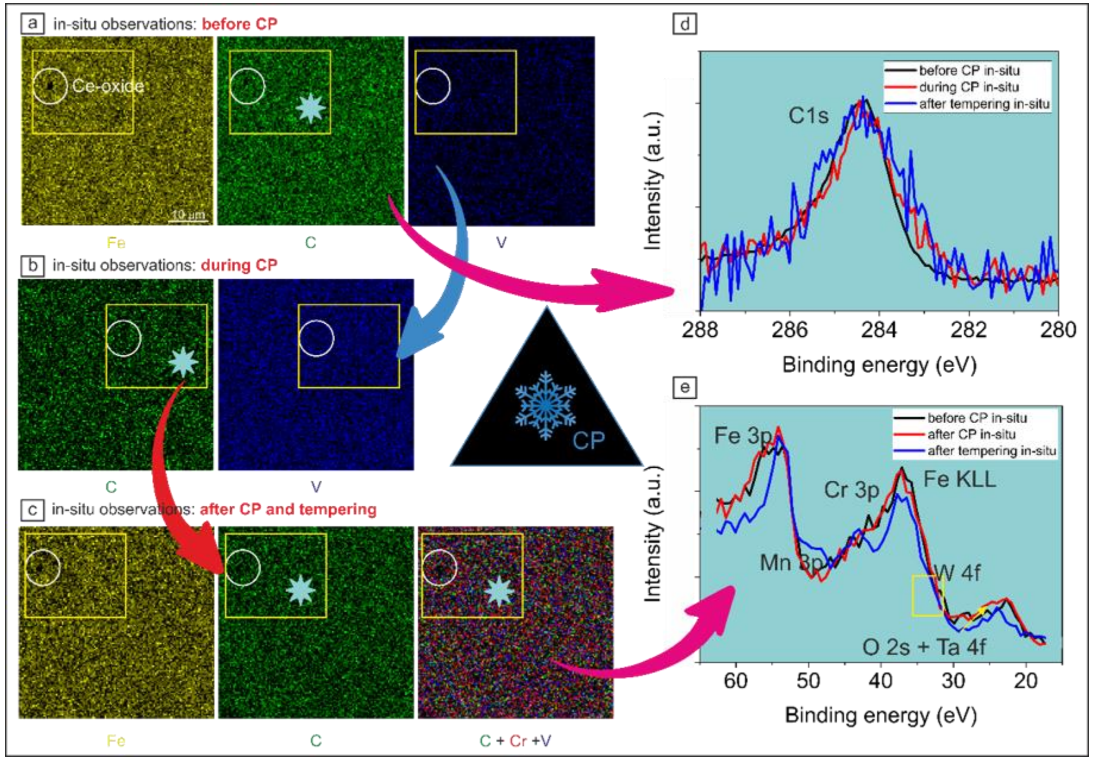

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Conclusions

- energy sector has a high demand for the improvement of metallic materials
- CP can be used to successfully manipulate the microstructure
- Ta and Mn dynamics on the surface layer may be important for the characteristics of the passivation layer
- CP has a bright future in alloying metallic alloys and to design a proper heat processing for changing properties for community to accelerate the understanding of Eurofer alloying dynamic and how the microstructure can be tailored to specific needs and applications
- detailed and systematic investigation of the effectiveness and application of CT is required

Thank you for your attention!

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DCT