Club Project: AlloyHard

1. Background / State of the Art

The standard composition for hardmetals or cemented carbides is tungsten carbide (WC) with a metallic binder consisting solely of Cobalt (Co) due to resulting excellent properties of this combination. However, there is an increasing incentive to **reduce or completely substitute Cobalt** for multiple reasons. Cobalt is classified as a CMR material hazardous to health as well as a critical raw material due to the high importance of this material combined with high risk associated with its supply. The increasing demand of Co for use in batteries of electrical vehicles has recently contributed price hikes of Co powder.

Many alternative binders based on metals such as Fe, Ni, Co, Mn, Cu, Cr, Al have been studied so far, but exhibit processing issues and poorer mechanical properties. More recent developments include so called **multi element binders** or medium or high entropy alloys (MEA/HEA) which are obtained from **elemental powders** [1, 2]**.** The formation of a solid solution of the starting mixture is expected to form 'in-situ' during the liquid sintering phase with presence of WC. After sintering the composition of the binder can substantially differ from the starting composition due to evaporation issues or formation of undesired phases [3]. **Prealloying** may help to avoid such reactions to achieve a homogenous binder, which is essential to achieve properties comparable to the benchmark WC-Co [4, 5].

2. Proposal / Objectives

The aim of this project is to compare the use of prealloyed (PA) metal binder powders with mixtures of elemental powders when preparing hardmetals with alternative binders using standard PM processing techniques. Two metallic binders will be selected from three alternatives:

a high entropy alloy (HEA) FeNiCoCuMn binder or
a medium entropy alloy (MEA) FeNiCoCr binder. As reference
a Cr-doped Co binder will also be studied.

Amongst the scientific/technological questions to be answered are:

- Which is the effect of PA powders on powder processing prior to sintering? (i.e. milling and compaction)
- How do PA binders change the sintering behavior? (e.g. carbon windows, solubilities, shrinkage, melting, mass losses due to oxide reduction, evaporation etc.)
- What is the final microstructure and relevant mechanical properties (HV, K_{1c}, TRS)?

Decision about the binders to be investigated will be made within WP1 at the Kick-Off-Meeting.

3. Work Plan and Description of Work Packages

WP1: Production and selection of starting powders

Lead Partner: CEIT, Support: IKTS

WP1 Description*:*

No prealloyed powders are available commercially for the binder compositions of interest. Therefore, such prealloyed powders will be prepared via atomization. This work package also includes the selection of starting powders as well as powder characterization.

Work package 1 is subdivided into three parts (tasks) as follows:

Task 1.1. Selection of elemental powders and additives, if available with similar mean particle sizes

Task 1.2. Atomization of prealloyed powders for the 3 selected alloys (HEA or MEA, Co reference): Optimization of parameters for obtaining D_{50}< 15 µm or if possible < 10 µm.

Task 1.3. Powder characterization: chemical analysis (IR and ICP spectroscopy), particle size distribution, SEM, XRD, BET, apparent density

Deliverable 1*:* Powder characteristics and availability of elemental powders as well as prealloyed powder for binder compositions of interest. Short report on powder characteristics.

Duration*:* 8 months

WP2: Fabrication of WC-alloyed binder components

Lead Partner: IKTS, Support: CEIT

WP2 Description*:*

The powders from WP1 are further processed to fabricate hardmetal samples using a conventional powder metallurgy route. This includes preparation of WC + binder powder mixtures, compaction and finally sintering. Basic properties such as density and magnetic properties (if possible) as well as microstructure and mechanical properties are investigated.

The same binder content of 32 vol% (equivalent to WC-20 wt% Co) will be used for all experiments. Two different WC powders (coarse grain, d_{FSSS} 6 µm and ultrafine, d_{FSSS} 0.6 µm) will be used to obtain two different sintered WC grain sizes.

Task 2.1. Milling, drying, sieving. Pressing aid addition. Characterization of powder mixtures: chemical analysis (C,O)

Task 2.2. Compaction including compaction curves.

Task 2.3. Thermal analysis: TGA, DTA/DSC

Task 2.4. Sintering: vacuum sintering vs. Sinter HIP

Task 2.5. Microstructural, physical and mechanical characterization

(a) Density, porosity (ISO 4499-ISO 3369)

(b) Magnetic properties (if applicable)

(c) Microstucture: SEM (ISO 4499)

(d) Hardness (ISO 3878)

(e) Fracture toughness (by indentation) ISO 28079

Deliverable 2*:* Fabricated WC-alloyed binder components and their measured properties

Duration: 18 months

Additional analysis can be ordered after completion of work packages 1 and 2 or as parts of a next stage. This additional work includes:

- SEM analysis of green compacts
- Additional thermal analysis: dilatometry, interrupted sintering tests
- Additional microstructure analysis with TEM
- Additional mechanical testing: hot hardness, fatigue, TRS (ISO 3327)
- Corrosion testing in 3 different medias

4. Estimated Time Plan

The project will start officially after the collection of all the Consortium Agreements and effectively at the Kick-off meeting (KoM). The total project duration after the KoM is 24 months. A midterm meeting will take place as virtual event at 12 month point. A final meeting will be organised at Fh IKTS or CEIT at the end of the project. All contractors should attend project meetings and teleconferences.

Work packages	Months																							
	1					6						12						18						24
WP1																								
1.1																								
1.2																								
1.3																								
WP2																								
2.1																								
2.2																								
2.3																								
2.4																								
2.5																								
	KoM											MT												FM

KoM: Kick-off meeting (at Fh IKTS/CEIT)
MT: Mid termin meeting (virtual meeting)
FM: Final Meeting (at Fh IKTS/CEIT)

Total duration: 24 months.

5. The Contractors

Fraunhofer **IKTS** is Europe's largest R&D institute dedicated to the study of ceramics, hardmetals and cermets. Powder technology processes are applied at high level under high throughput capacities and are continuously refined.

Ceit is a non-profit technology center, created on the initiative of the University of Navarra in 1982, and whose main task is to carry out industrial research projects in close collaboration with the R&D departments of the companies. Ceit has more than 30 years of experience in powder metallurgy and has extensive equipment, e.g. a powder atomization pilot plant.

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