

Optimisation of Iron-manganese based binders compositions for tungsten carbide

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Context – About WC-Co

WC-Co :

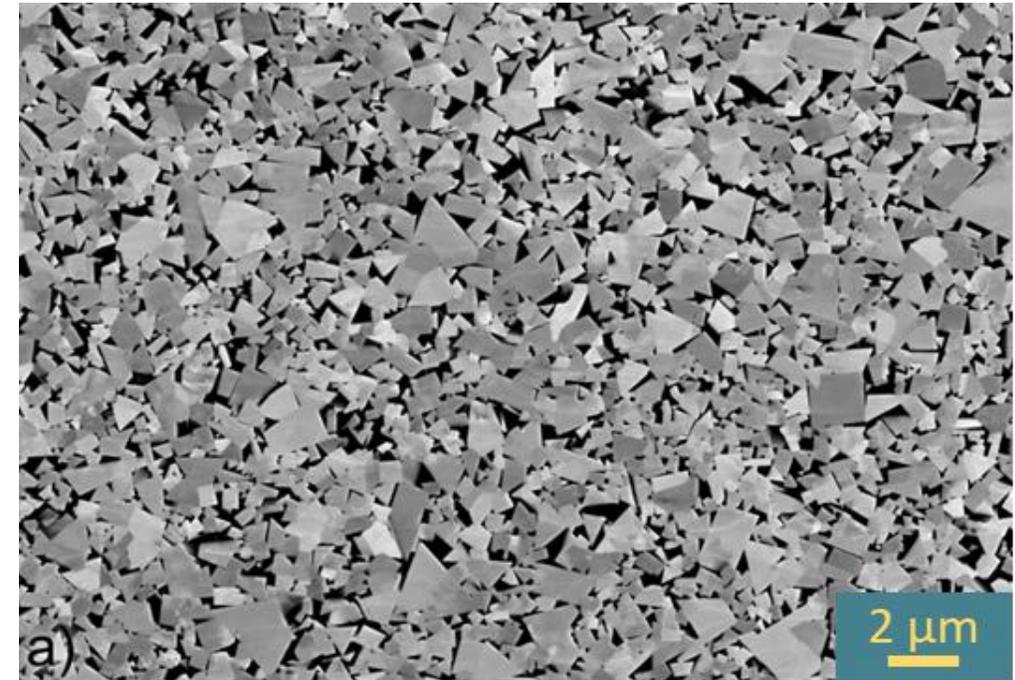
- High hardness (1600HV₃₀) and fracture toughness (9 MPa.m^{1/2})
- High oxidation and wear resistance, refractory
- Wide range of applications
- Well-known processing route

Carbide phase

Ensures hardness
90 wt.%

Binder phase

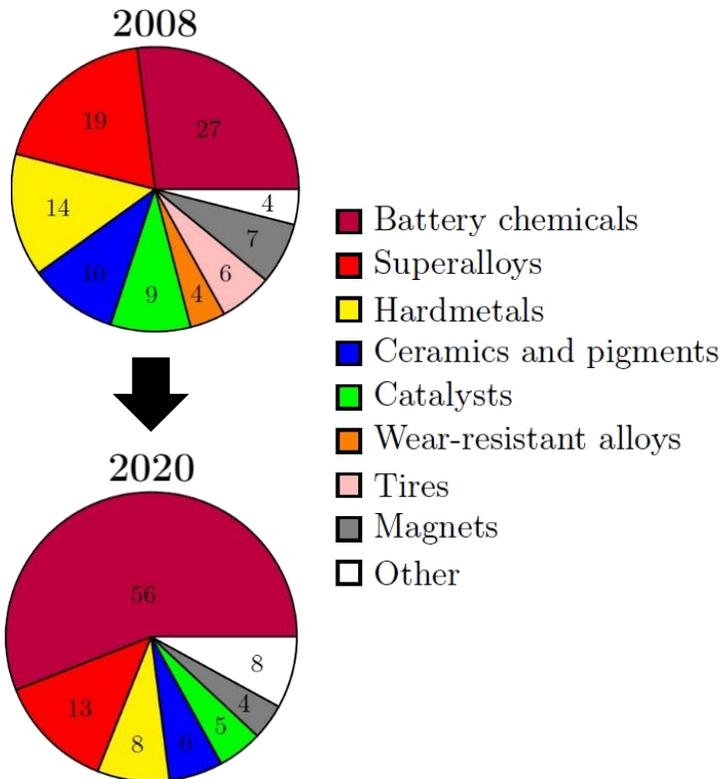
Ensures toughness
10 wt.%



Cobalt issue

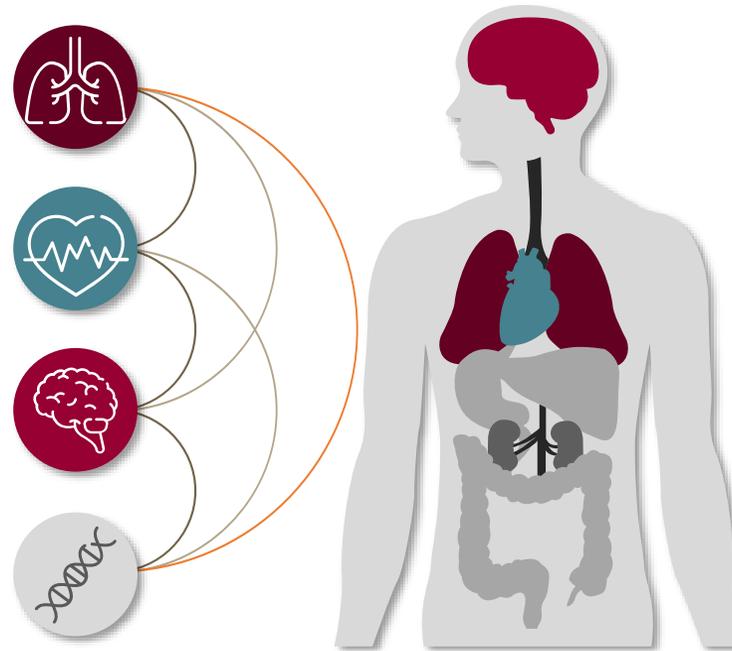
Critical...

Since 2011 in EU



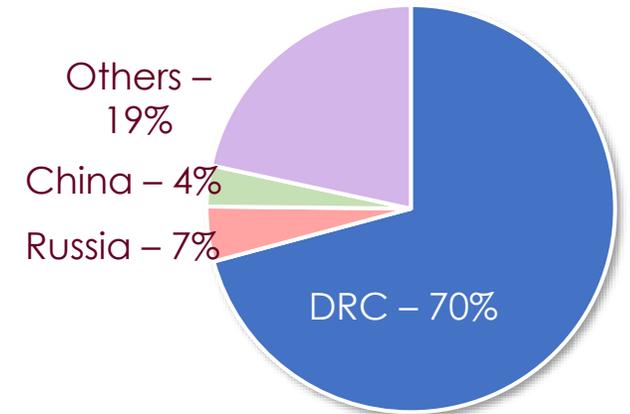
Source : European Commission

... toxic...



... and presents supply risks

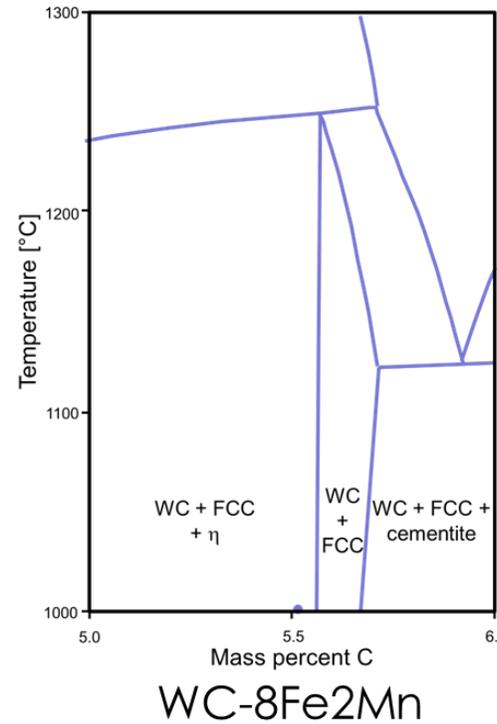
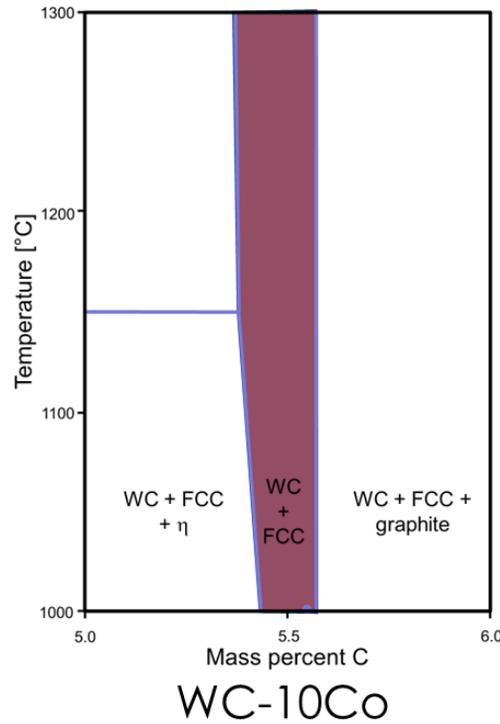
World cobalt extraction



2 000 deaths /year, incl. 20% children

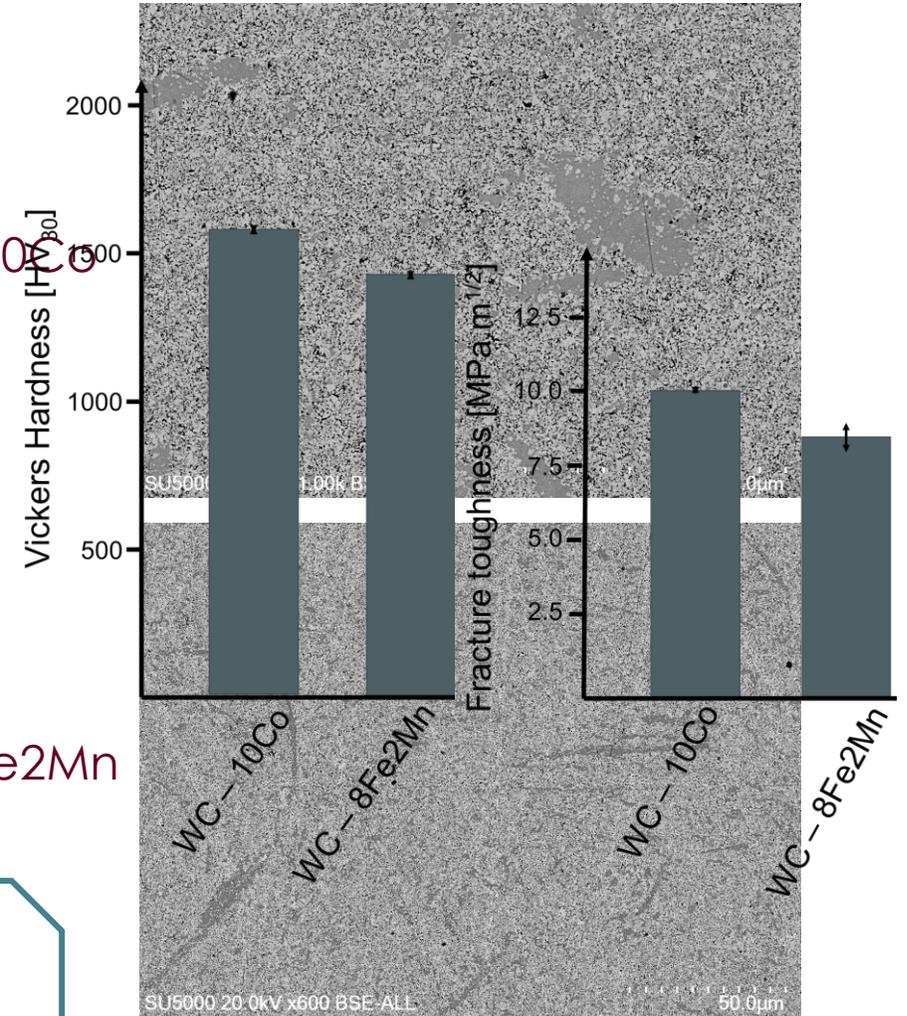
Source : independent.co.uk

Solution : FeMn-based binders ?



WC-10Co

WC-8Fe2Mn



Aim of this study: Optimization of FeMn-based binders compositions for tungsten carbide

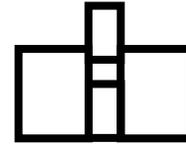
Presented at 21Plansee seminar (2025)

Design of experiments



Milling

- High energy planetary mill
- Two-step milling (10 h, then 5 h)
- 300 rpm
- Ethanol



Pressing

- Cold uniaxial pressing
- Zinc stearate lubricant



SPS-Sintering

- 50 MPa pressing
- 5' at 1200 °C
- 100 °C/min heating and cooling rates

Powders

- Grain size and **morphology**
- Repartition of the binder/WC grains

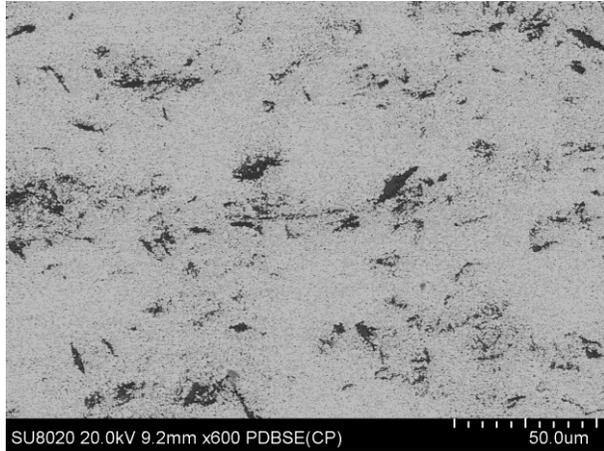
Microstructure

- Grain size
- Phase répartition
- Porosity characterization

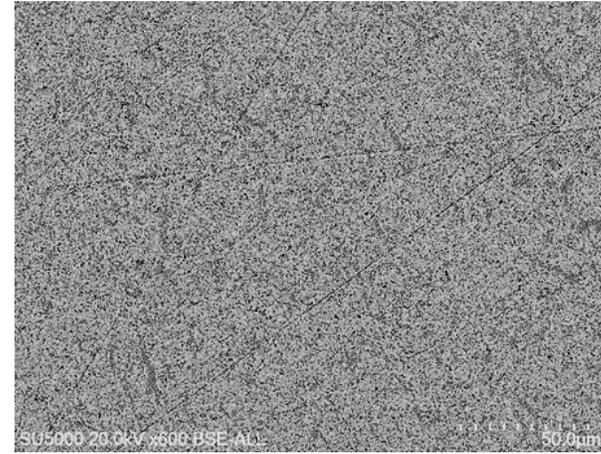
Mechanical properties

- Vickers **hardness**
(aim : $> 1600 HV_{30}$)
- Palmqvist **toughness**
(aim : $> 9 MPa.m^{1/2}$)

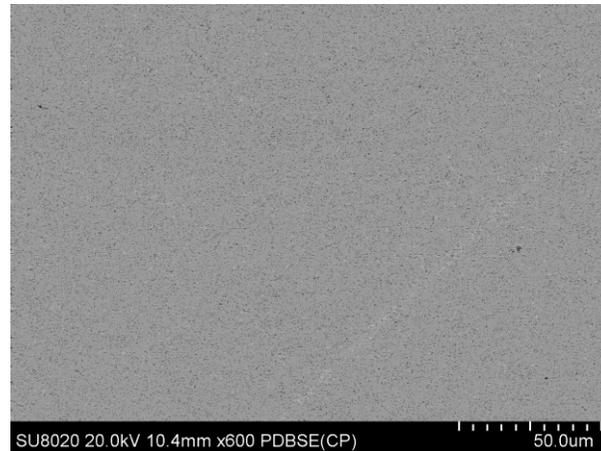
Results & interpretations



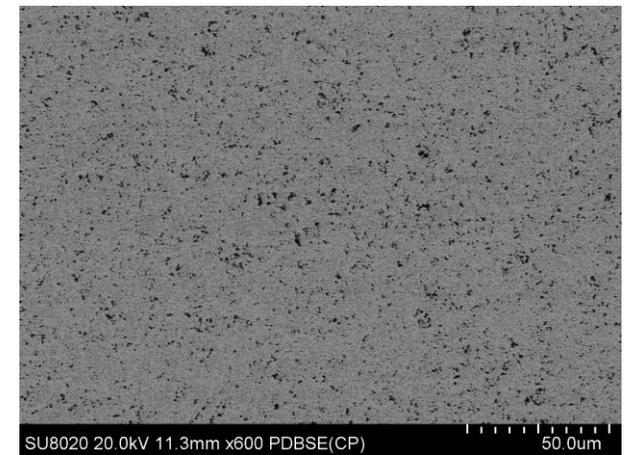
WC-10Co



WC-8Fe2Mn+2C

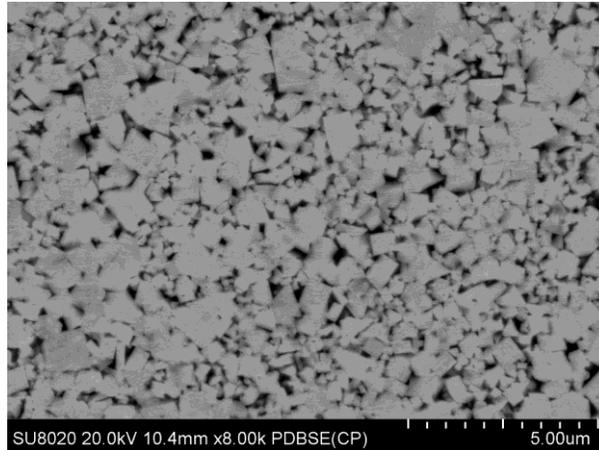


WC-10Fe+2 wt. %C

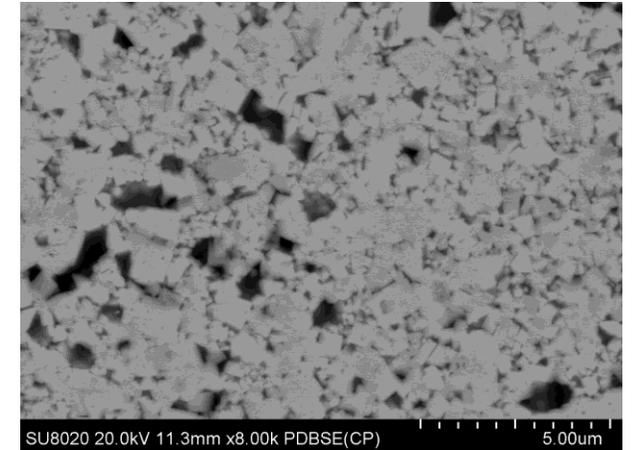


WC-6Fe4Mn+C

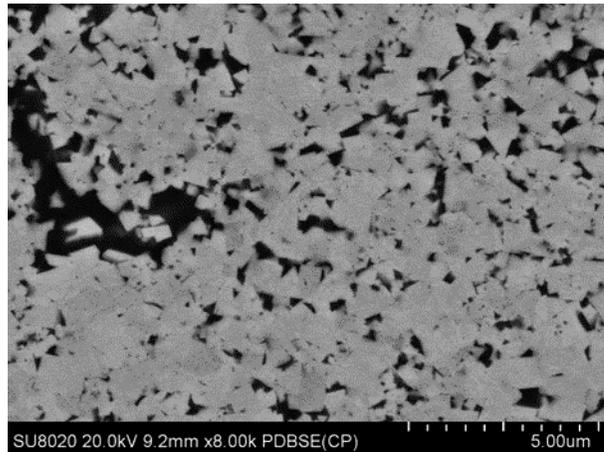
Results & interpretations



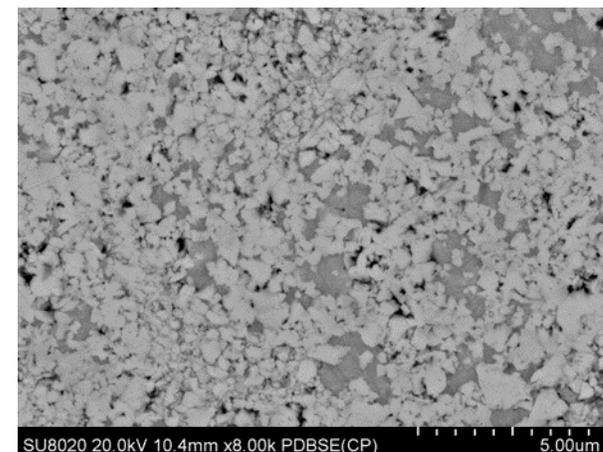
WC-10Fe+2 wt. %C



WC-6Fe4Mn+C



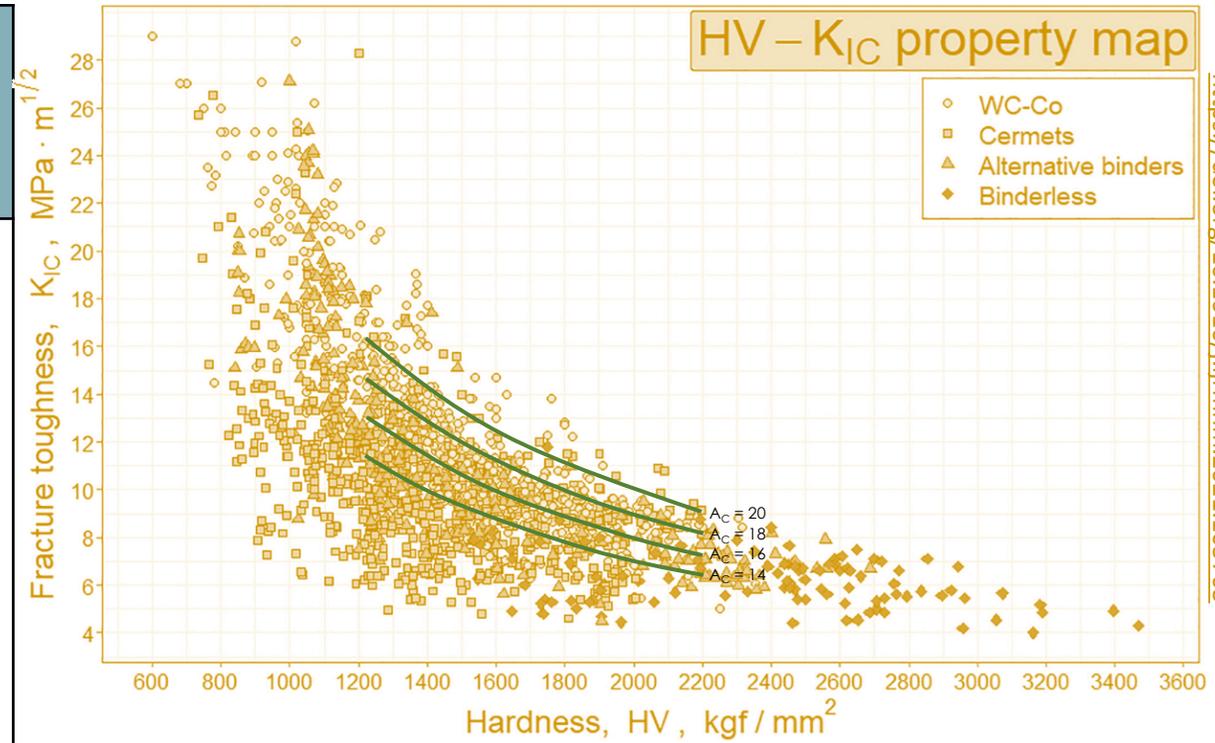
WC-10Co



WC-8Fe2Mn+2C

Results & interpretations

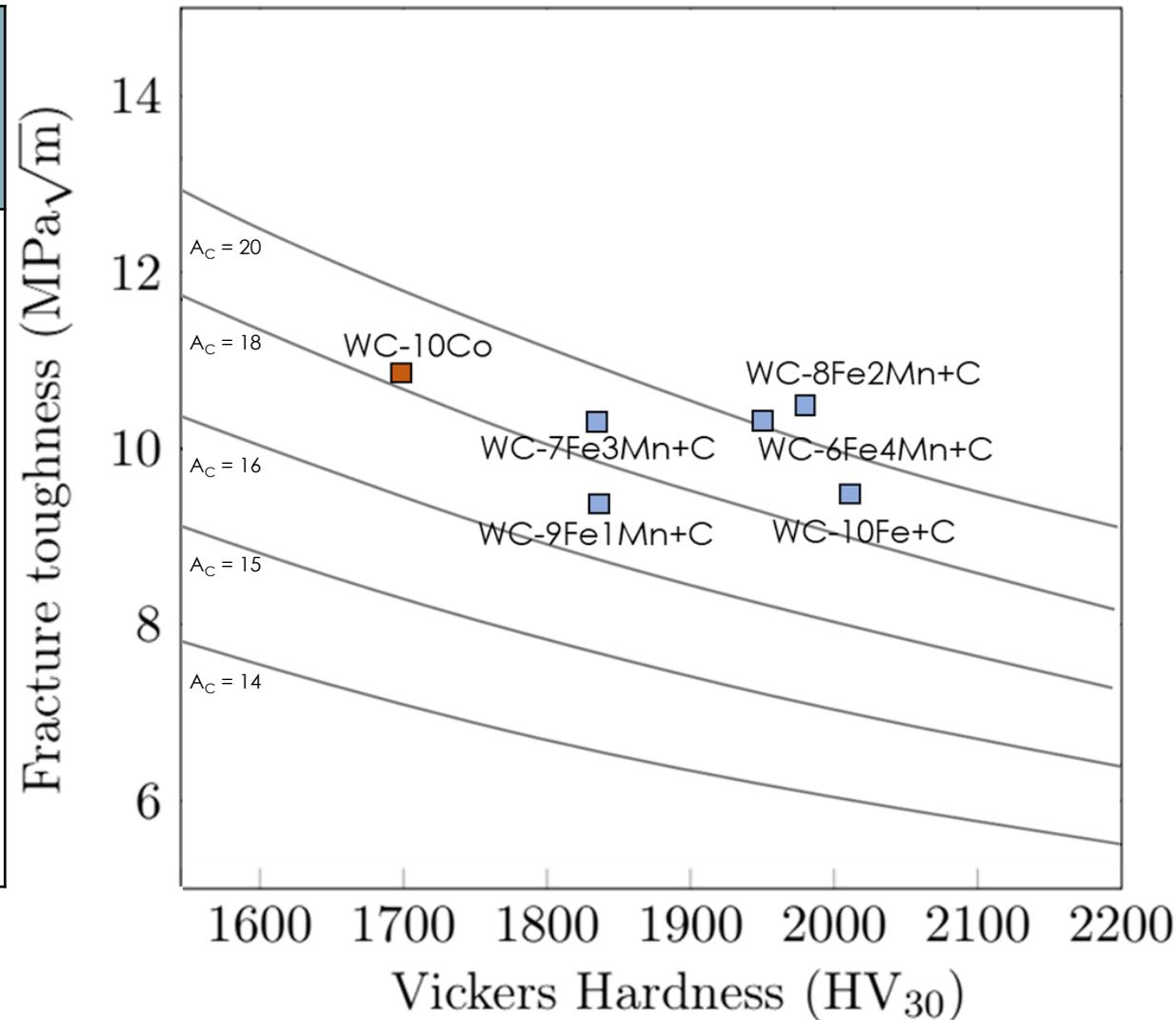
	Relative density [%]	HV ₃₀	K _{IC} [MPa·m ^{1/2}]
WC-10Co	94	1699±40	10.8±0.3
WC-10Fe	92	2026±29	9.7±0.2
WC-9Fe1Mn+C	94	1851±41	9.7±0.3
WC-8Fe2Mn+C	96	1976±54	10.3±0.2
WC-7Fe3Mn+C	93	1830±37	10.2±0.3
WC-6Fe4Mn+C	93	1950±41	10.2±0.7



$$\frac{HV_{30}}{K_{IC}} = A_c$$

Results & interpretations

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Conclusions & perspectives

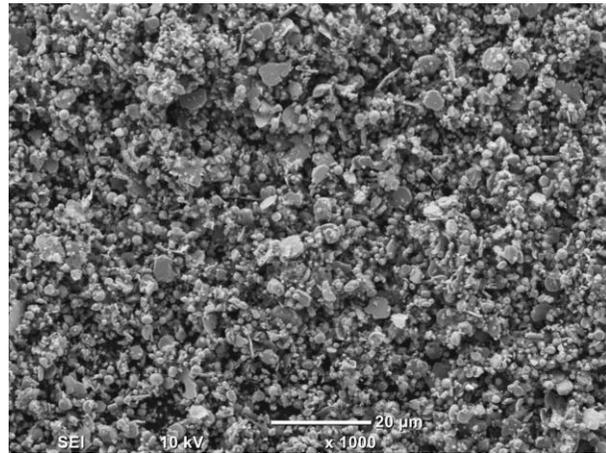
- **SPS Sintering** of WC-8Fe2Mn(+C) and comparison with WC-10Co composites:
 - More homogeneous microstructure, even with higher porosity rate
 - Better HV₃₀ and K_{IC} ratio
- Carbon-doping of the binder allows to avoid η-phase generation
- Future studies will investigate the optimization of the sintering parameters, to adapt them fully to the new composites

Acknowledgements

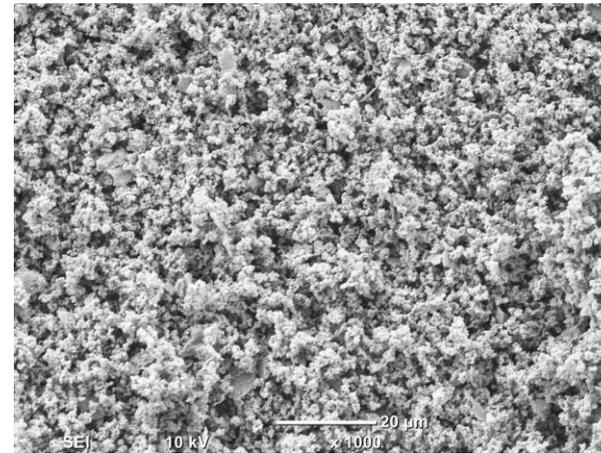
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- We gratefully acknowledge financial support from the **FRIA/FNRS** (Fonds National pour la Recherche Scientifique) **FRIA**_{fnrs}



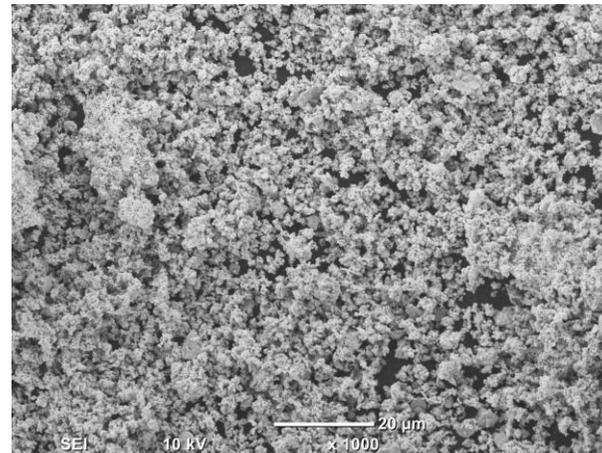
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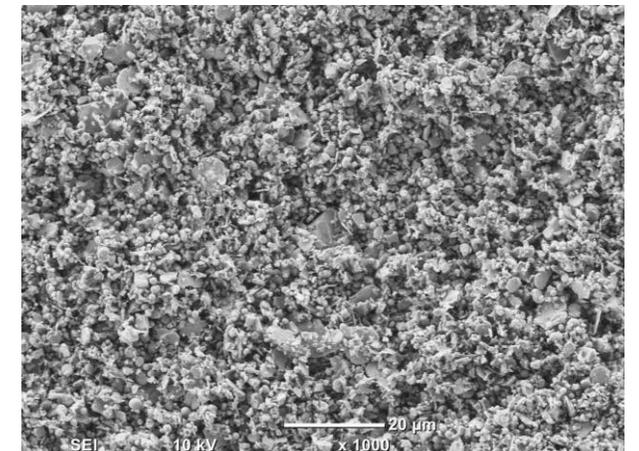
WC-10Co



WC-8Fe2Mn



WC-10Fe



WC-6Fe4Mn