Designing ultra-radiopure, high-strength, electroformed CuCr and CuCrTi alloys, for rare event searches

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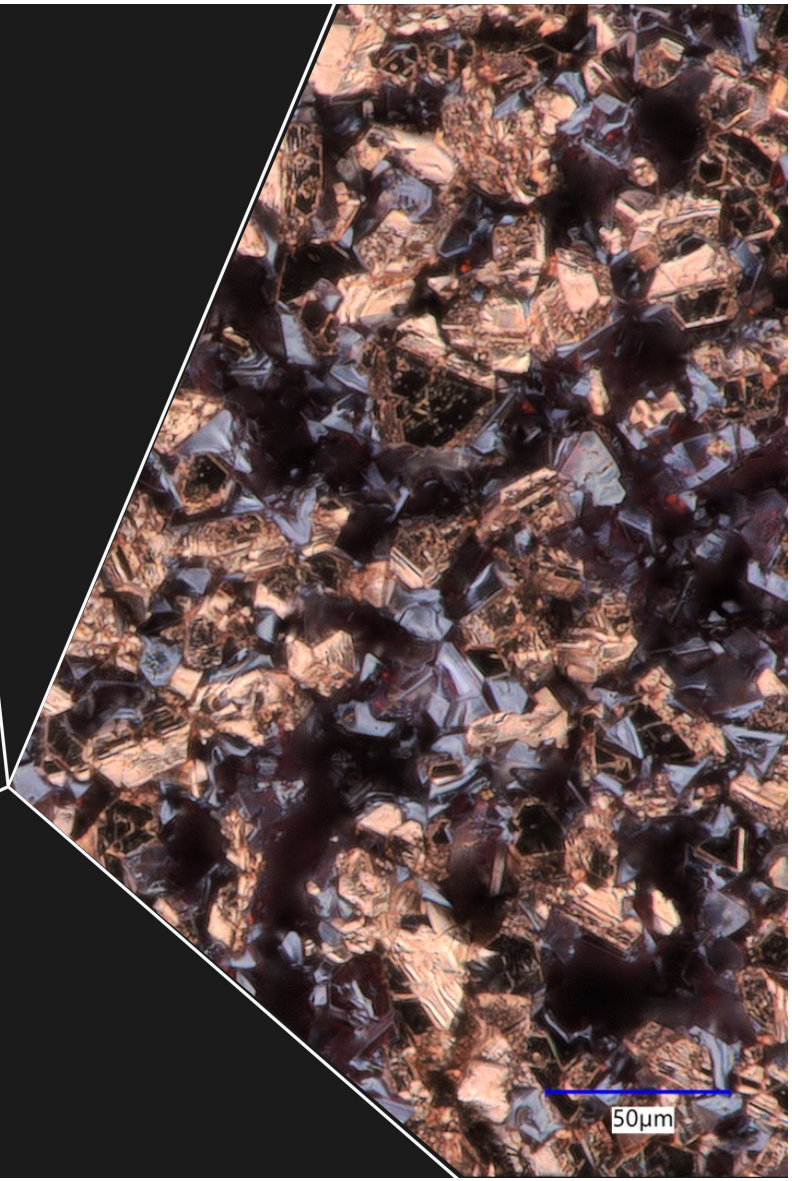

Motivation of ultra-pure, high-strength Cu-based alloys

- ✓ 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)

fundamental science applications:
e.g. DarkSPHERE, XLZD, nEXO, NEXT,

Alloying EFCu 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)

~70% harder

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

EFCu	72 HV
Cu-0.585Cr	121 HV

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

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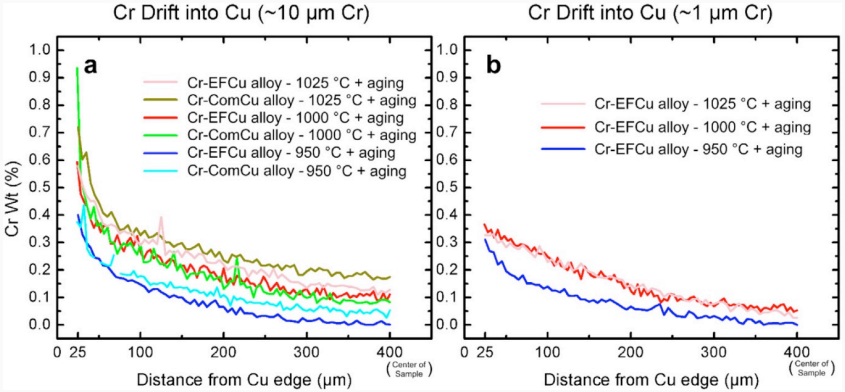

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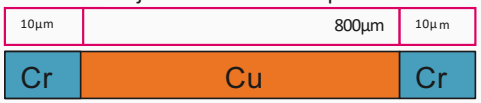
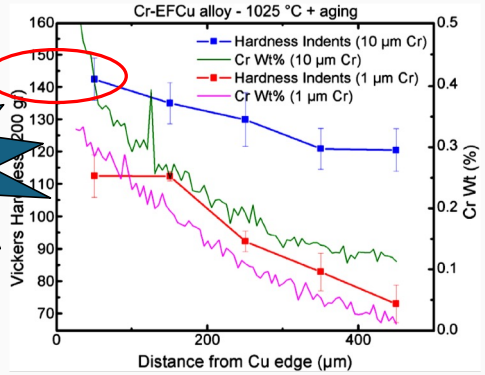
Cr and Cu layers

EFCu	72 HV
Cu-0.585Cr	121 HV

adjacent diffusion couples



~100% harder



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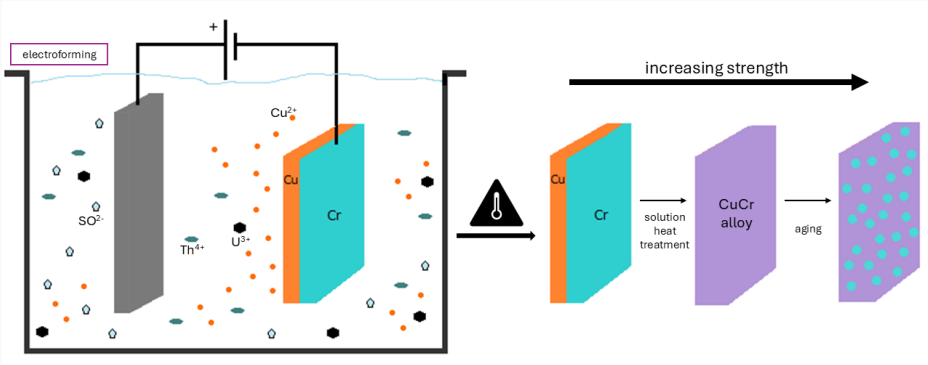
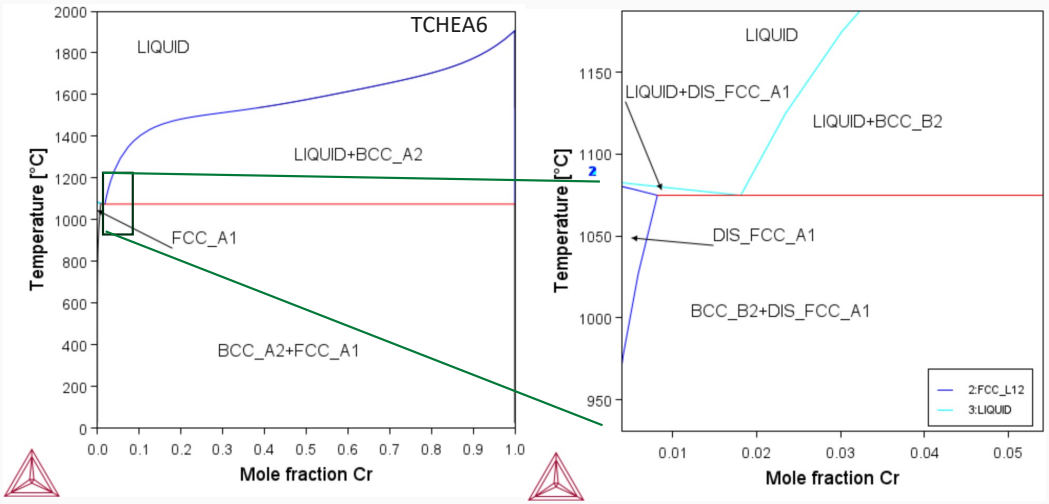
Suriano et. al. AIP Conf Proc 1921, 1003 (2018) 080001

A. Vitale et. al. NIMA 1003 (2021) 165291

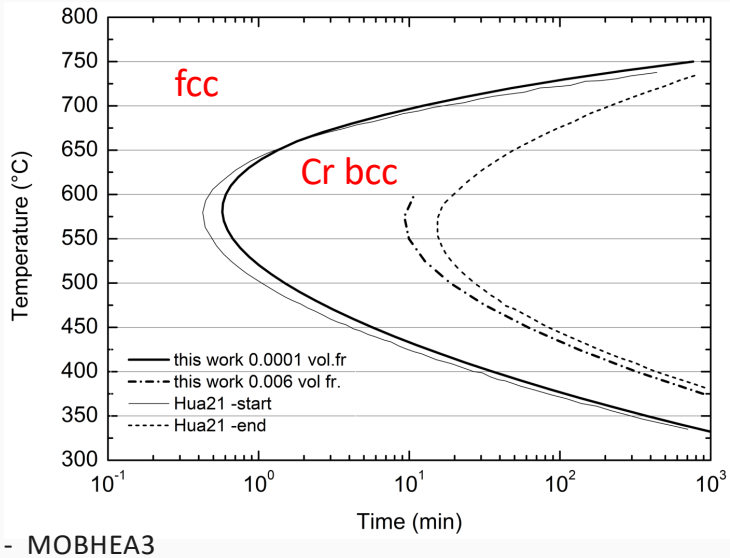
CuCr alloys
solution heat treatment
precipitation strengthening



Cu-Cr phase diagram



Calculated TTT diagram using TC-PRISMA



TCHEA6 - MOBHEA3
Compared with
TCCU3 - MOBCU3

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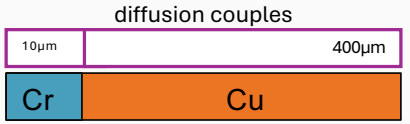
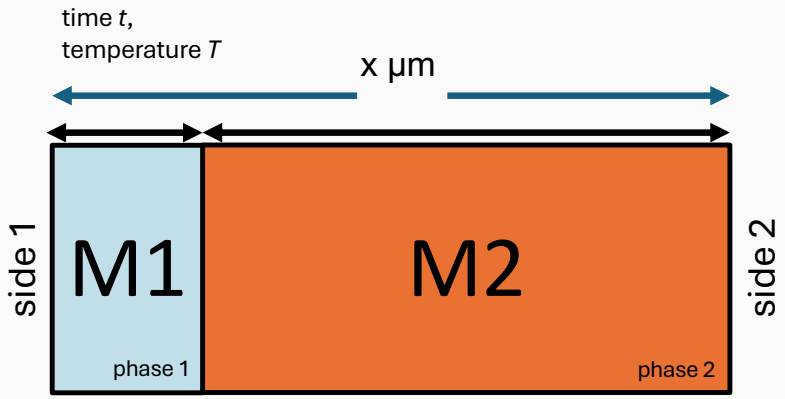
Modelling solution heat treatment

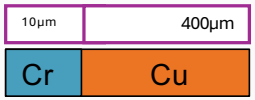


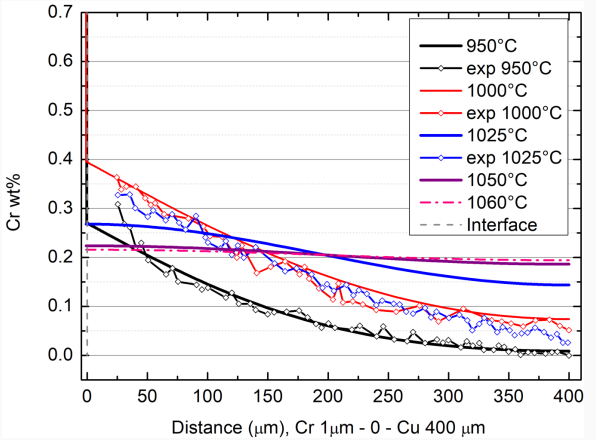
Predict *t* and *T* for solution heat treatment

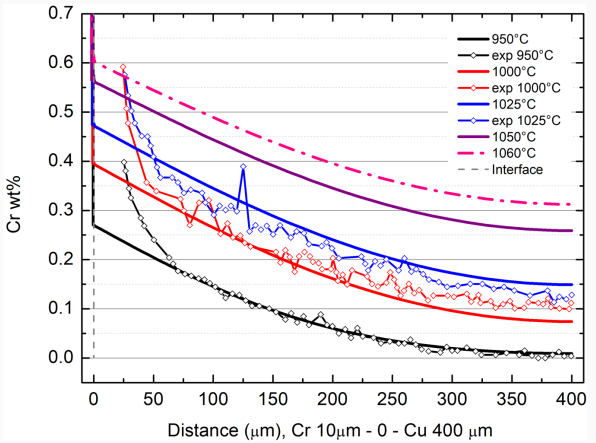


D. Spathara J Alloys Compd (2018)

Thermo-Calc databases
TCHEA6 - MOBHEA3
24h isothermals







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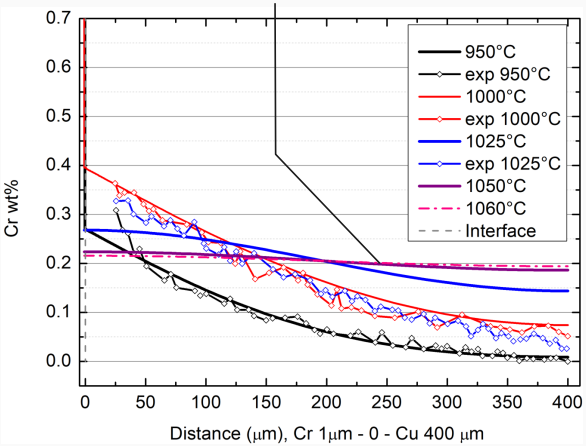
Modelling solution heat treatment

Cu-0.2Cr
1060°C or more than 24h



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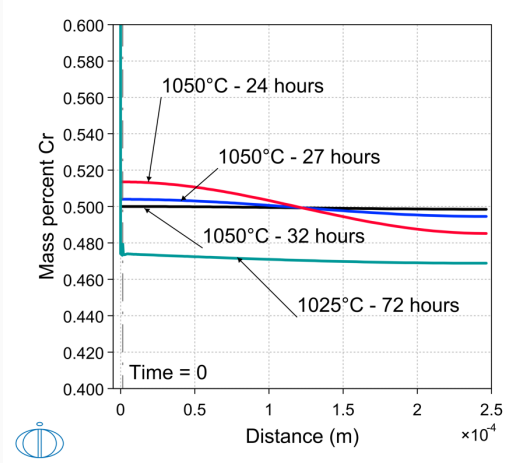
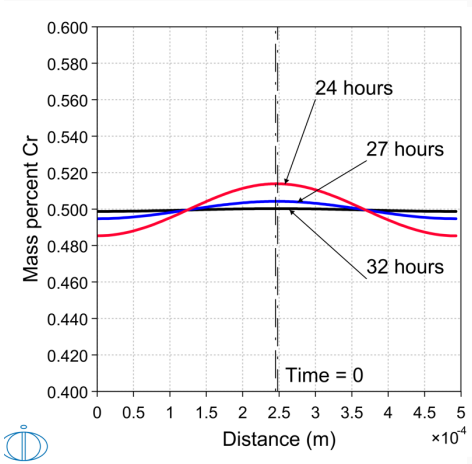
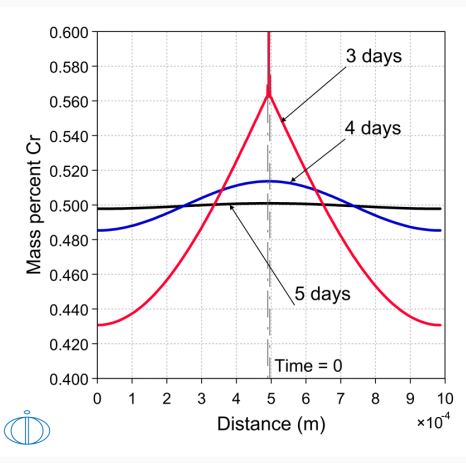
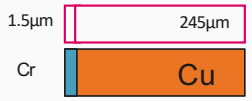
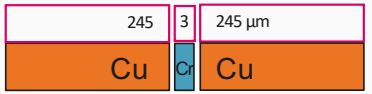
Solution heat treatment → Cu-0.5Cr – 32h

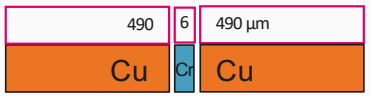












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Thermo-Calc databases
TCHEA6 - MOBHEA3

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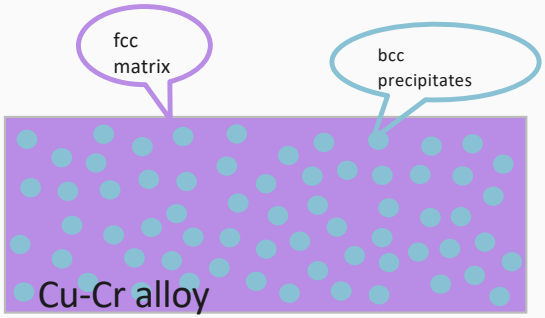
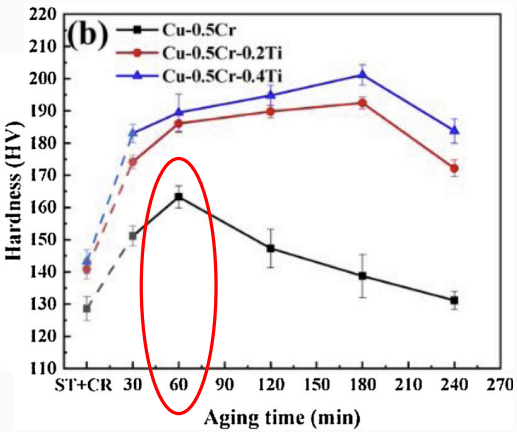
Strengthening mechanism during aging

Predict *t* and *T* for aging



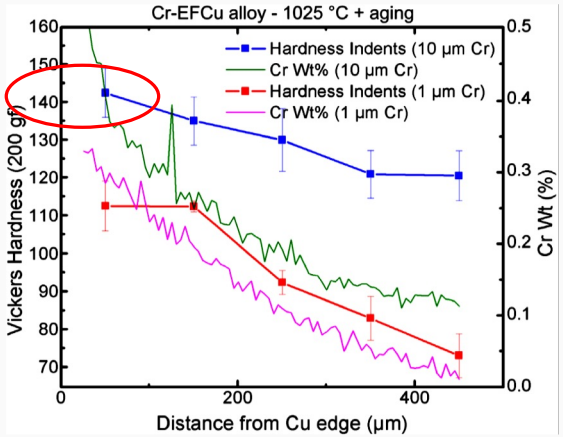
450°C – 60 min



Cu-0.5Cr	150 HV
Cu-0.5Cr0.2Ti	230 HV
Cu-0.5Cr0.4Ti	280 HV

Huang et. Al 2021

500°C – 12 hours



Cu-0.4Cr	140 HV

Vitale et al. 2021

EFCu	72 HV
Cu-0.585Cr	121 HV

Suriano et. al. 2018

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Predicting strengthening during aging using TC-PRISMA

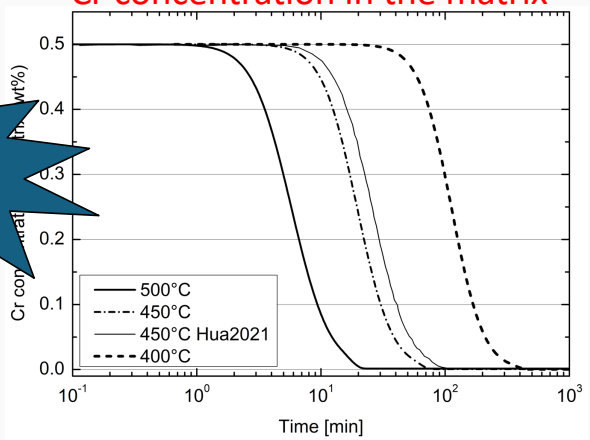
Effect of Ti in CuCrTi alloys (Huang et al. 2021)

Cu-0.5Cr

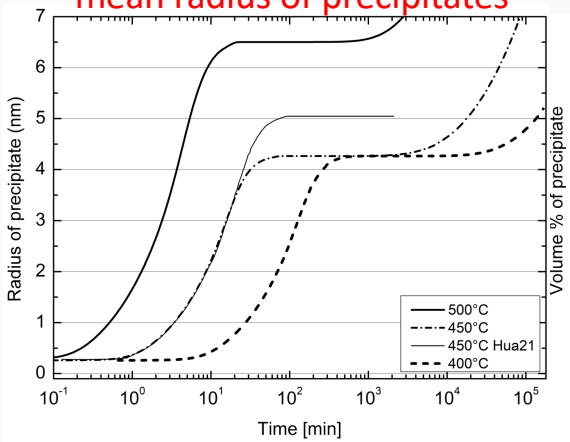
Thermo-Calc databases

TCHEA6 - MOBHEA3

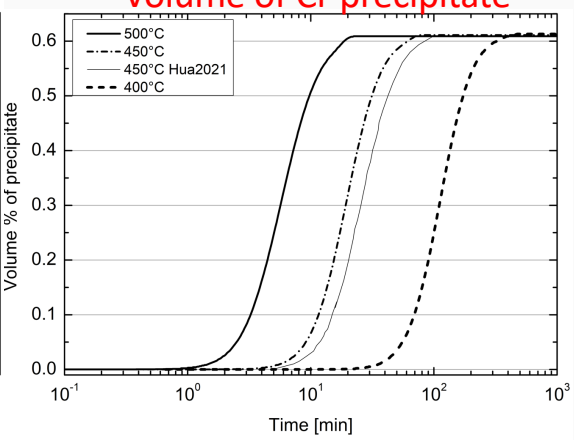
Cr concentration in the matrix



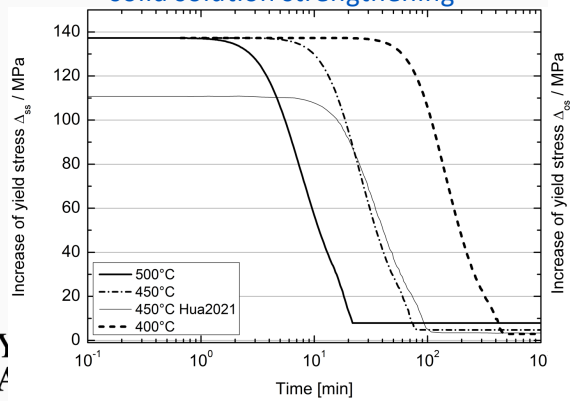
mean radius of precipitates



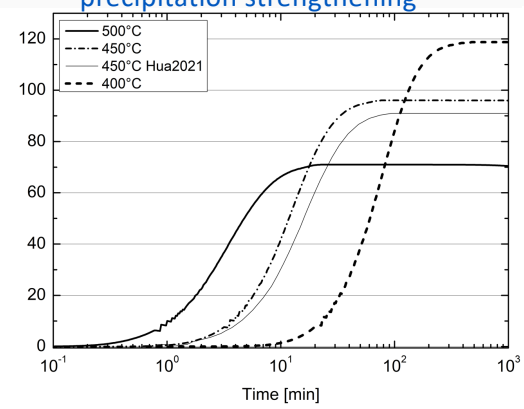
Volume of Cr precipitate



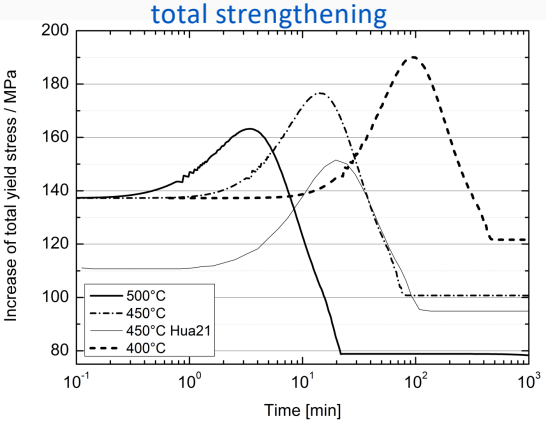
solid solution strengthening



precipitation strengthening



total strengthening



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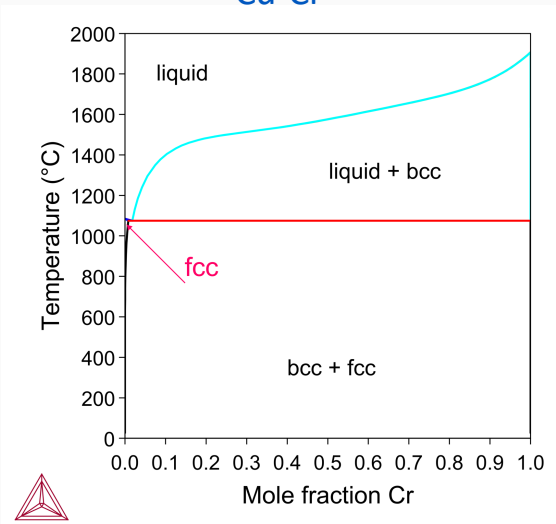
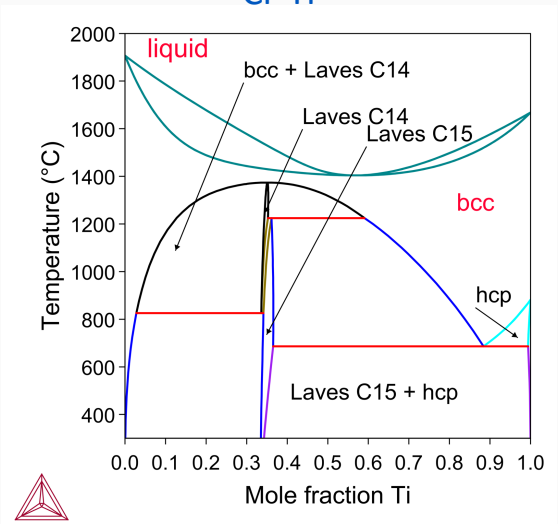
Radiopure Cu-based alloys: from CuCr to CuCrTi alloys

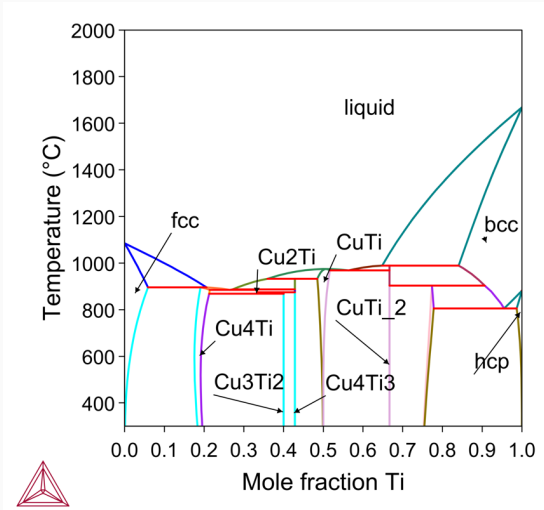
Cu-Cr

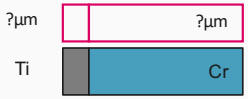


Cr-Ti

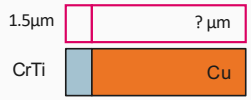


Cu-Ti





Cr-Ti



Cu-0.5Cr-xTi

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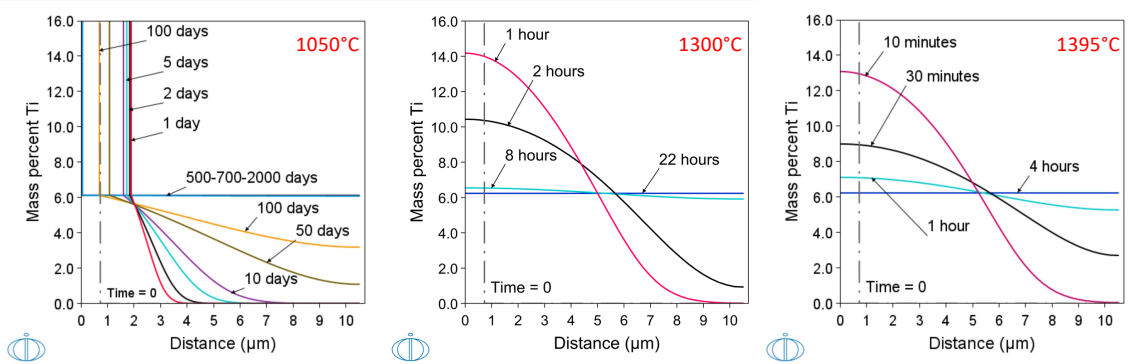
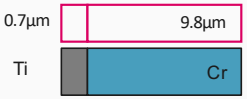
Radiopure Cu-based alloys: from CuCr to CuCrTi alloys

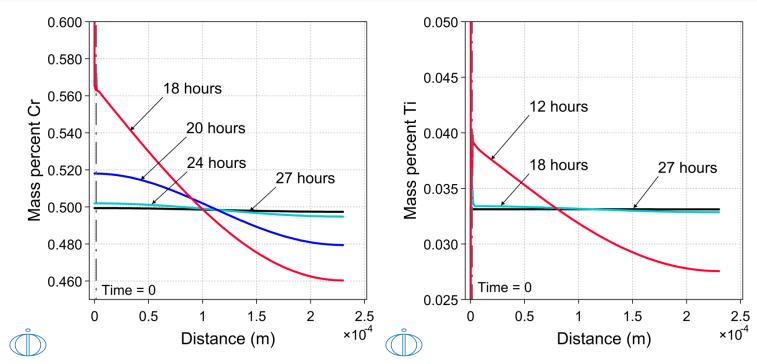


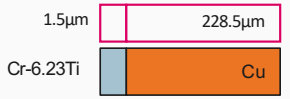


Cr-6.23Ti
3 temperatures

1050°C

Cu-0.5Cr-0.032Ti





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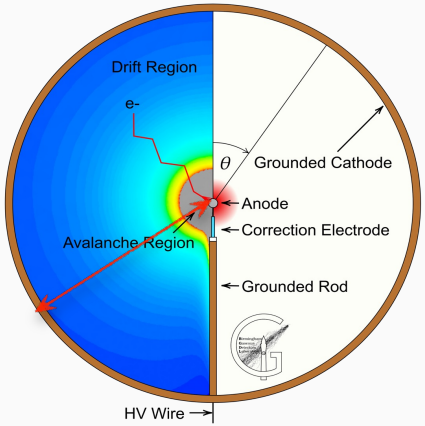
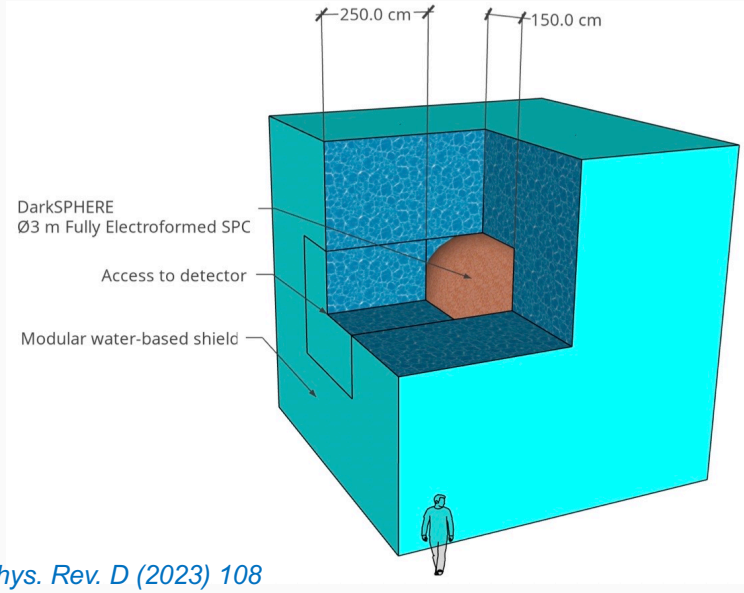
case study: DarkSPHERE

- ✓ 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)

a high-purity CuCr alloy with double the strength over EFCu, would allow operation at 10 bar and reduce the required data collection time to 150 days.





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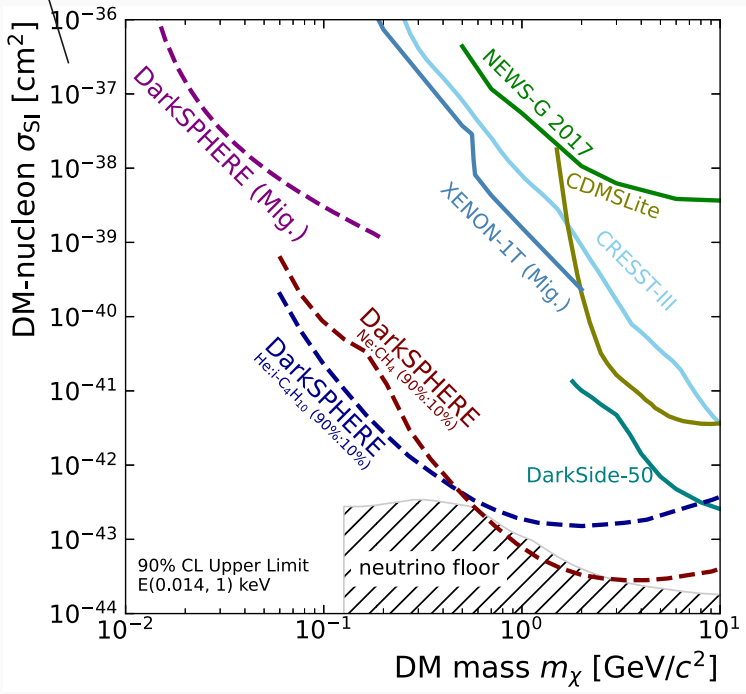

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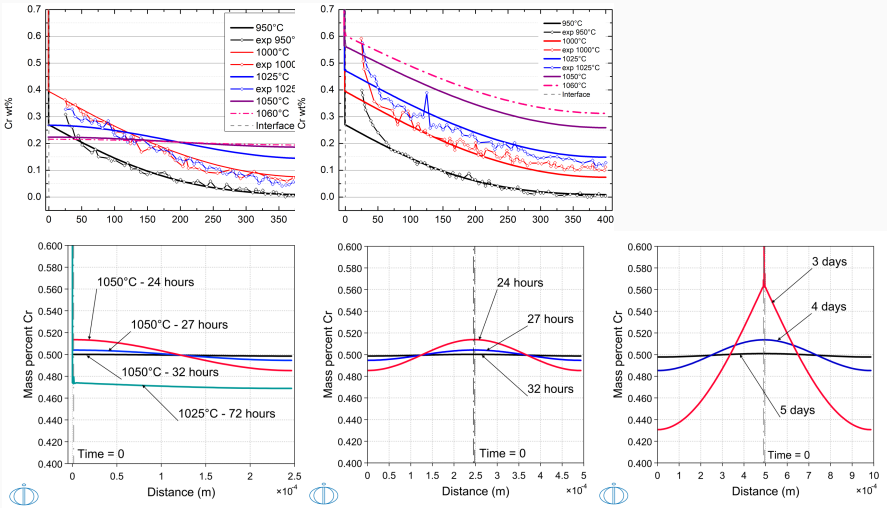
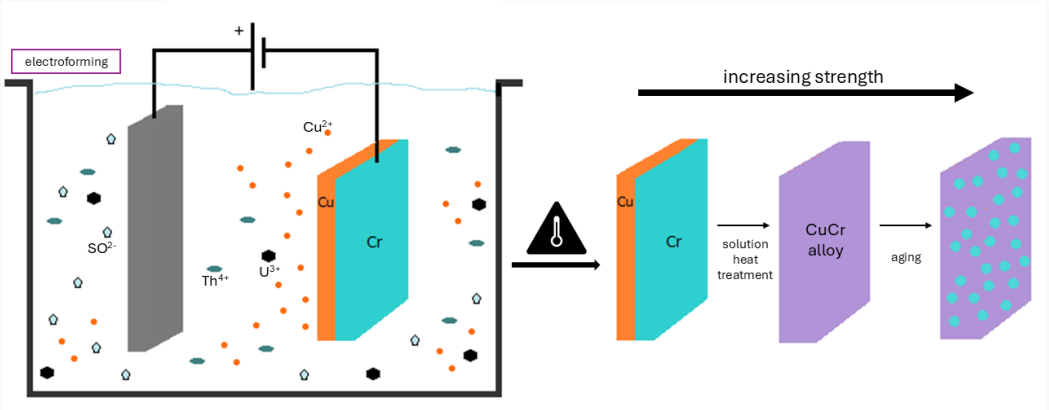
Thank you for your attention!

- ✓ Based on early experimental trials, synthesis of CuCr alloys is possible during electrodeposition
- ✓ Solution heat treatment simulations validated – aging time/ duration needs to be explored further with experiments
- ✓ Modelling tools are available for optimising thermal processing
- ✓ Cr/Cu and Cr/Ti and Cu/CrTi layer configurations to manufacture Cu-05.Cr and Cu-0.5Cr-0.032Ti
- ✓ Next steps: manufacture + characterise CuCr and CuCrTi alloys

More on PureAlloys:
https://dematerializ.github.io/purealloys/



UK Research and Innovation

Horizon Europe

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