SYNTHESIS AND FABRICATION OF Cu–W COMPOSITES COMBINING SHS AND HEC TECHNOLOGIES

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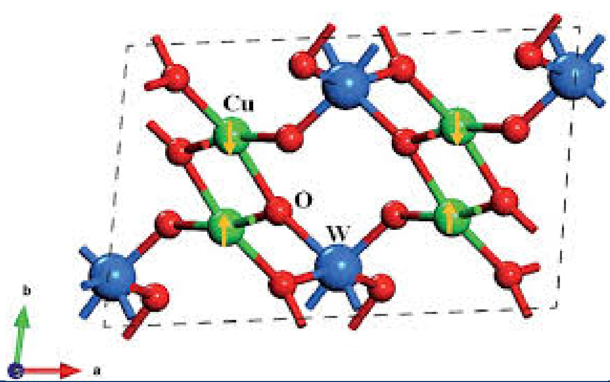
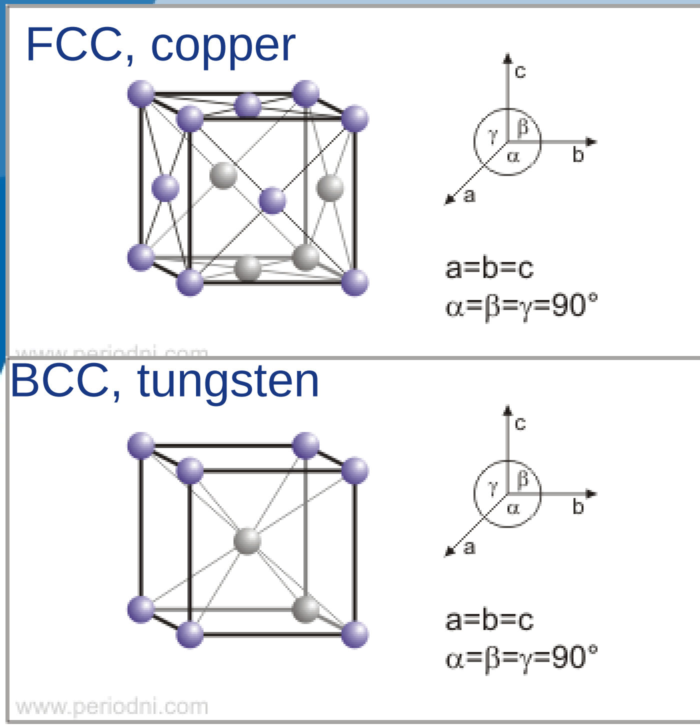


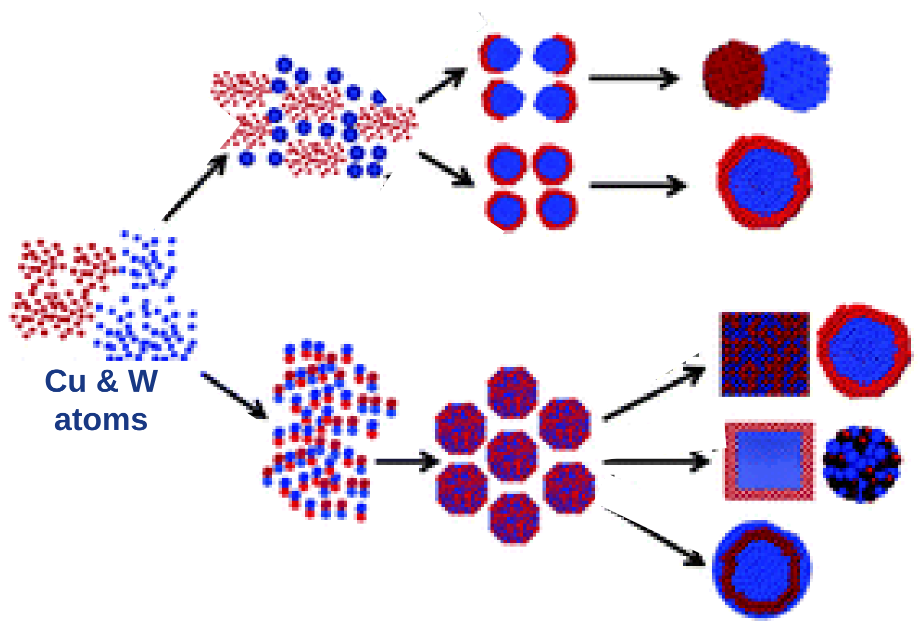
Portugal, Coimbria, 2016

W-Cu pseudoalloys



1) significant difference in lattice parameters of metals (a(W)=0.316nm, a(Cu) = 0.361 nm)

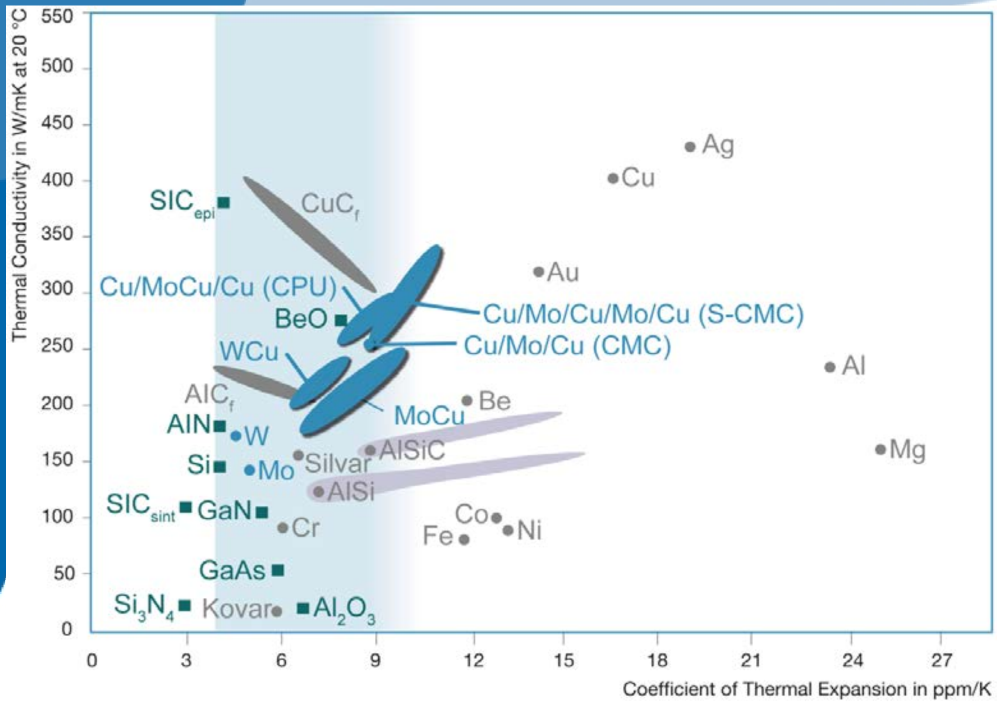
2) the high difference of melting points of copper and tungsten T_{Cu}=1083°C, T_{W}=3422°C



3) W and Cu insolubility in both solid and liquid states

they form a material with absolutely new structure which is therefore rather a metal matrix composite (MMC) instead of a true alloy or solid solution.

W-Cu pseudoalloys



- high thermal and electrical conductivity
- low thermal expansion

High-power device

LED

Heat sink

Golf Weight Attachment

Electrode

Aim

To develop a new way to fabricate W-Cu composites of various compositions directly from the oxide/salt precursors by combining energy efficient combustion synthesis method and HEC technology.

Approach

To perform joint reduction of oxide/salt in controlled combustion mode using the coupling of low exothermic reduction reactions (MeO+C) with a high-energetic one (MeO+Mg)

Investigated systems

$CuO - WO_3 - Mg - C$

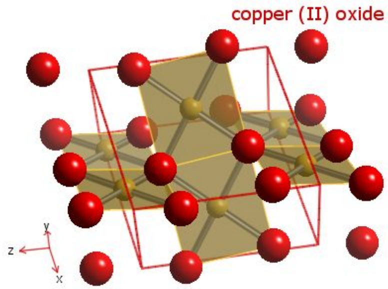
$CuWO_4 - Mg - C$

Technical approach and methodology

Precursors preparation

Mixing of WO_3, CuO

Making a salt by co-precipitation or calcination



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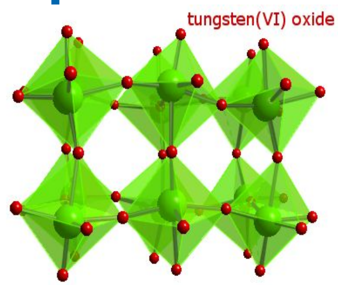
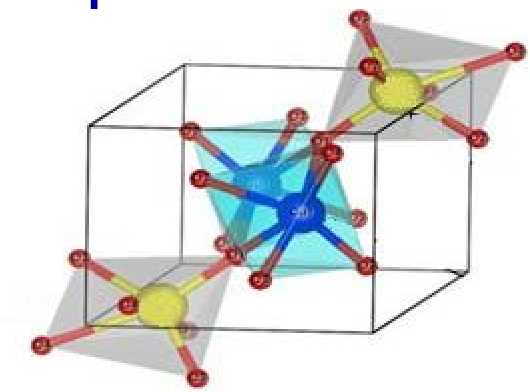




SHS co-reduction b
(Mg+C) mixture

W-Cu powders HEC consolidation

W-Cu powders and billets physicomeachanical characterization

Coupling approach in SHS

$WO_3 + 3Mg$, $T_{ad} = 3500$ K, $\Delta H = -840$ kJ/mol

$CuO + Mg$, $T_{ad} = 3100$ K, $\Delta H = -162$ kJ/mol

Explosive reactions

$WO_3 + 3C$, $T_{ad} = 320$ K

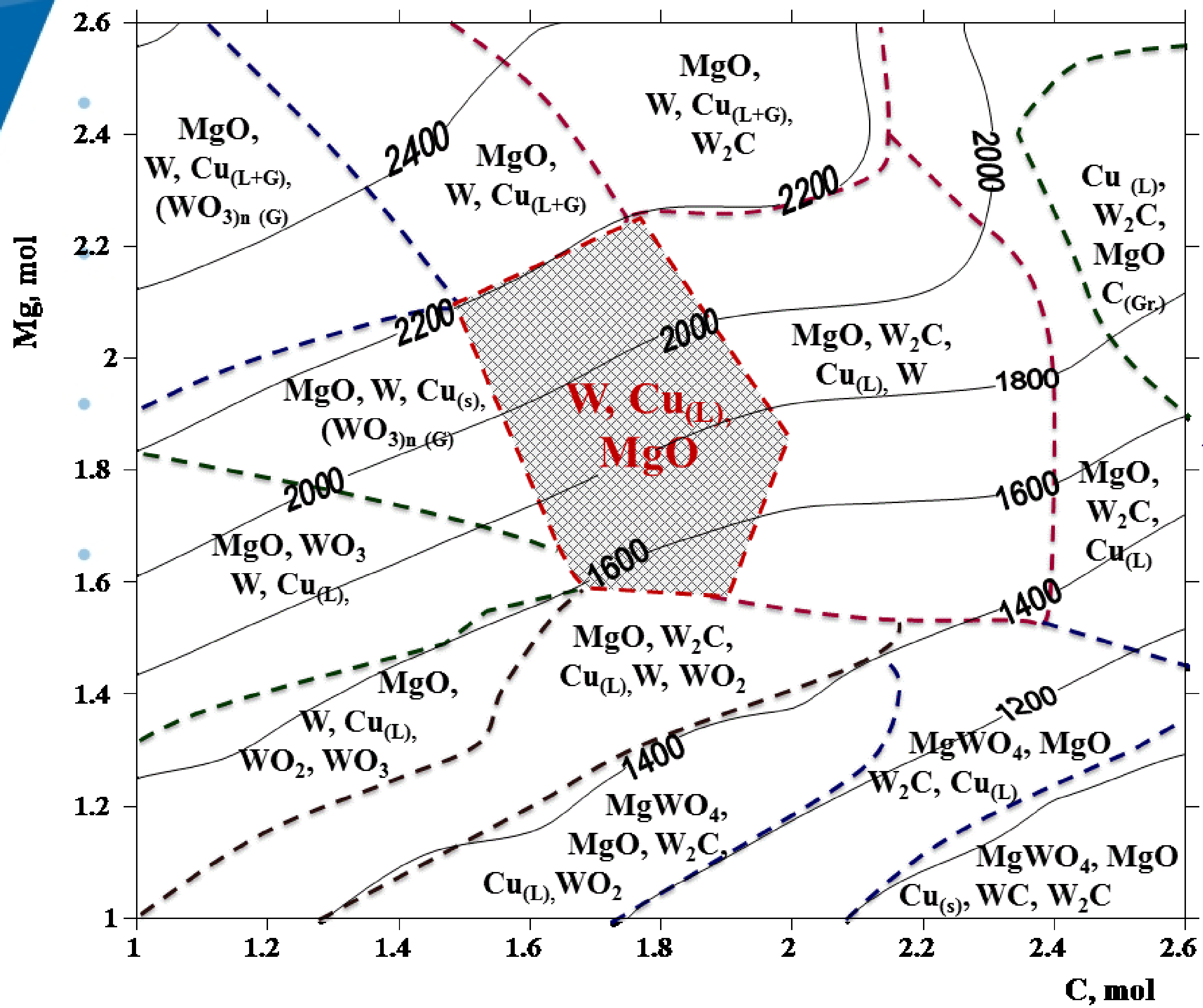
$CuO + C$, $T_{ad} = 830$ K

Low exothermic reaction

No combustion

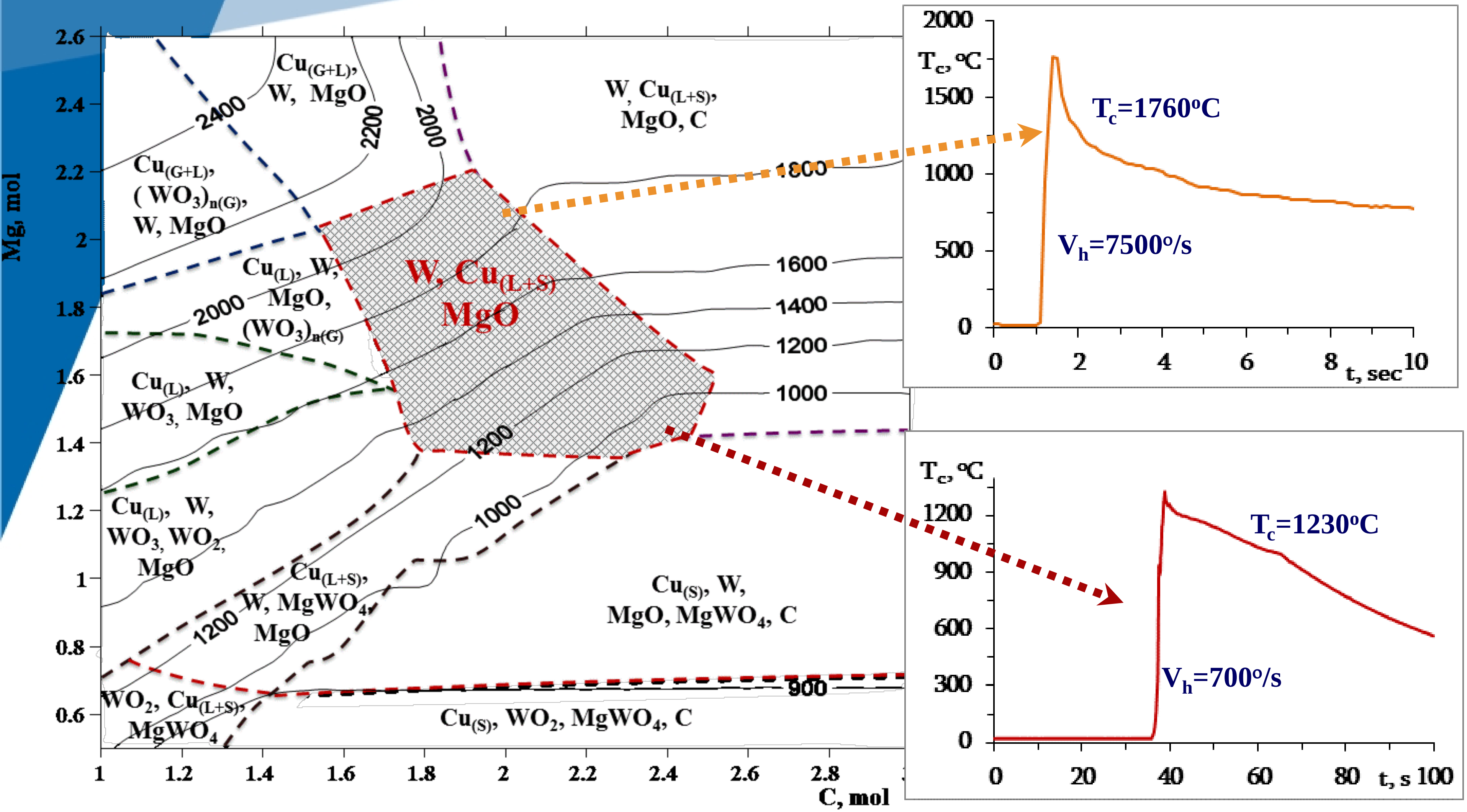
$CuO - WO_3 - Mg - C$, $T_{ad} = 1000 - 2500$ K

Thermodynamics of the WO_3-CuO-*y*Mg-*x*C system, including the formation of tungsten carbides



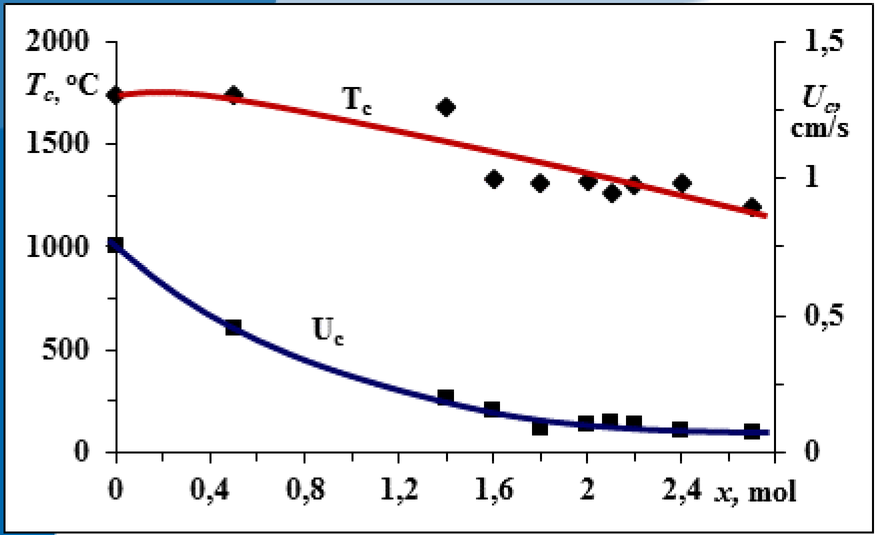
$P_{(N2)}$=0.3-0.5 MPa

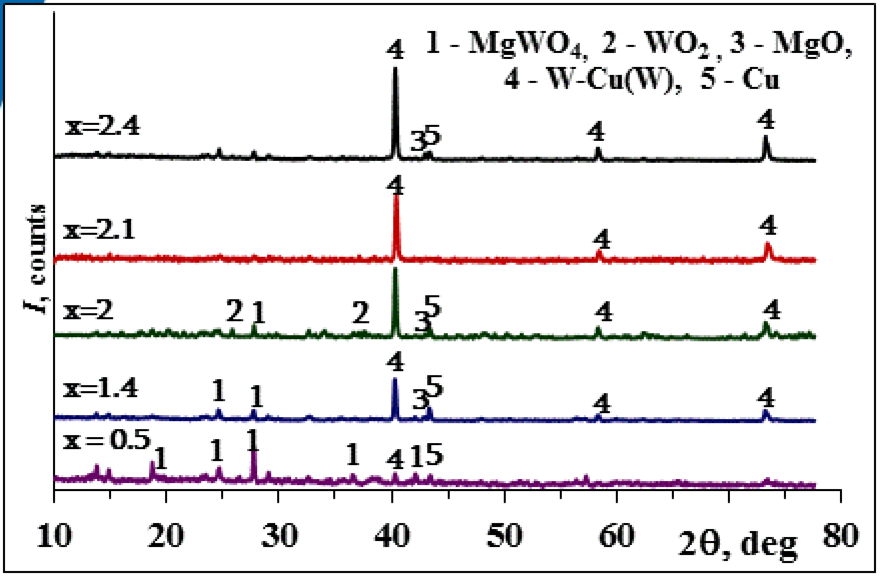
Thermodynamics of the WO_3-CuO-*y*Mg-*x*C system, excluding the formation of tungsten carbides

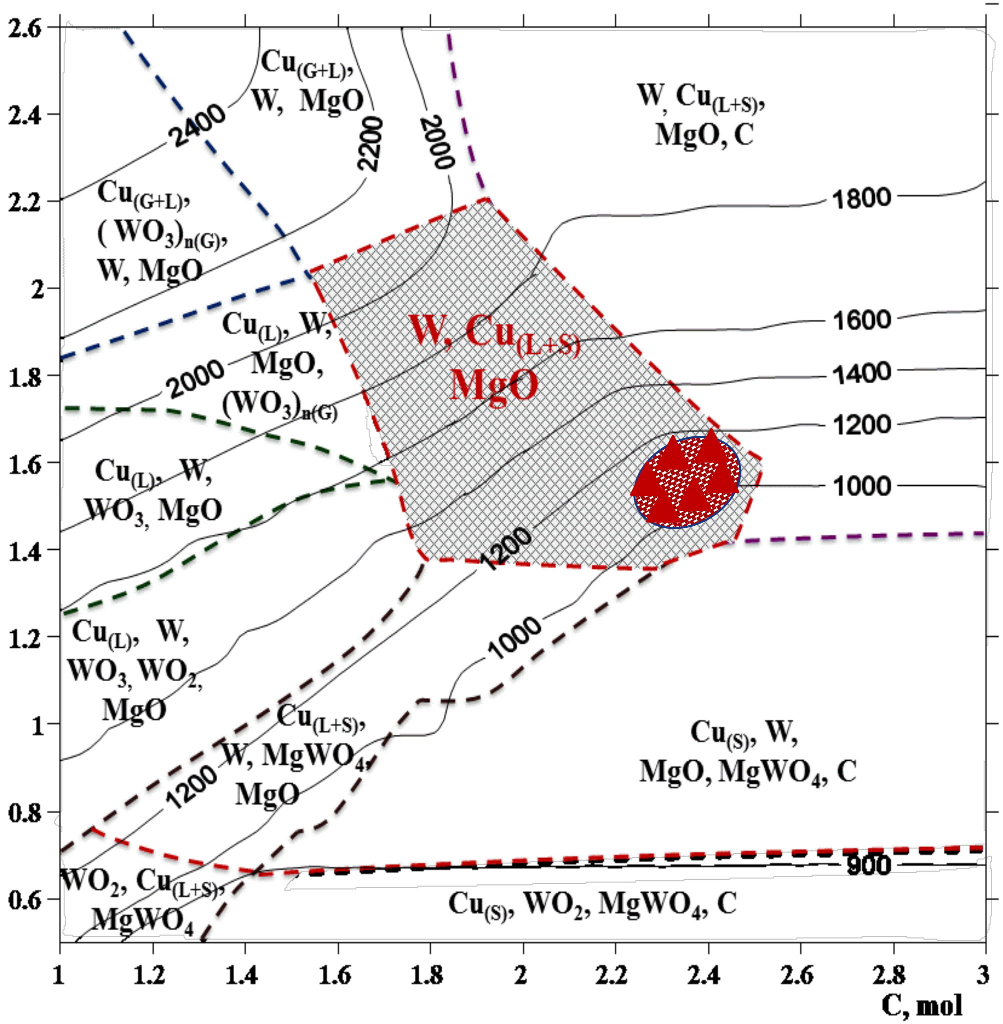


$P_{(N2)}$=0.3-0.5 MPa

Combustion parameters and phase composition vs. carbon content x of WO_3-CuO-1.3Mg-xC mixtures

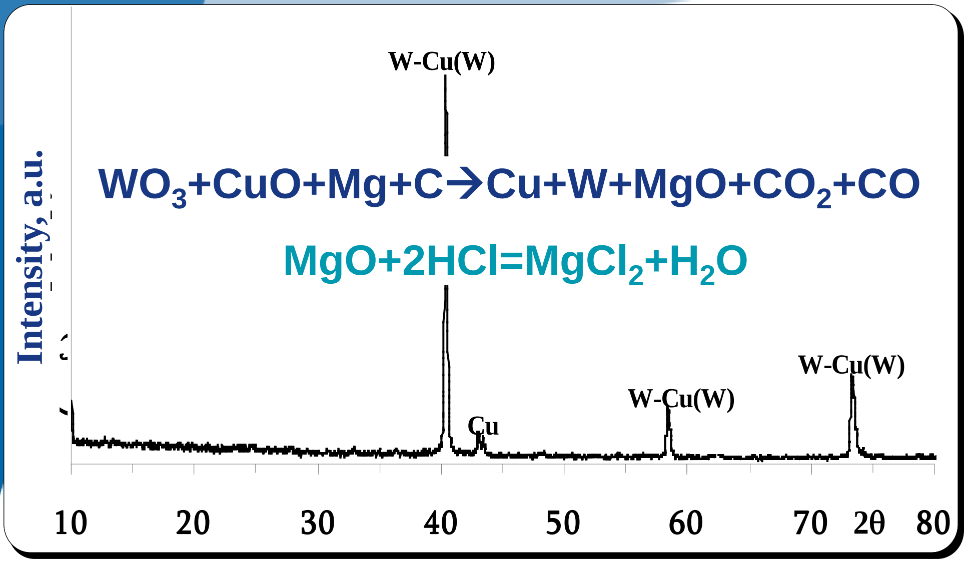






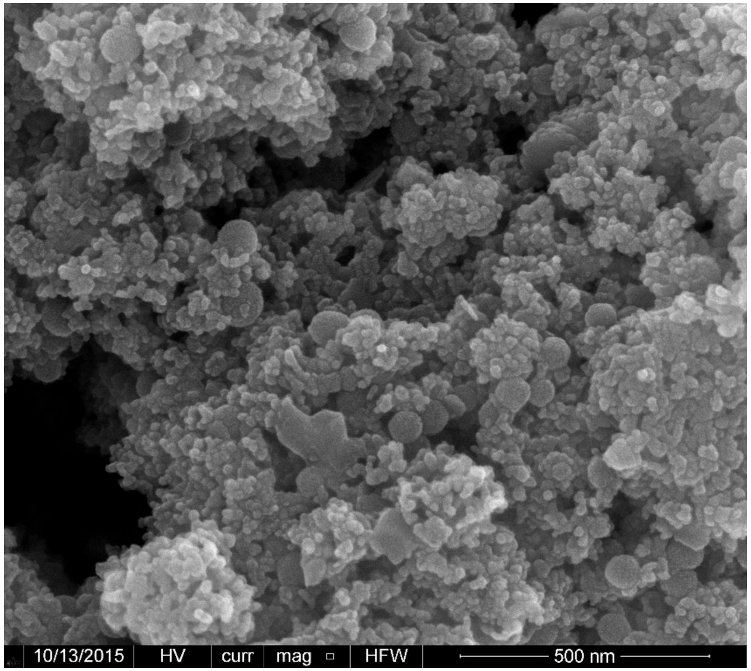
$P_{(N2)}$=0.3-0.5 MPa

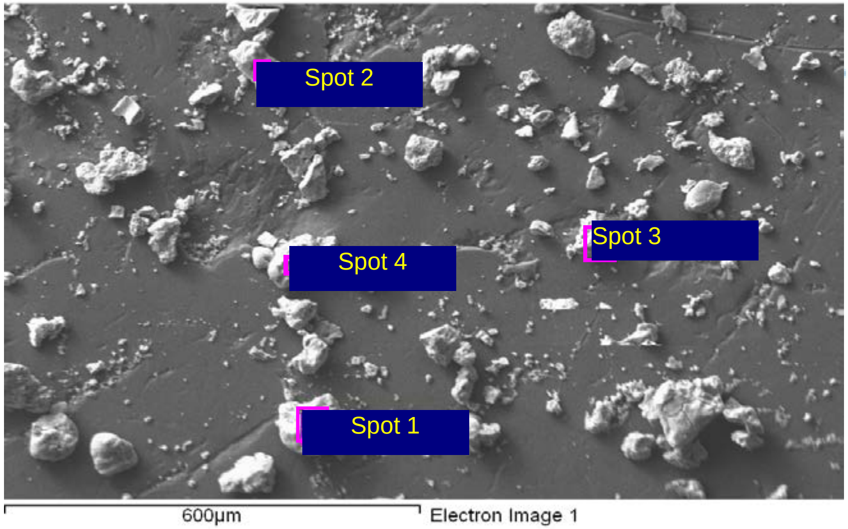
XRD pattern, SEM image and EDS analysis of W-Cu composite powder after acid treatment



$$WO_3+CuO+Mg+C \rightarrow Cu+W+MgO+CO_2+CO$$

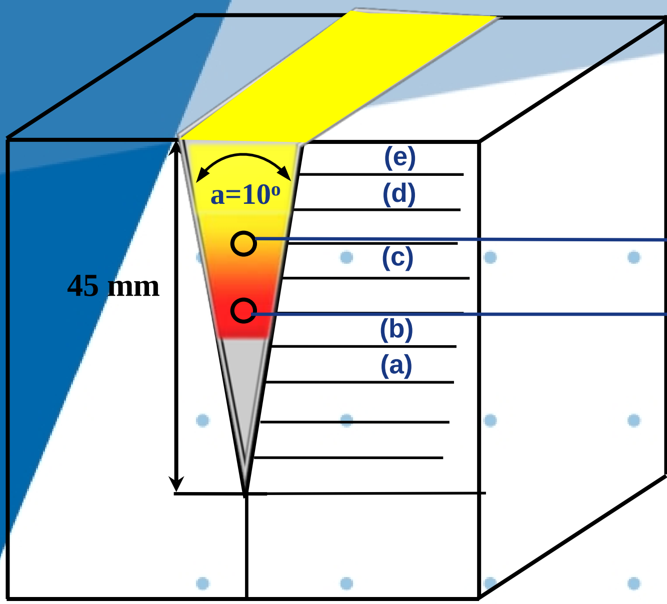
$$MgO+2HCl=MgCl_2+H_2O$$

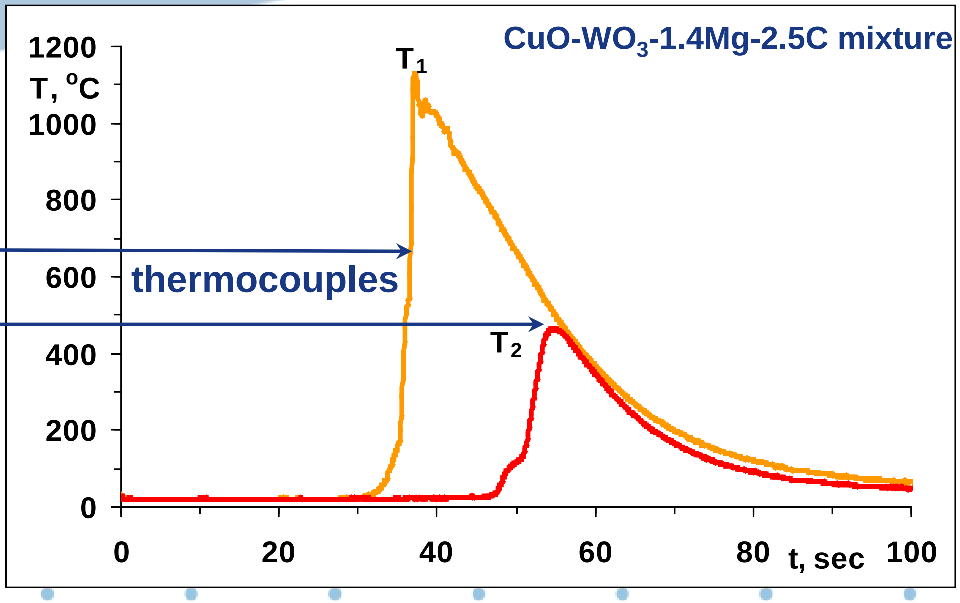




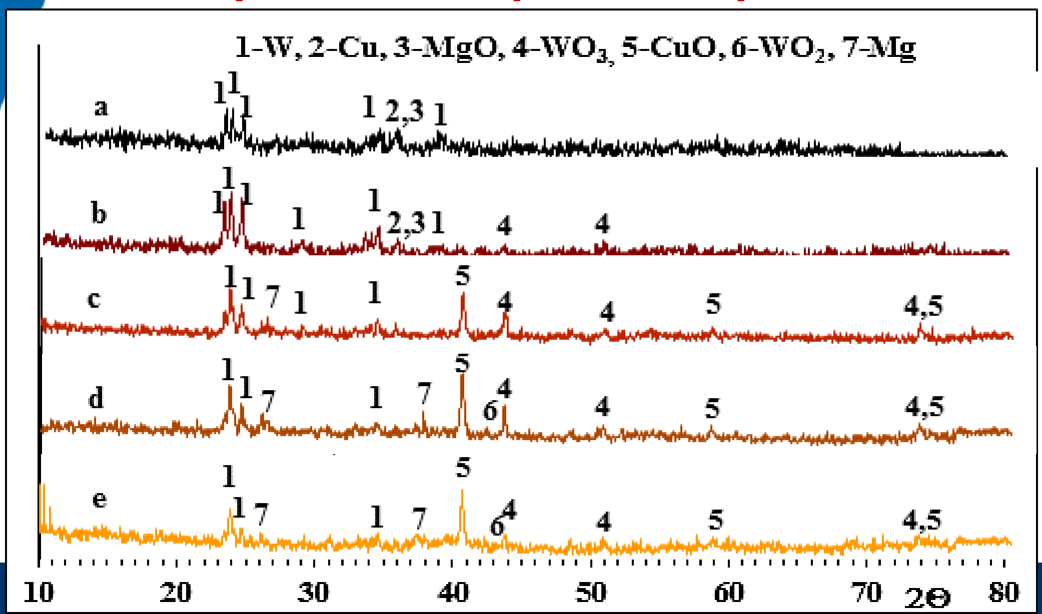
Spot 1 Cu:W = 1.0:1.14
Spot 2 Cu:W = 1.0:1.29
Spot 3 Cu:W = 1.12:1.0
Spot 4 Cu:W = 1.29:1.0

Experimental Results in Copper Wedge





XRD patterns of quenched products



(a) Initial mixture

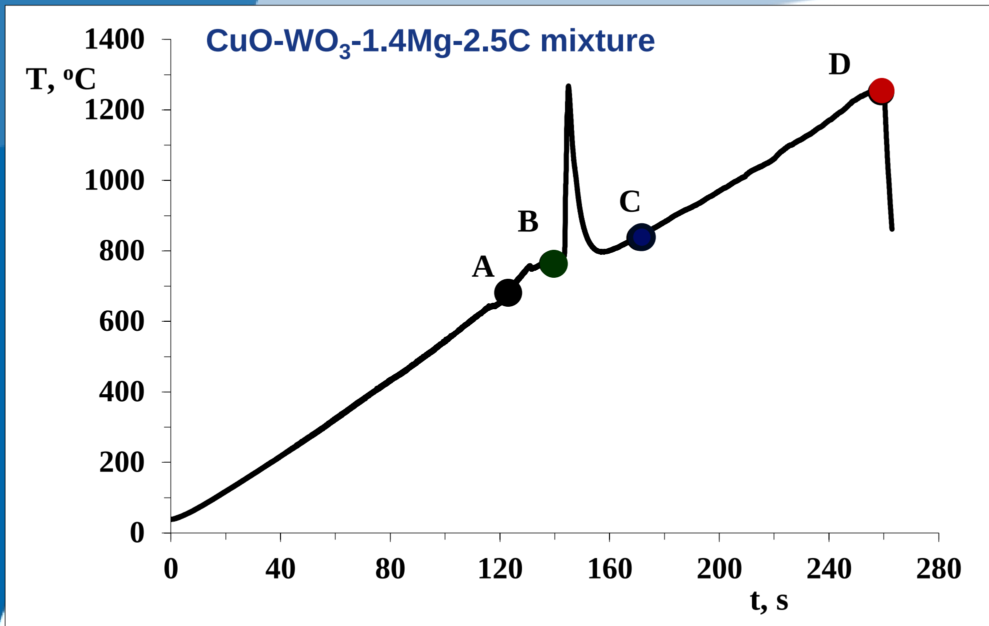
(b, c) I stage

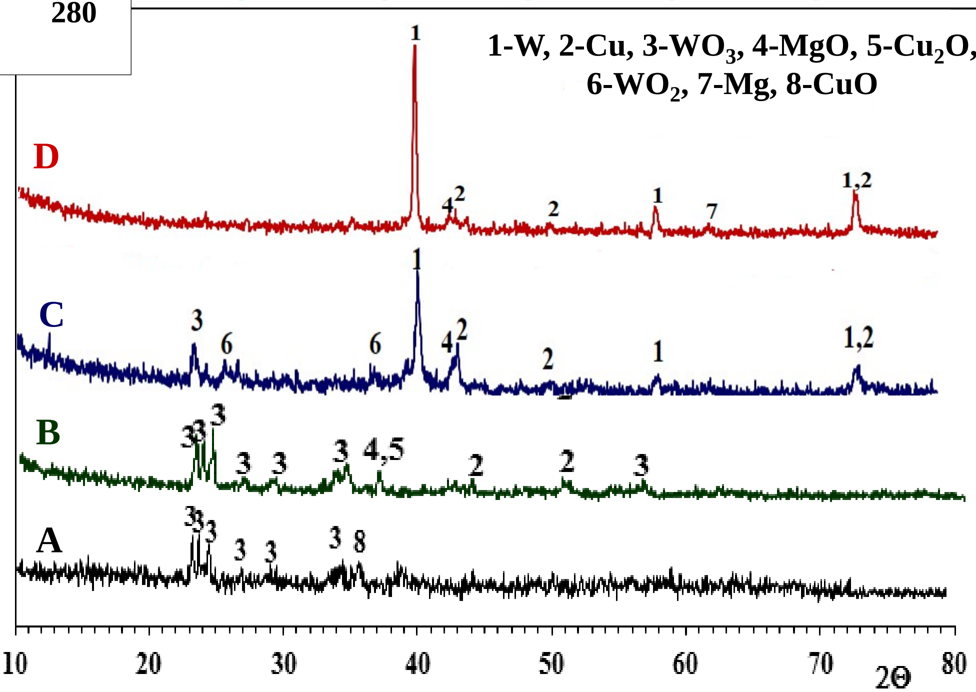
Carbothermic reduction

(d, e) II stage

Magnesiothermic reduction

HSTS analysis of the $CuO\text{-}WO_3\text{-}xMg\text{-}yC$ system





$V_h \sim 300\ ^o/min$

$T_{max} \sim 1300\ ^oC$

REDUCTION MECHANISM IN THE WO_3-CuO-Mg-C SYSTEM

I step $CuO + C \rightarrow Cu + CO(CO_2)$ and

$WO_3 + C \rightarrow WO_{2.9}(WO_{2.72}) + CO(CO_2)$

$WO_{2.9}(WO_{2.72}) + C \rightarrow WO_2 + CO(CO_2)$

II step $WO_3 + Mg \rightarrow W + MgO$

$WO_2 + Mg \rightarrow W + MgO$

At insufficient amount of reducers

$WO_3 + MgO \rightarrow$ **magnesium tungstate**

At excess amount of carbon (& long duration)

$WO_2 + C \rightarrow W\ (W_2C, WC) + CO(CO_2)$ **and**

$W + C \rightarrow W_2C, WC$

Hot Explosive Consolidation (HEC)

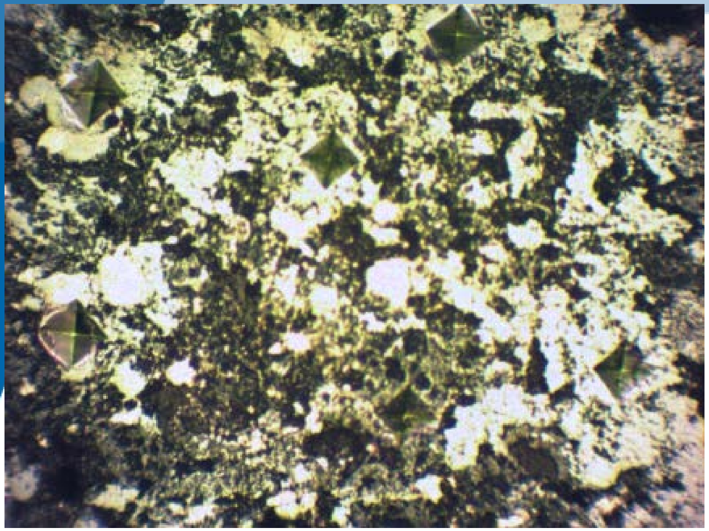
Cylindrical steel tubs containers, ampoules with upper cork (115x22x3mm)

Explosive predensification of W/Cu composite powder with W:Cu=1:1 at room temperature pressure 10 GPa

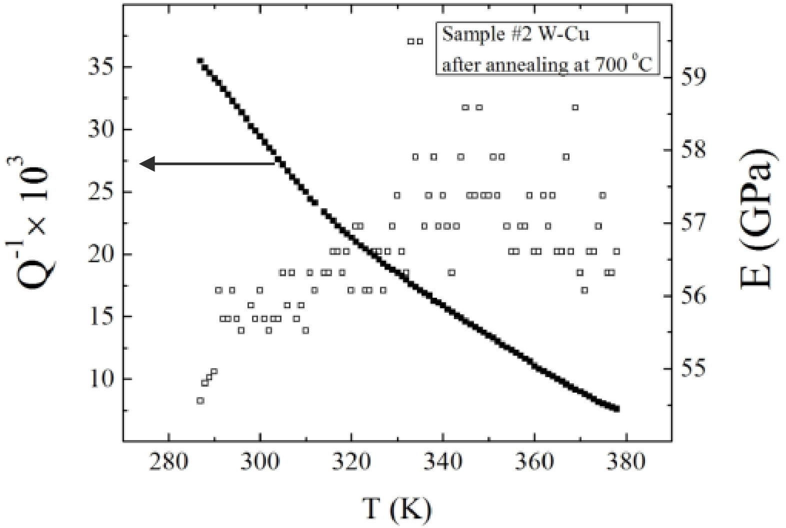
Hot Explosive Consolidation (HEC)

Cylindrical HEC billets of Cu:W=1:1composite after 2 stage loading (5GPa) at 700, 930 and 1000°C

Microstructure of HEC consolidated sample, 700°C



The temperature dependence of Young modulus (E) and internal friction Q-1(T)



Microhardness measurements for different sections after two-stage HEC of W-Cu=1:1 composite, 10 & 5 GPa

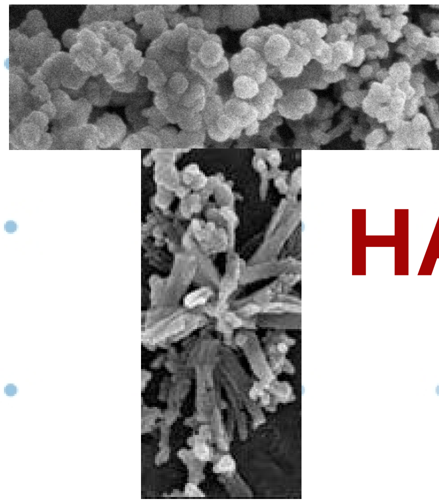
Sample	Temperature, °C	Microhardness, kg/mm^2
1	700	274
2	930	297
3	1000	383

Conclusions

1. Combustion synthesis of W-Cu composite was performed directly from oxides via reaction’s coupling approach. Optimum conditions of target nanocomposite (W-Cu) SHS synthesis were found.

2. The reduction mechanism was proposed due to copper wedge technique and HSTS method. It was shown that firstly reacts weak reducer (carbon), then stronger one (Mg).

3. Explosive consolidation of fine W-Cu precursors allows to fabricate high dense cylindrical billets near to theoretical density without cracks and uniform distribution of consisting phases.



HANK YOU FOR YOUR

KIND ATTENTION

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Microhardness kg/mm² measured on a PMT-3 at P = 100g			
		According to the formula	Tabular results
1	Cu : W = 1 : 1 t = 1000⁰C	129.76 206.97 277.88 179.59 241.28 102.50 169.42 442.03 291.95 307.12 291.95 350.47	128 206 274 181 236 100 170 464 297 297 297 350
2	Cu : W = 1 : 1 t = 930⁰C	307.12 136.46 198.52 198.52 190.58 148.95 166.29 30.38 86.79 176.07 117.69	297 135 193 193 193 151 170 30.5 87.6 181 116
3	Cu : W = 1 : 1 t = 700⁰C	392.27 595.82 536.47 186.85 186.85 183.11 125.54 70.31 110.56 381.32 119.55 428.95 57.67	383

Khrushchev-Berkovich method

H = (1854x100)/C2 kg/mm2 where C is diagonal of impression of micrometer eyepiece.

Microstructures of the Cu-20%W composite consolidated at 900° C