On the manufacturing process of novel ultra-radiopure, high-strength, electroformed Cu-based alloys for rare event searches

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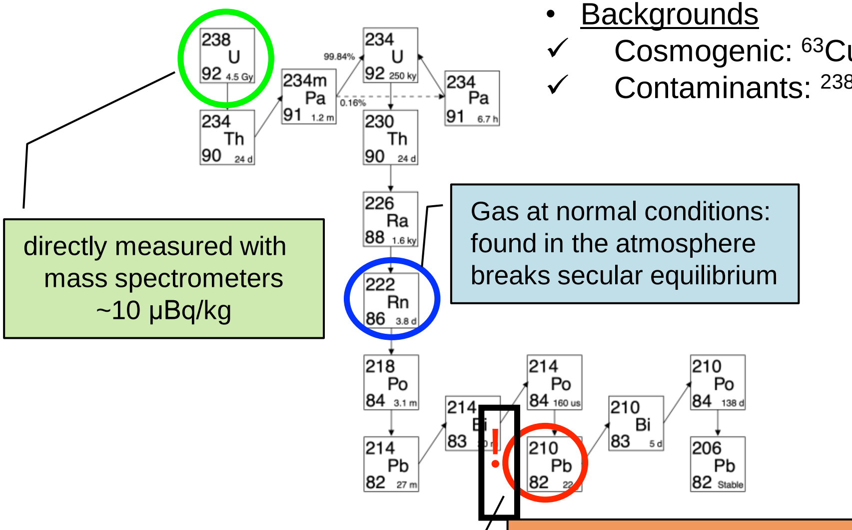
Horizon Europe

Motivation of radiopure Cu for rare event searches

- Cu: common material for rare event searches experiments
  - ✓ Electrically conductive
  - ✓ Strong enough to build low-pressure gas vessels
  - ✓ No long-lived isotopes (^{67}Cu $t_{1/2}$=62h)
  - ✓ Low cost/commercially available at high purity
- Backgrounds
  - ✓ Cosmogenic: ^{63}Cu(n,α)^{60}Co from fast neutrons
  - ✓ Contaminants: ^{238}U/^{232}Th decay chains



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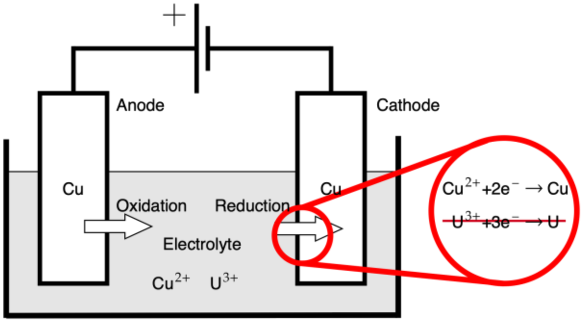
Motivation of radio-pure Cu for rare event searches

Cu 'High reduction potential'

→ Preferentially deposited → Additive-free, electroforming



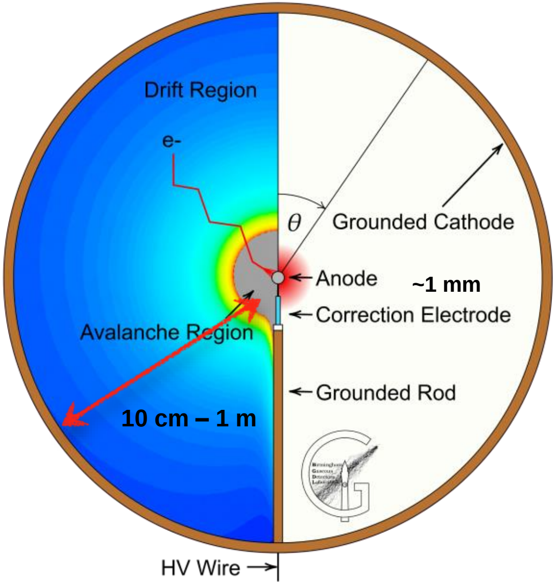
rare event searches:
e.g. LEGEND, NEWS-G, ANAIS, Majorana, nEXO

Motivation of ultra-pure, high-strength Cu-based alloys

- ✓ Retain EFCu capabilities for rare event searches
- ✓ Option for stronger material compared to Cu
- ✓ Scale up the current geometries for gas vessels (i.e. maximising the physics potential in DM experiments)

<u>fundamental science applications</u>:
e.g. NEWS-G, nEXO, NEXT

<u>other applications</u>:
- Electronic circuits
- Storage technology



Pierre Gorel
Poster/ 35

NEWS-G S140 in SNOLAB

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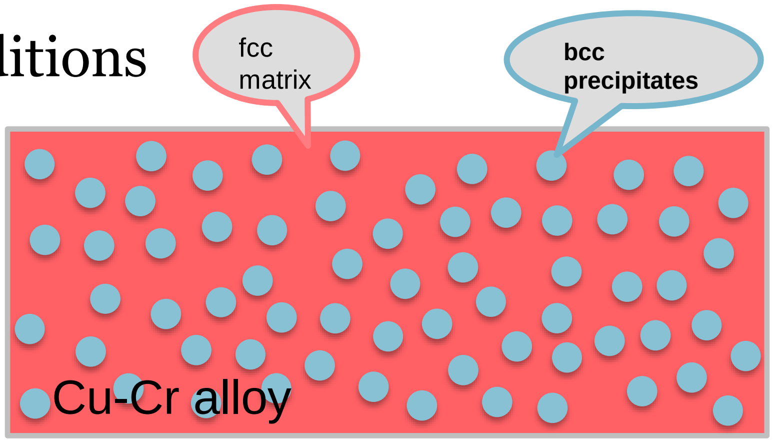
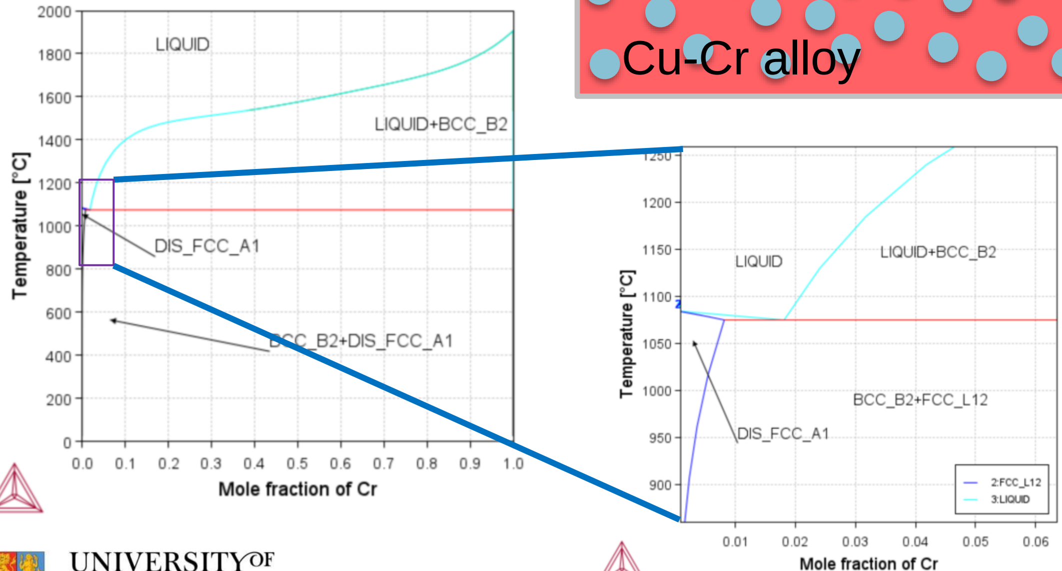
Alloying Cu with Cr additions

- ✓ retain Cu electrical conductivity
- ✓ stronger than Cu
- ✓ radiopure





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Alloying Cu with Cr additions

1. Cr and Cu layers from separate solutions
2. Solution heat treatment at **1000ºC** (homogenisation)
3. Aging at **400ºC – 12 hours** (precipitation strengthening)

Sample	[Th] pgTh/gSample	±sd	[U] pgU/gSample	±sd
EFCu	0.011	0.005	0.017	0.003
Cr	8.72	0.32	2.37	0.61
Cu-Cr(0.585wt%) **projection**	0.062	0.007	0.031	0.007

Cr and Cu layers

Cr	Cu	Cr	Cu

EFCu	72 HV
Cu-0.585Cr	121 HV

~70% stronger

Suriano et. al. AIP Conf. Proc. 1921, 1003 (2018) 080001

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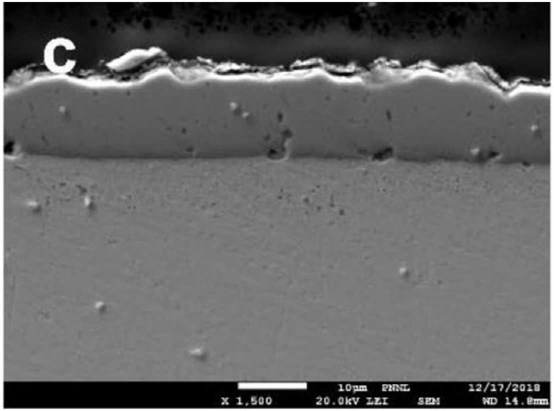
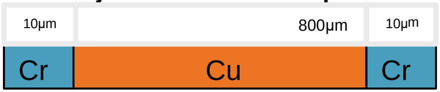
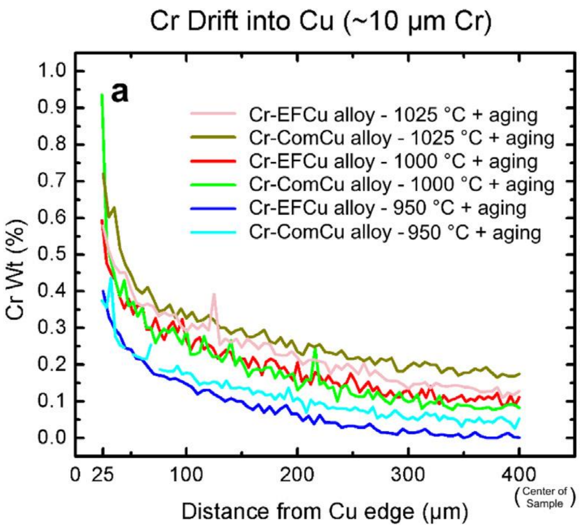
Towards simplifying manufacturing process



10 μm Cr on Cu

adjacent diffusion couples





Explore which model resembles findings

A. Vitale et. al. Nuclear Inst. and Methods in Physics Research, A 1003 (2021) 165291

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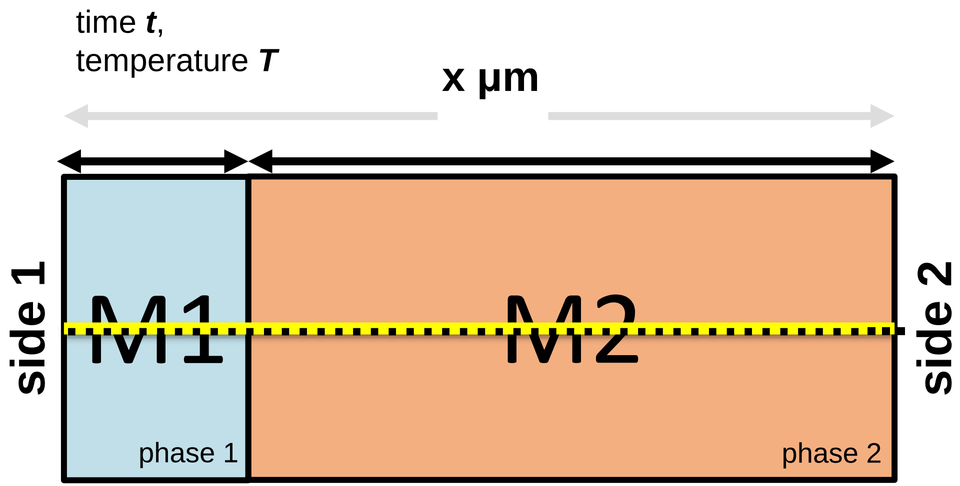
Modelling: DICTRA 1D Simulations



Outputs in 1D:
- ✓ Composition profiles
- ✓ Phase fraction profiles

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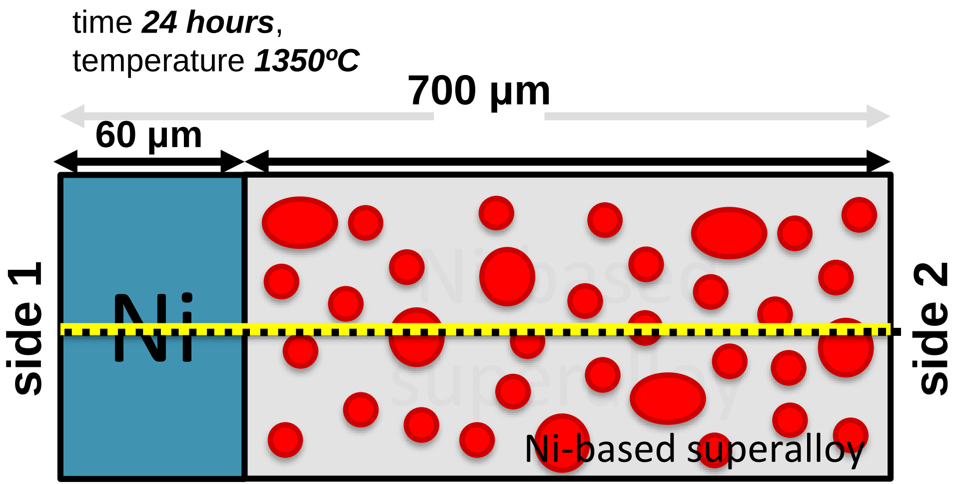
J.-O. Andersson et al., Calphad, 26, (2002) 273–312.

Modelling: Diffusion Couple (complex microstructures)



Spathara et al, Metall Mater Trans A, 49 (2018) 4301–4307

Outputs in 1D:

- ✓ Composition profiles
- ✓ Phase fraction profiles

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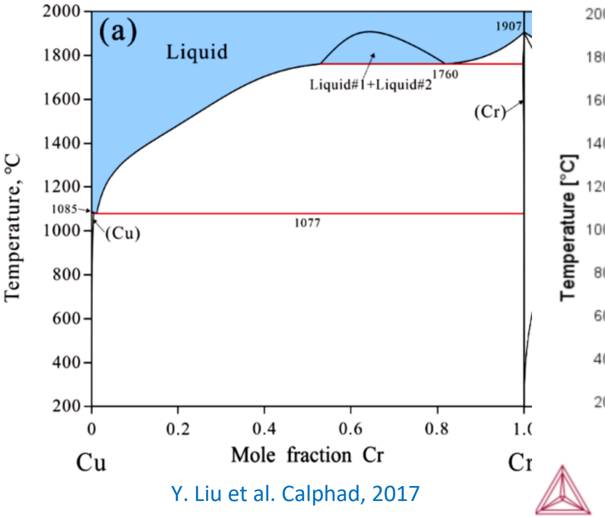
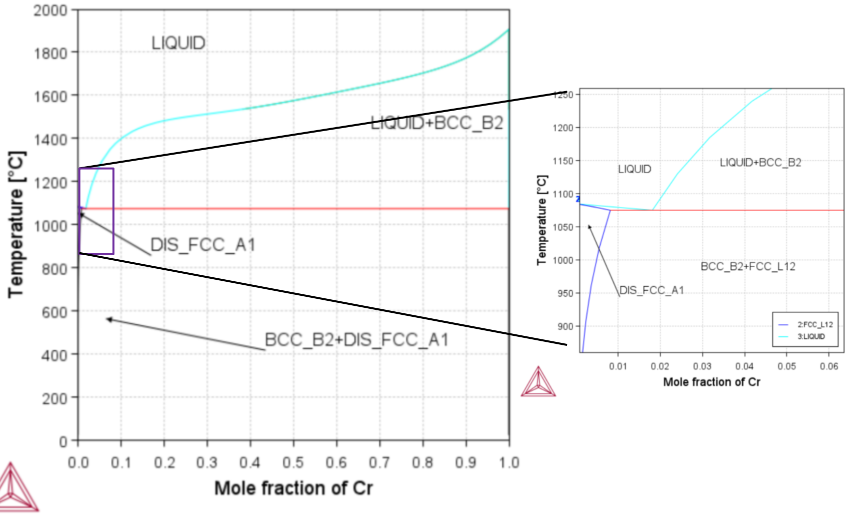
On the accuracy of thermodynamic description

Cu-Cr



Y. Liu et al. Calphad, 2017

TCHEA6



Cr-Cu-Ti evaluation: Y. Shi. et. al, Calphad, 2023

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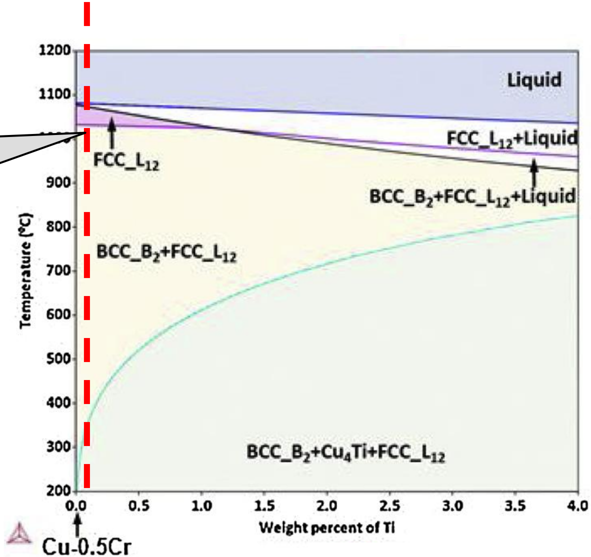
Adding Ti as a 3rd element towards a CuCrTi alloy

Cu-0.5Cr-0.2Ti alloy (after casting):
✓ hardness 192.6 HV,
✓ tensile strength 629.3 MPa,
✓ yield strength 603.0 Mpa



Thermo-calc Cu-based alloys database

Z. Huang et. al, Mater Today Comms 2021

Challenges for CuCr radio-pure alloys:
- Limited to low voltages
- Any deformation (heat entailing)
- Cr solubility
- Heat treatments / aging for large scale structures

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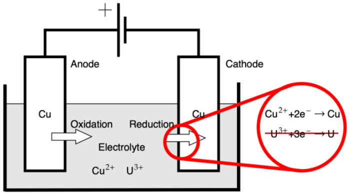
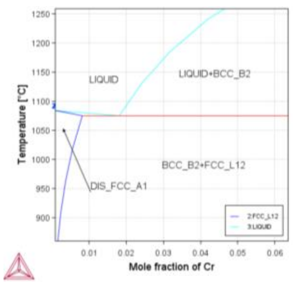
Summary



- EFCu current choice of material
- *PureAlloys* project:
  → ultra-radiopure, high strength Cu-based alloys

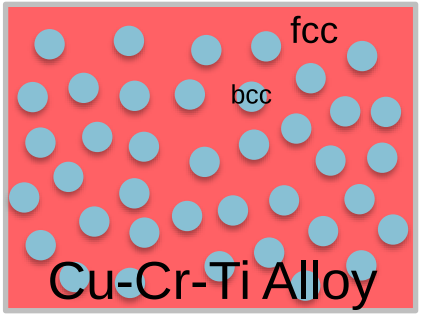
Cu-Cr



- On thermodynamic and kinetic properties
  → accurate description required

<u>Plan</u>:

- ○ Develop strengthening mechanism model
- ○ Alloy manufacturing
- ○ Validate and optimise model



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