Modelling
Corrosion and mass transfer

IAEA Technical Meeting on Compatibility Between Coolants and Materials for Fusion Facilities and Advanced Fission reactors
30 October - 3 November 2023, Vienna

Luigi Di PACE, RINA Consulting, Italy
Overview of ACP simulation codes suitable for the fusion field

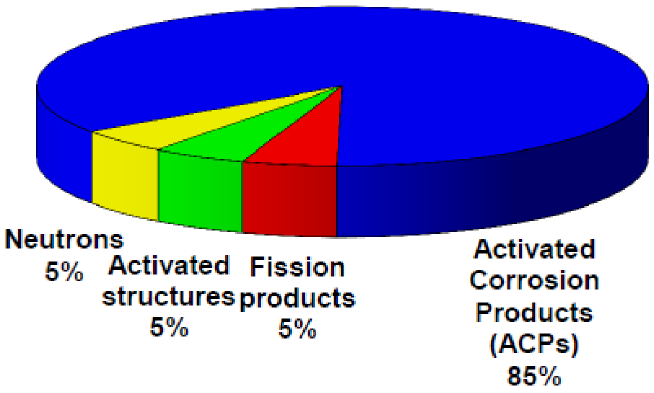
Frédéric DACQUAIT, CEA, France
Modelling the corrosion product transfer in fusion systems: the OSCAR Fusion code

Dario CARLONI, ITER Organization
Parametric study of ITER main Primary Heat Transfer System coolant chemistry and operational parameters using OSCAR-Fusion v1.4.a code

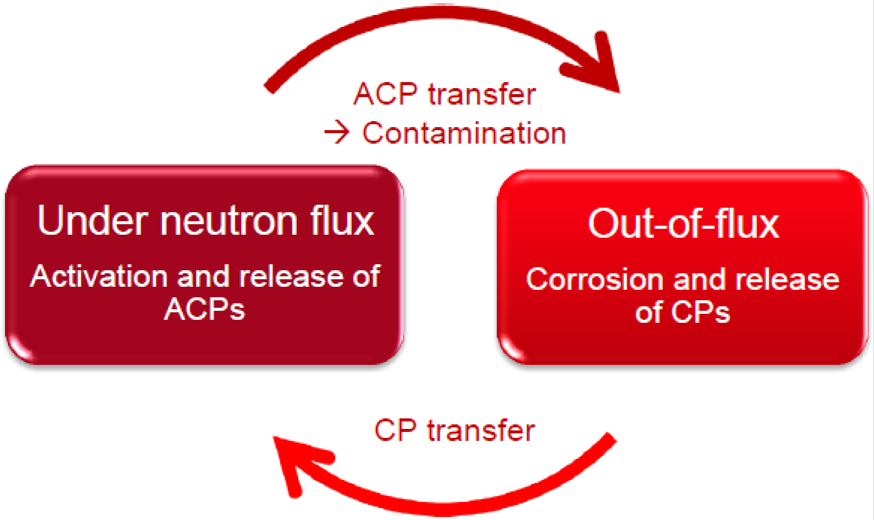
Chloé CHERPIN, CEA, France
Improving the prediction of activity transfer in nuclear water circuits by integrating colloidal behaviour : modelling and experimental advances for the OSCAR code

Chantal SHAND, UKAEA, UK
Modelling the transport of activated fluids and corrosion products in cooling environments

Collective dose for operation and maintenance of PWRs



Principle of contamination transfer in a nuclear cooling system



Type of contamination (always)

- ACPs
- CAPs

Types of contamination

- Surface
- Volume

Forms of contamination transfer

- Solubles
- Particles
  - < 1 µm (colloïds)
  - > 1 µm

Stakes:

- Radioprotection: Reduction of Occupational Radiation Exposure (ORE)
- Environment: Minimization of release/waste – Optimization of dismantling process
- Availability: Optimization of reactor operation
- Safety: Source term in case of accident/incident

Neutron activation reactions:

- $^{54}Fe\ (n,\ p)\ ^{54}Mn$
- $^{63}Cu\ (n,\ \alpha)\ ^{60}Co$
- $^{16}O\ (n,\ p)\ ^{16}N$
- ……

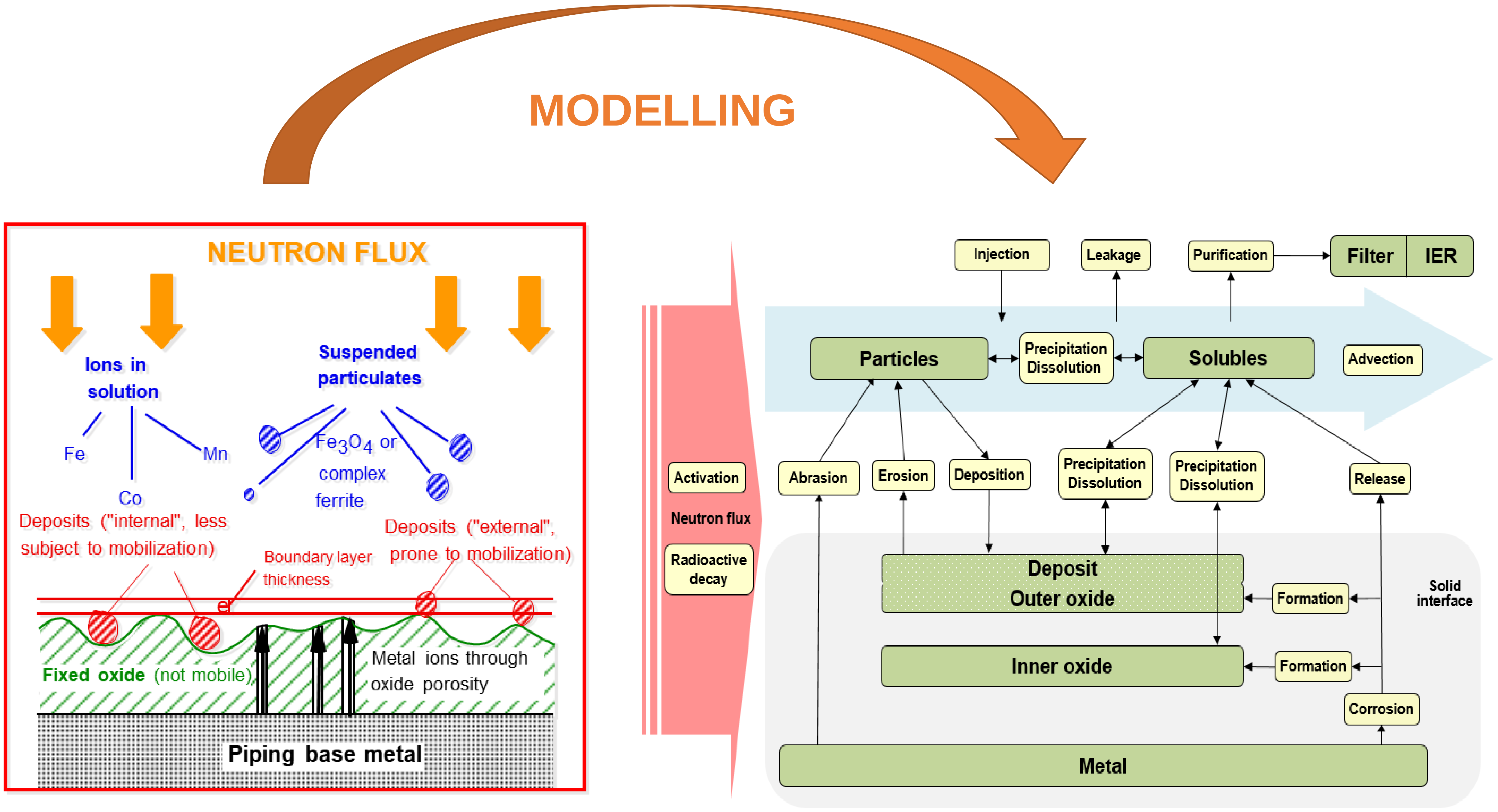
Fundamental safety function for DEMO

Key uncertainty for ITER safety demonstration

Need to control contamination

- Specifications on
  - Materials (composition, manufactoring process)
  - Coolant chemical conditionning (pH, redox)
  - Operation

- Development of simulation codes


MODELLING
NEUTRON FLUX
Ions in solution
Fe
Co
Mn
Suspended particulates
Fe_3O_4 or complex ferrite
Deposits ("internal", less subject to mobilization)
Deposits ("external", prone to mobilization)
Boundary layer thickness
e
Fixed oxide (not mobile)
Metal ions through oxide porosity
Piping base metal
Activation
Neutron flux
Radioactive decay
Injection
Leakage
Purification
Filter
IER
Particles
Precipitation Dissolution
Solubles
Advection
Abrasion
Erosion
Deposition
Precipitation Dissolution
Precipitation Dissolution
Release
Deposit
Outer oxide
Formation
Solid interface
Inner oxide
Formation
Corrosion
Metal

Numerous calculation codes

- Mainly for PWRs: ACE, CRUDTRAN, CORA, OSCAR…)
- Codes for Fusion reactors: TRACT, CATE, OSCAR-Fusion (Reference code for ITER and EU-DEMO)
- Codes for liquid metal coolant reactors: OSCAR-Na,…
- Fuid activation codes & tools (UKAEA): GammaFlow, ActiFlow & FARBASE

- **Codes for Fusion reactors leverages from codes for Fission reactors**:
  - Models of corrosion/release, dissolution/precipitation, erosion, deposition under sub-cooled nucleate boilling conditions, deposition of colloïds, ….)
  - Large validation domain for OSCAR

- OSCAR-Fusion used for predicting and optimizing design and operating parameters for ITER (pH, H_2, CVCS flow rate, baking, roughness, Co content)

- But specific characteristics of Fusion reactors:
  - Materials (RAFM steels, Cu-base alloys)
  - Variability of neutron flux
  - Plasma pulsed mode
  - High energy neutron flux
  - Cyclic slightly oxidizing environment
  - Intense magnetic field

Needs to conduct experiments in test loops

- Existing loops at CEA (used for PWRs), Studsvik, RINA, in China…
- Projected loops at JET, UKAEA, RINA….

➢ To obtain data (corrosion rates, deposition rates, zêta potentials…) and to validate codes for ACPs and CAPs

CONCLUSION

- **Very strong synergy** between **LWRs, Advanced fission reactors** (EPRs, SFRs, SMRs…) and **Fusion facilities** (ITER, DEMO, DTT) **for the modelling of contamination transfer in cooling systems** (interactions between coolants and materials)

- **Fusion scientific community benefits from over 5 decades of experience from Fission scientific community** (tests loops, calculation codes and expertise)

- Advancements in Fusion also drive progress in Fission