Design of high-C Cr-Co-Ni medium entropy alloy for tribological applications

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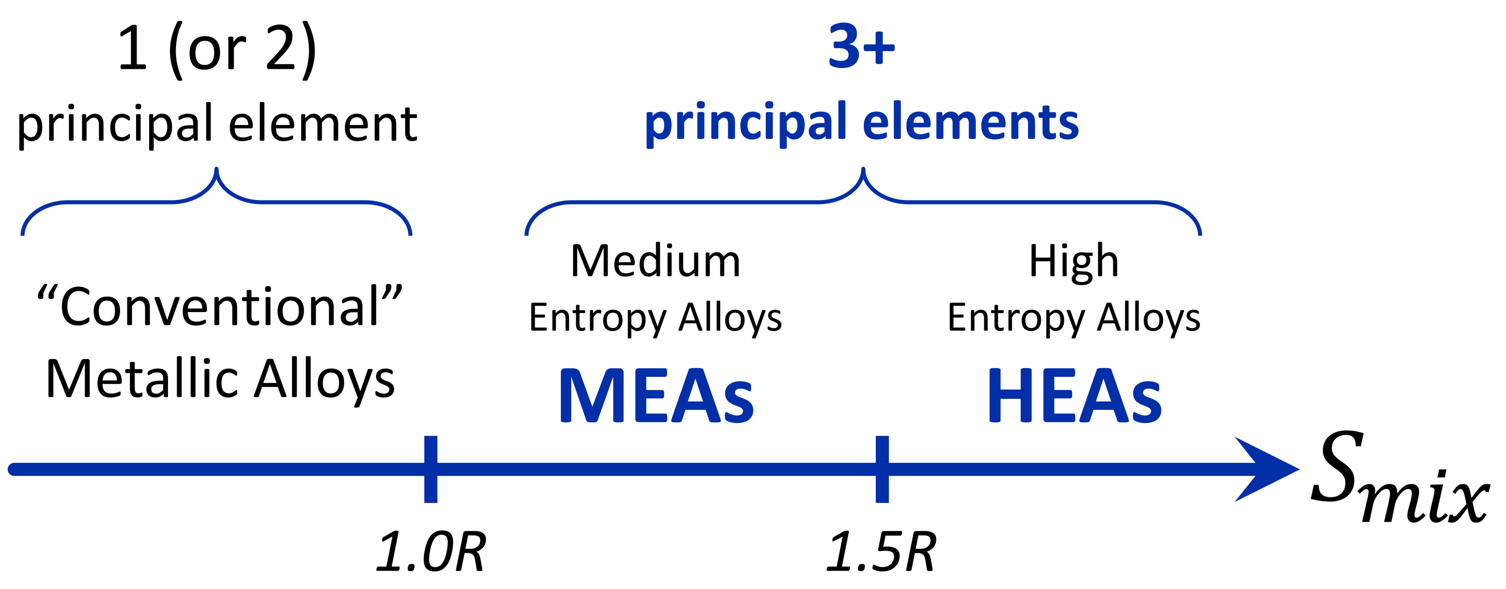
Background / Motivation



$\uparrow S \xrightarrow{G = H - TS} \downarrow G \rightarrow \uparrow$ Phase Stability

Multiple principal elements [1]:

- S and H contribute to the phase competition. Depending on the alloys system and processing a single-phase or multi-phase microstructure may form;
- There are an almost infinite number of possible combinations;
- It is possible to achieve different combination of properties.

Methods / Results

- Computational thermodynamic calculations (CALPHAD method) (**Fig. 1**) was used to predict the effect of **C additions** in **Cr-Co-Ni MEAs** (some of the toughest materials ever made **[2]**, promising corrosion resistance **[3]**);
- C can be incorporated into the alloy by melting in a graphite crucible, enabling **C saturation in the melt** (controlled by the casting T, see **Fig. 1**);
- In the present work, 24 at% C was incorporated by melting at 1500 ºC.

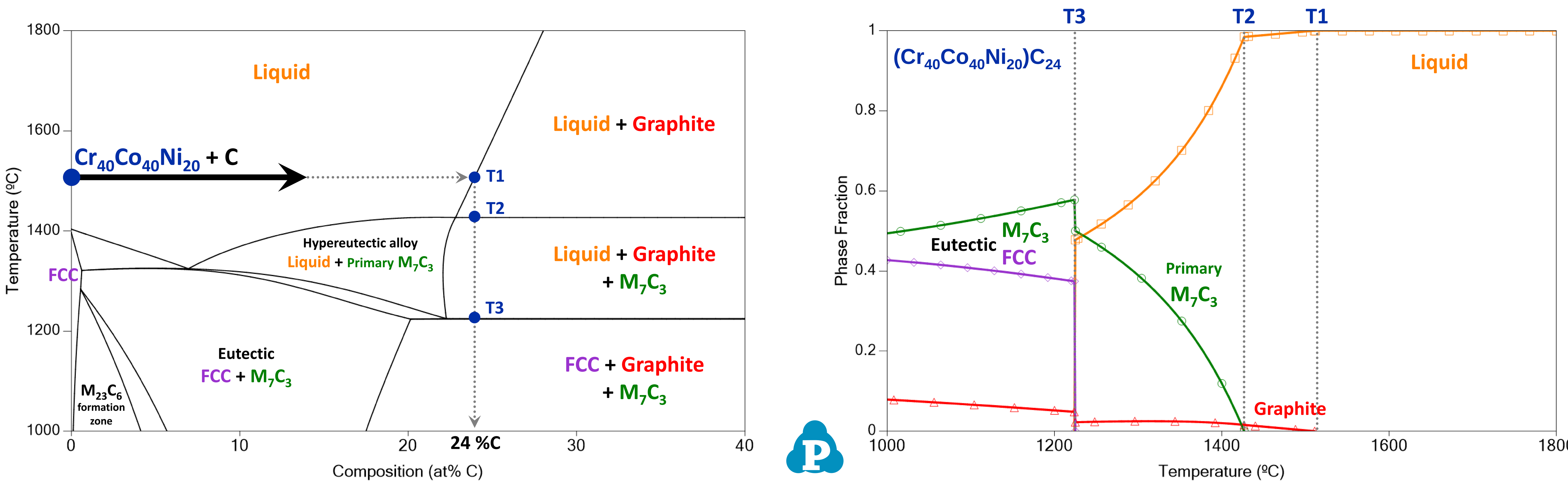


Fig. 1: Computational thermodynamic calculations (CALPHAD method), Pandat® software, PanHEA2020 database. On the left: isopleth $Cr_{40}Co_{40}Ni_{20}$ – C (at%), the arrows highlight that the casting temperature control the C saturation in the melt. On the right: equilibrium phases of $(Cr_{40}Co_{40}Ni_{20})C_{24}$ at different temperatures. T1 = graphite formation; T2 = primary M_7C_3 carbide formation; and T3 = the remaining liquid solidifies into a eutectic (FCC + M_7C_3). In lower temperatures, M_7C_3 carbide may be completely or partially converted to M_3C_2 carbide, if kinetic conditions allow it.

- A **$(Cr_{40}Co_{40}Ni_{20})C_{24}$ MEA was produced**, as described above, and characterized by XRD and SEM-EDS (**Fig. 2**).

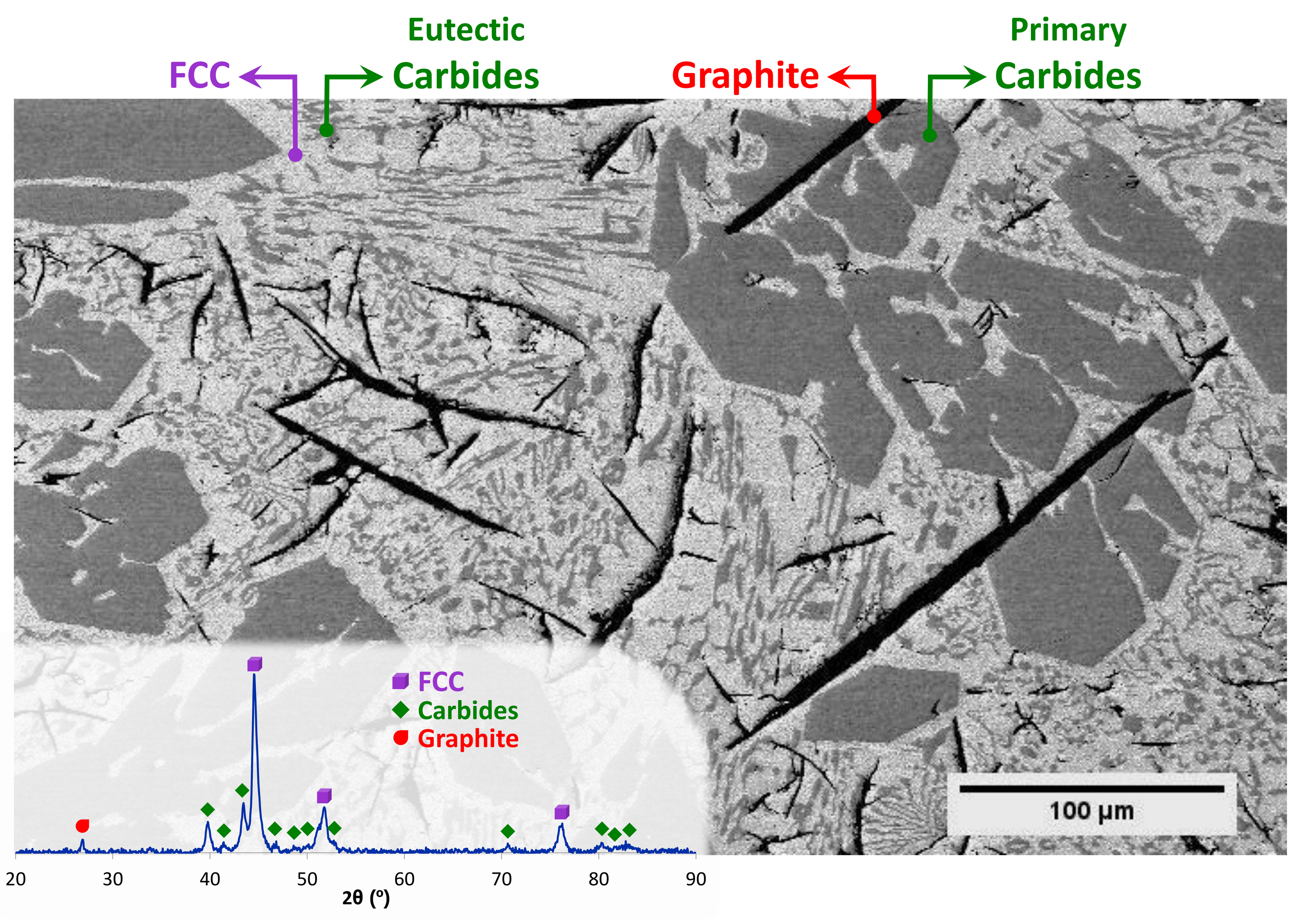


Fig. 2: SEM-BSE image and X-ray diffraction pattern of as-cast $(Cr_{40}Co_{40}Ni_{20})C_{24}$ MEA.

Conclusions

- A **MEA with promising microstructure for resisting wear** was developed;
- In good agreement with CALPHAD, $(Cr_{40}Co_{40}Ni_{20})C_{24}$ displayed:
  - Graphite (**lubricating** component)
  - Primary carbides (**hard** component)
  - Eutectic matrix of carbides and FCC phase (**tough** component)

Future Work

- Refine size, morphology and distribution of carbides → treatment by electric current **[4]** and/or rapid cooling;
- Increase graphite fraction → solid-state electropulsing **[5]**;
- Wear testing to confirm expected good behavior.

References

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