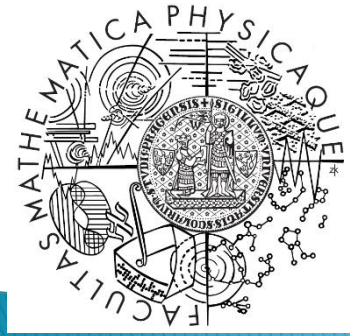
Defects in high entropy alloy HfNbTaTiZr

F. Lukac[1,2*], J. Cizek[1], J. Kuriplach[1], M. Dudr[2], R. Musalek[2], M. Vilemova[2] , J. Zyka[4], J. Malek[4]

[1]*Charles University, Faculty of Mathematics and Physics, , V Holesovickach 2, CZ-180 00 Praha 8, Czech Republic*

[2]*Institute of Plasma Physics CAS, Za Slovankou 3, 182 00, Praha, Czech Republic*

UJP PRAHA a.s., Prague, Czech Republic



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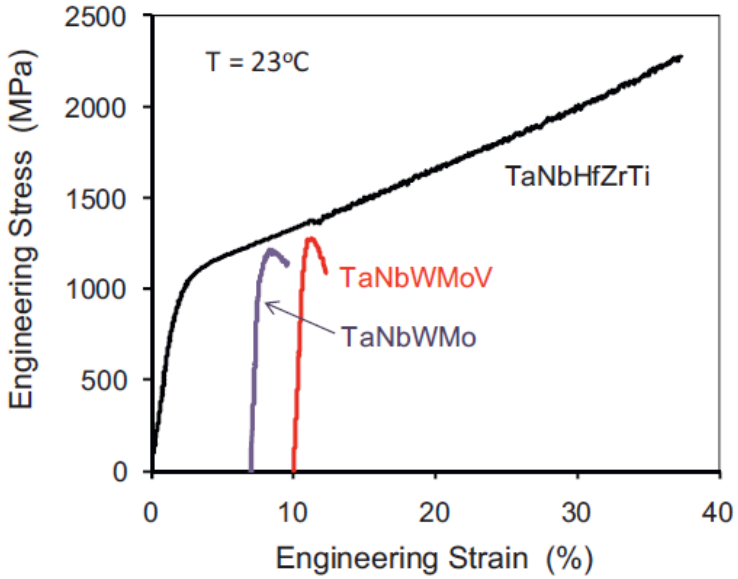
Motivation

1. Interesting mechanical properties of refractory alloy **HfNbTaTiZr** - equimolar

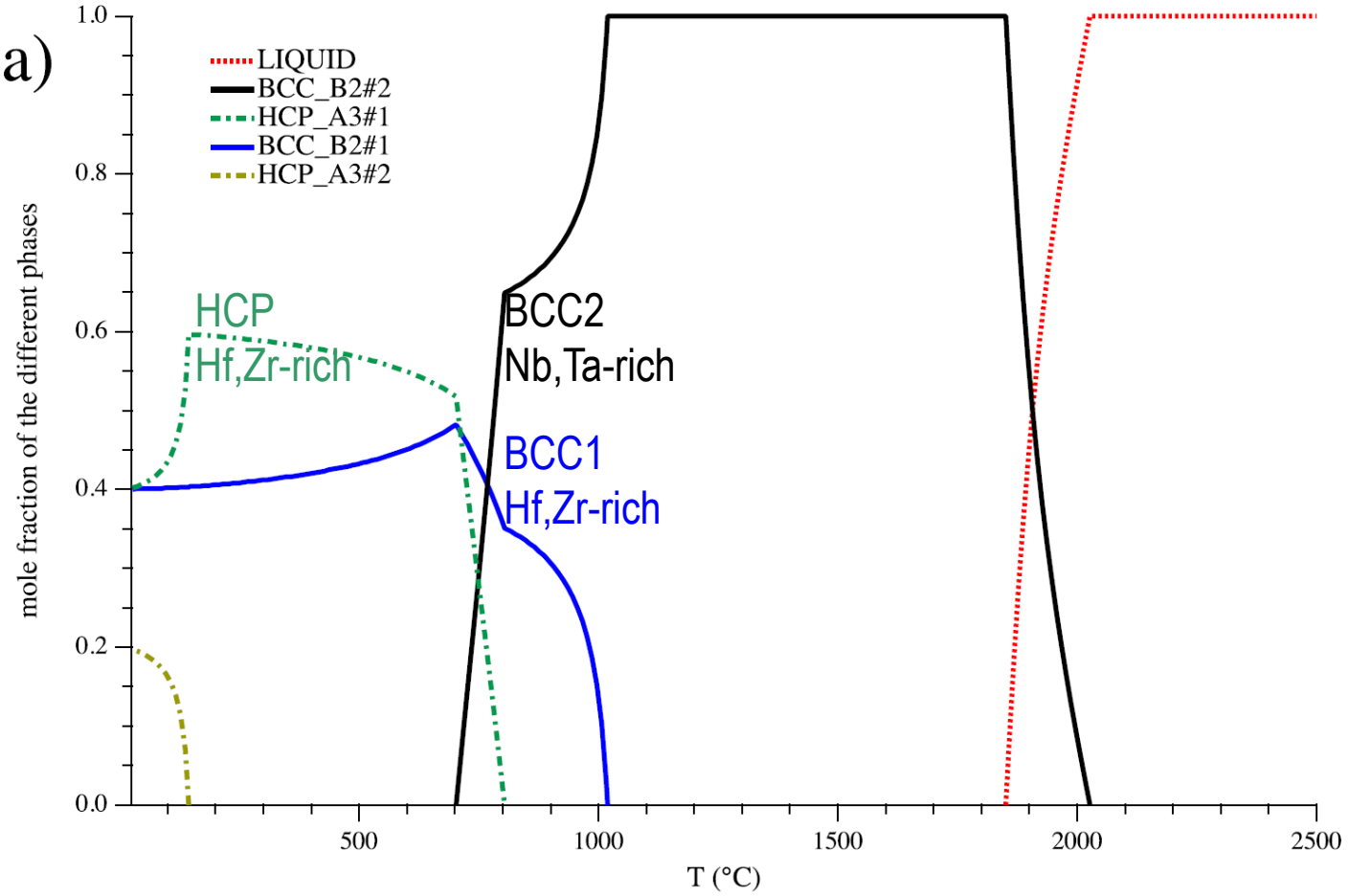


2. Single BCC phase alloy, T_m= 2200°C, ρ = 9.94 g.cm^{-3}

3. Young modulus ~100 GPa + non-toxic elements ~ biocompatible

O.N. Senkov et al. / Journal of Alloys and Compounds 509 (2011) 6043–6048
O.N. Senkov, S.L. Semiatin / Journal of Alloys and Compounds 649 (2015) 1110–1123

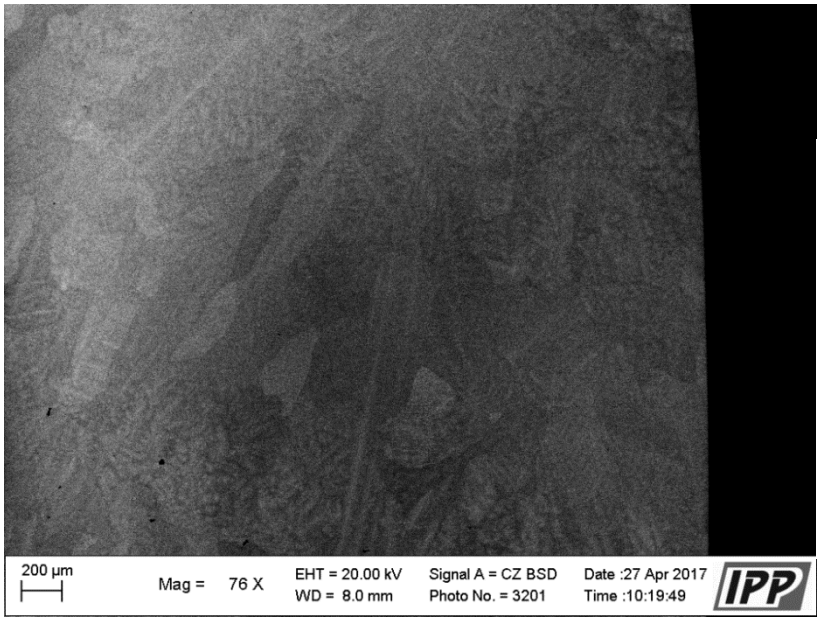
Phase stability of HfNbTaTiZr alloy

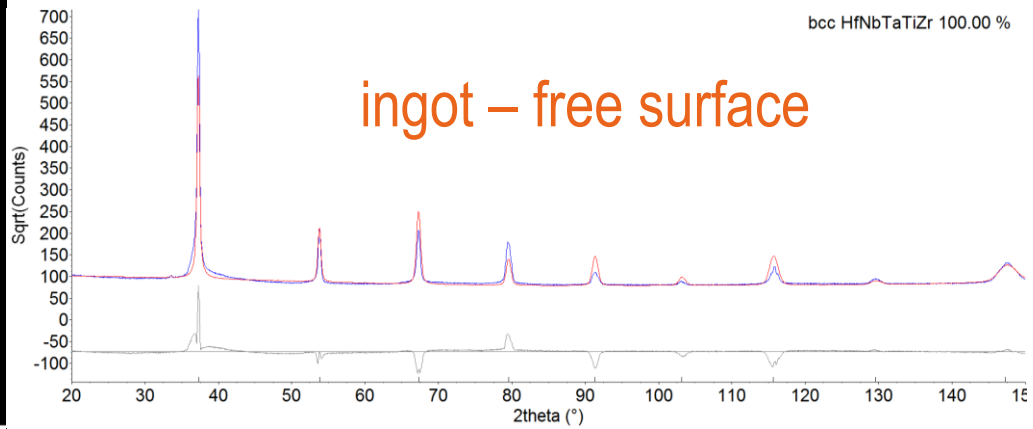


B. Schuh, B. Voelker, J. Todt, N. Schell, L. Perriere, J. Li, J.P. Couzinie, A. Hohenwarter, Thermodynamic instability of a nanocrystalline, single-phase TiZrNbHfTa alloy and its impact on the mechanical properties, Acta Mater. 142 (2018)

HfNbTaTiZr - arc melting, 99.9 %

ingot



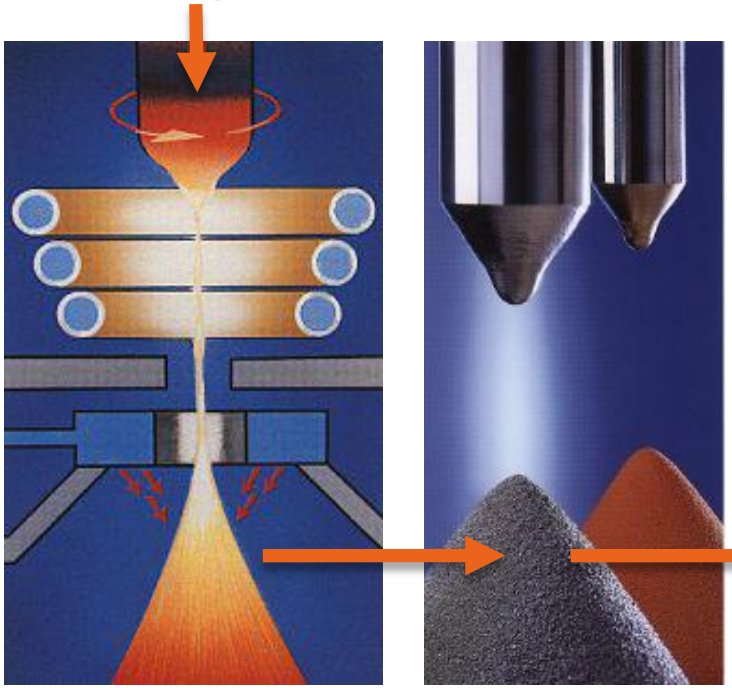


Convential production: - arc melt casting + additional 1200 °C / 24 h annealing
- chemical inhomogeneity

Alternative?

Powder metallurgy

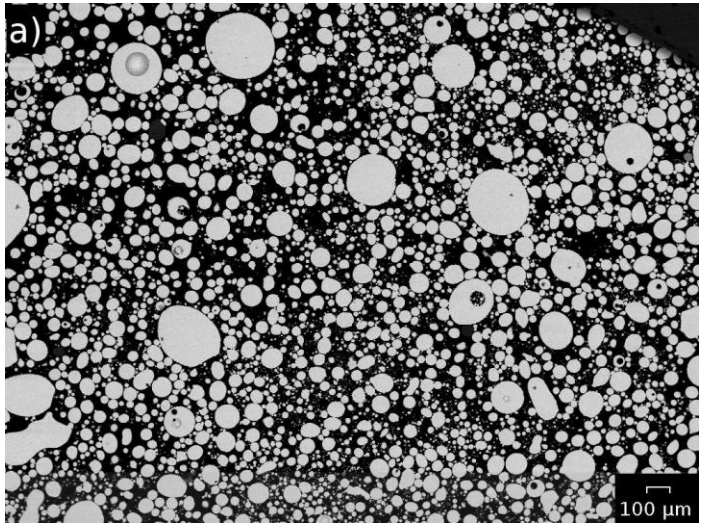
- from ingot of cast HfNbTaTiZr

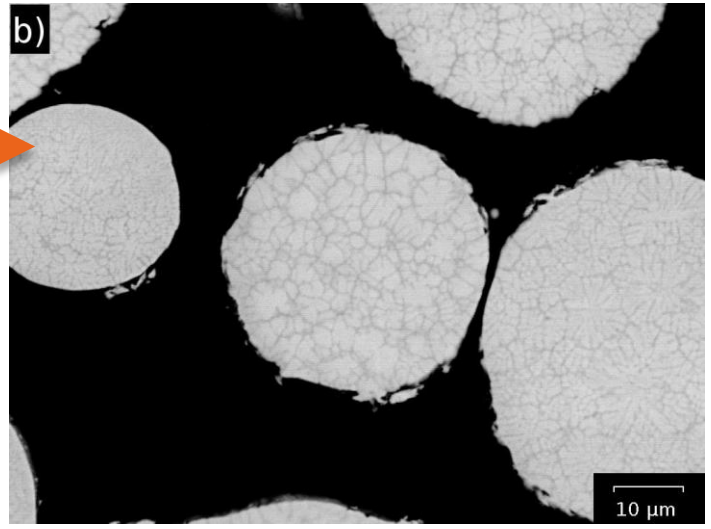


- to powder by gas-atomization

EIGA (*Electrode Induction-melting Gas Atomization*)

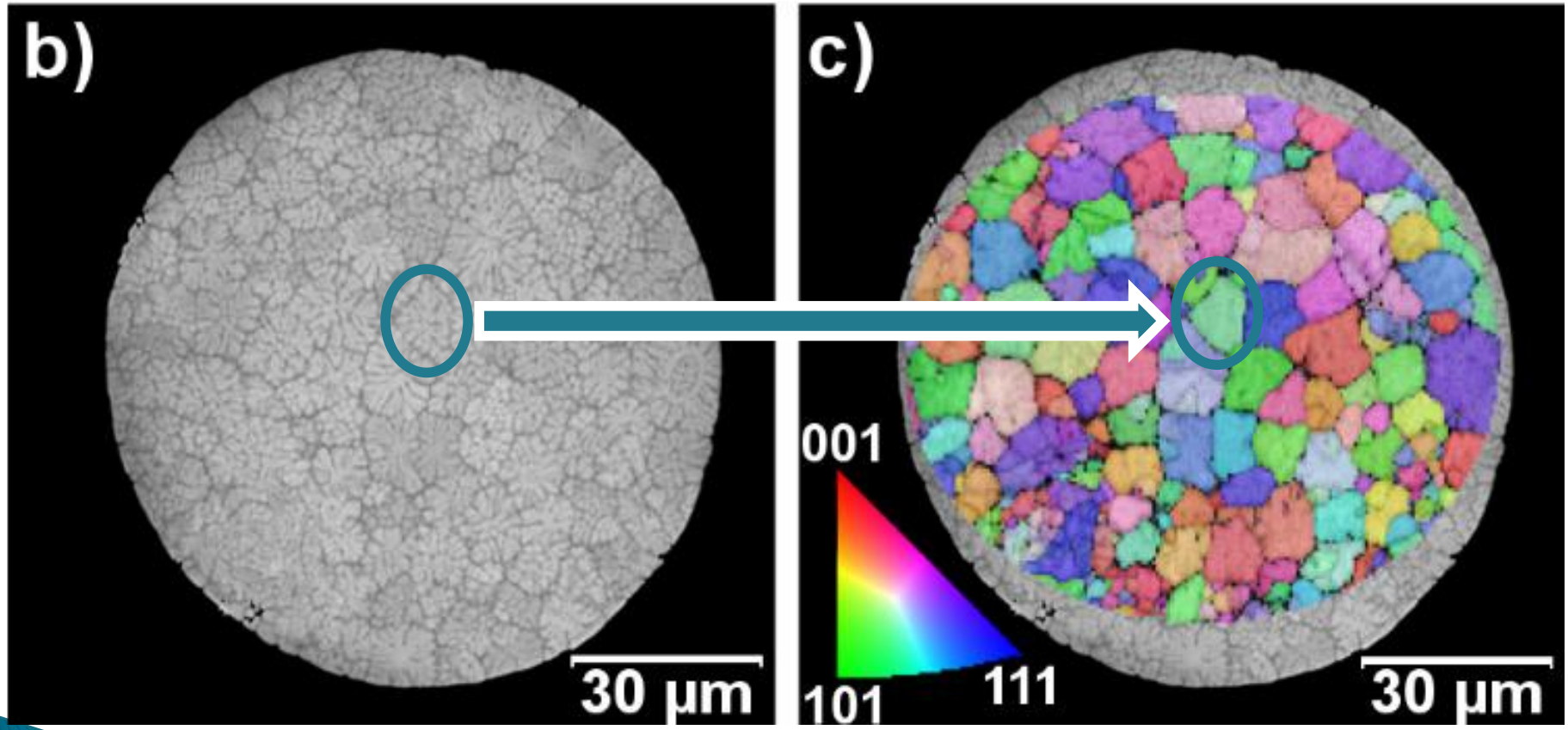
Atomized powder



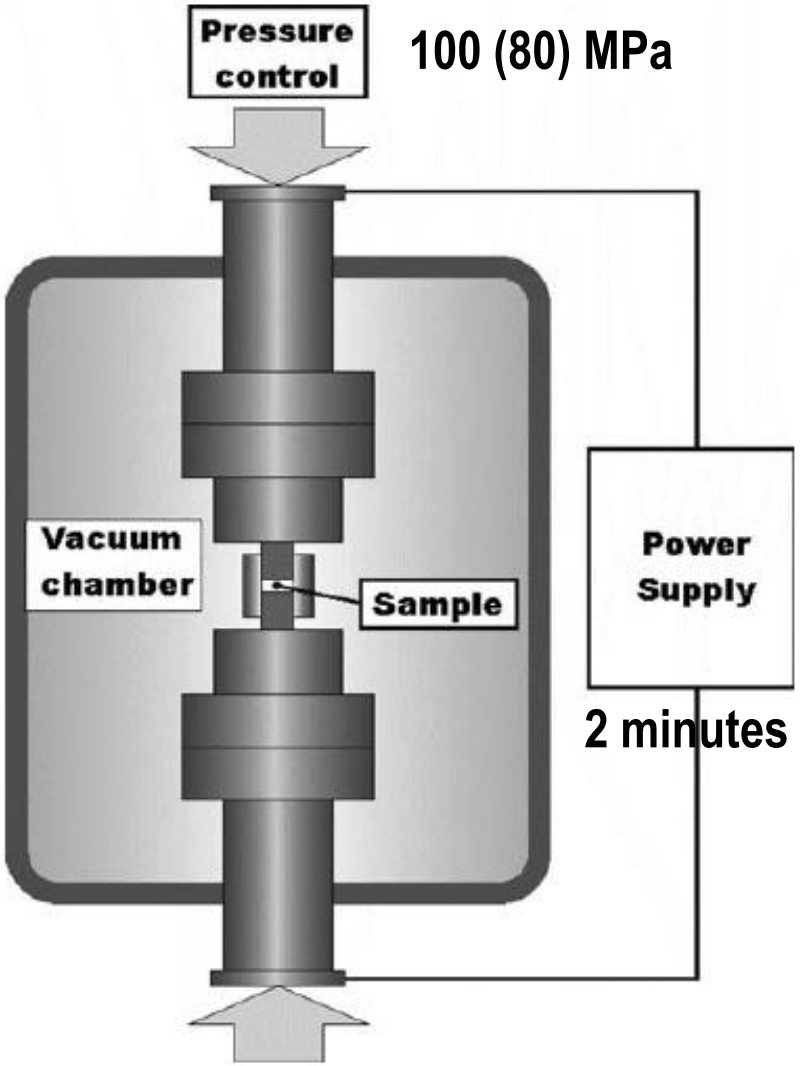


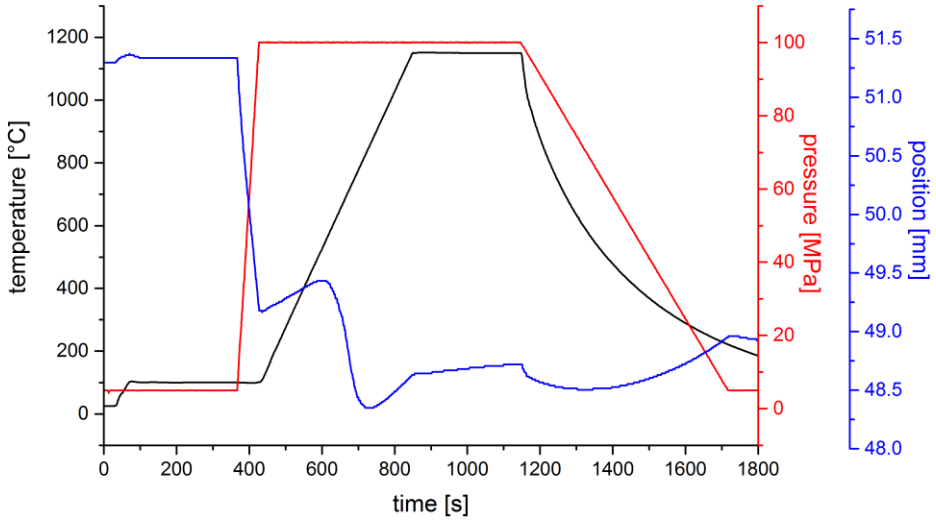
Atomized powder

Grain size ~ 9 μm



Spark Plasma Sintering – Powder metalurgy





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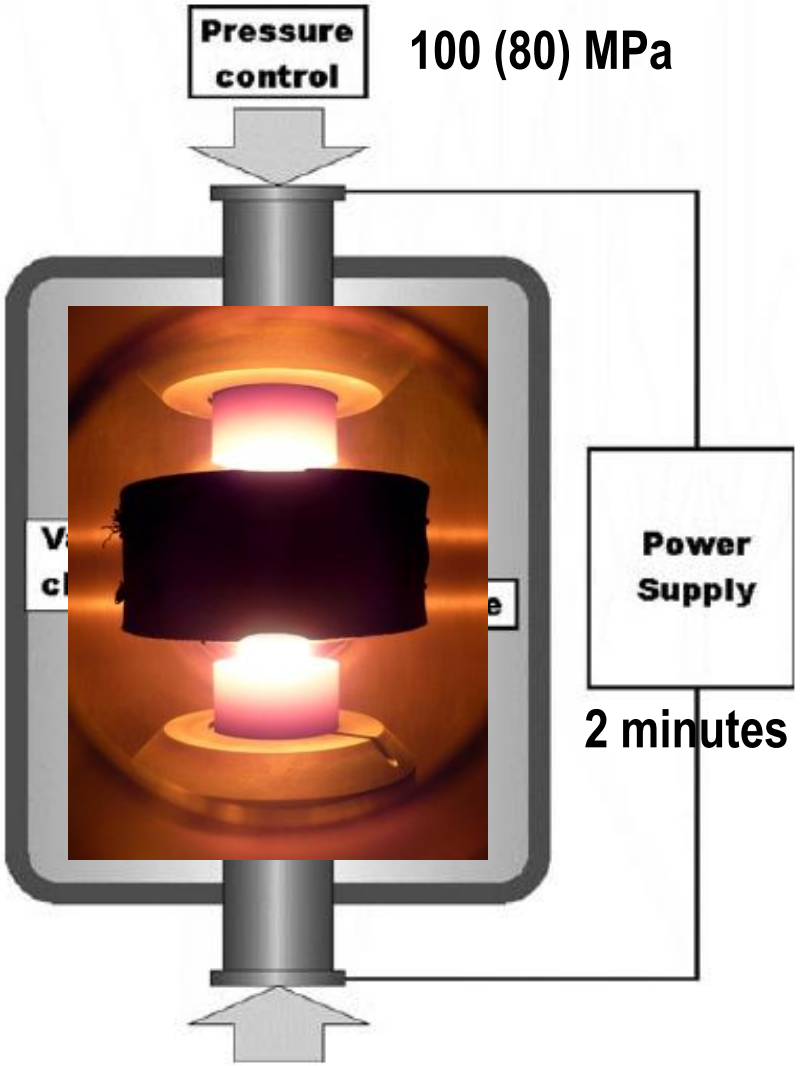
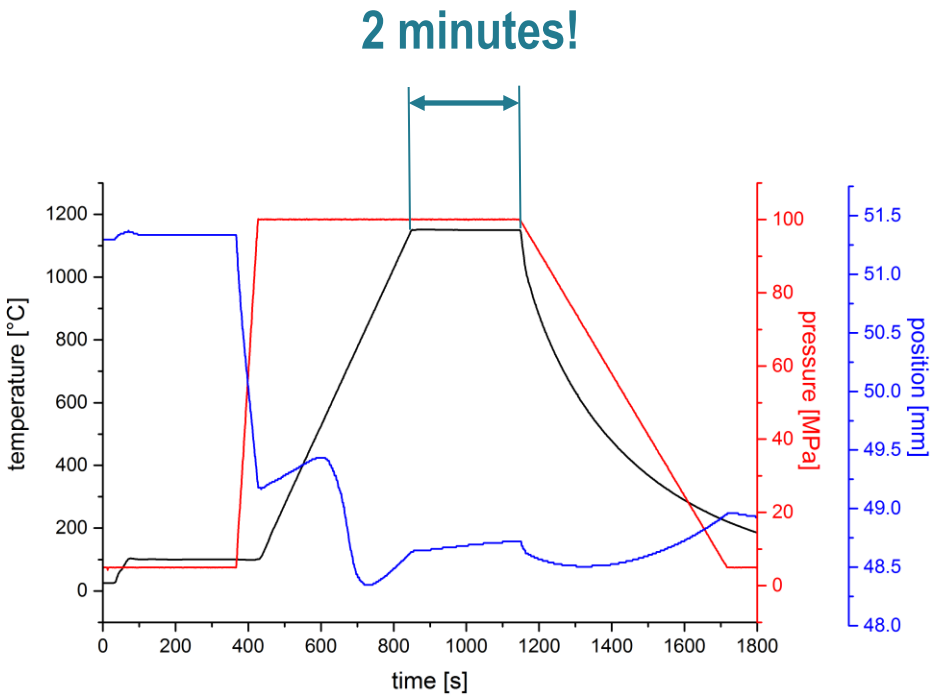
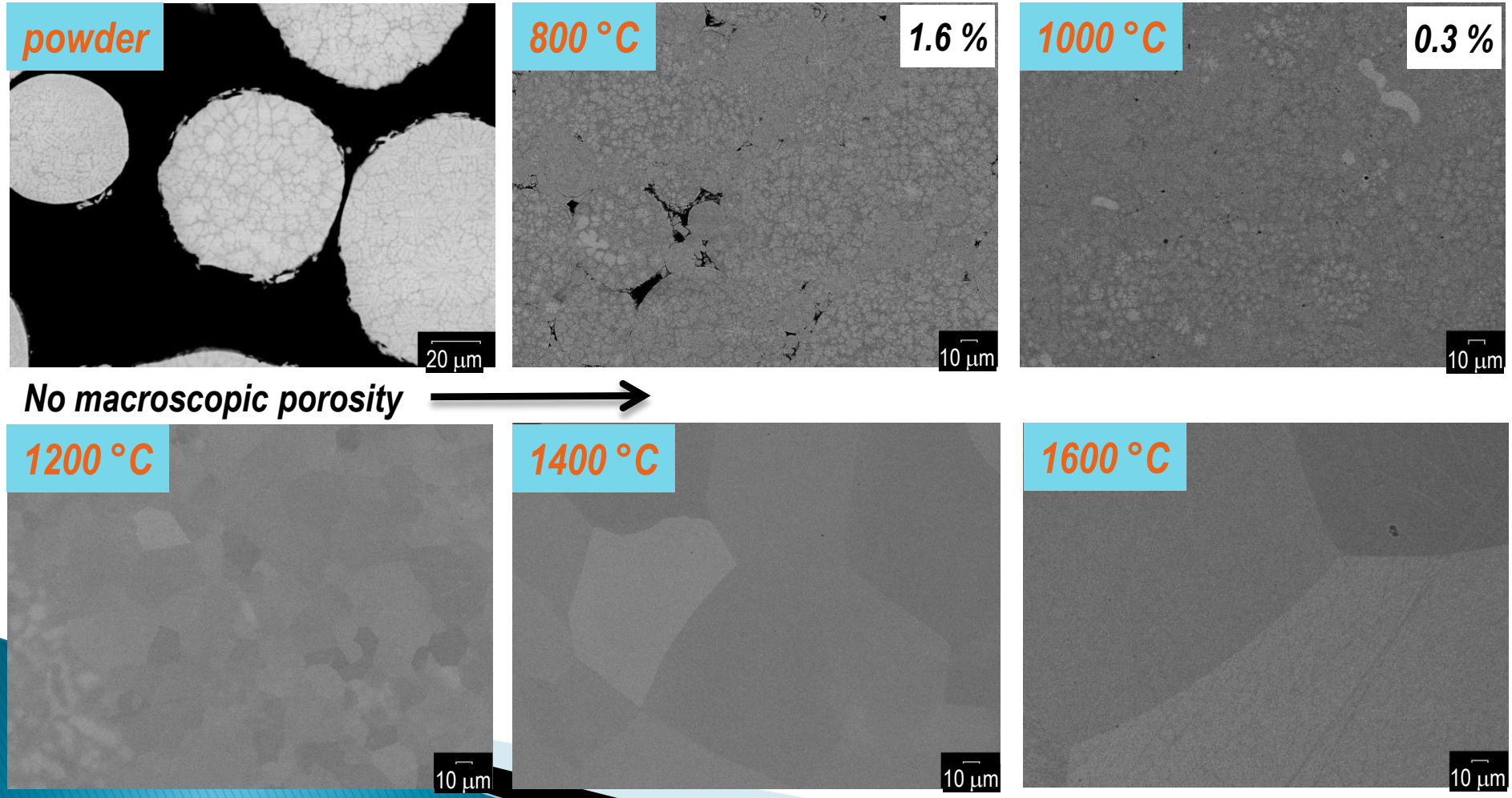


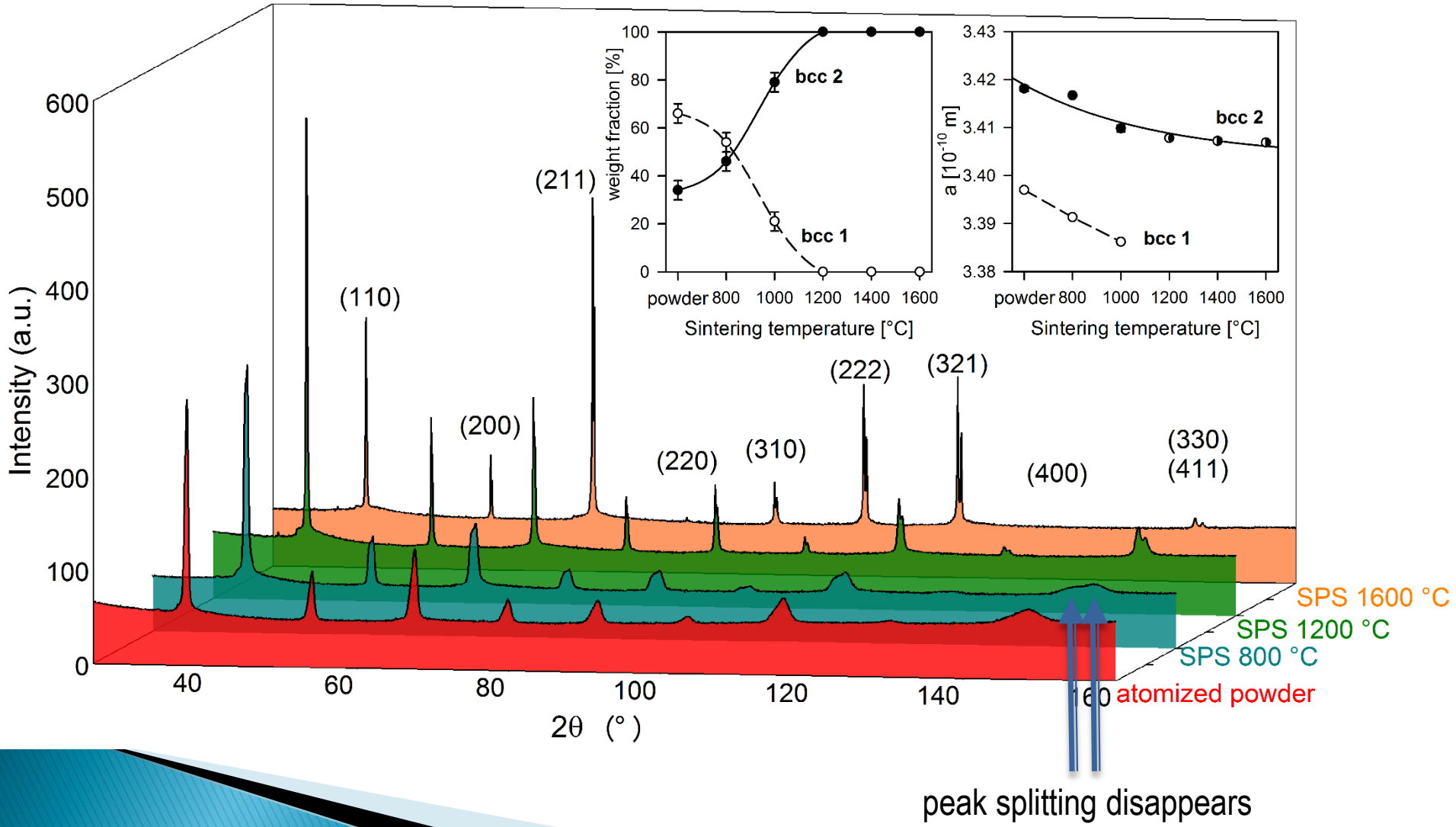


Spark Plasma Sintering – Powder metalurgy

- Optimization of sintering temperature



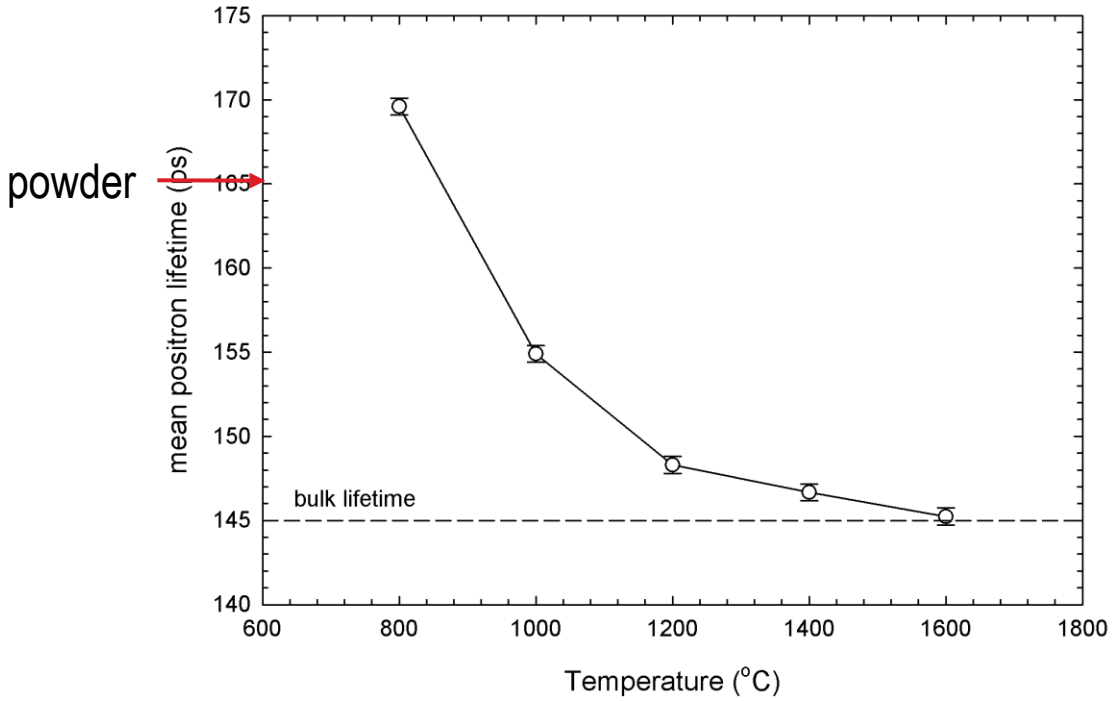
XRD Rietveld refinement



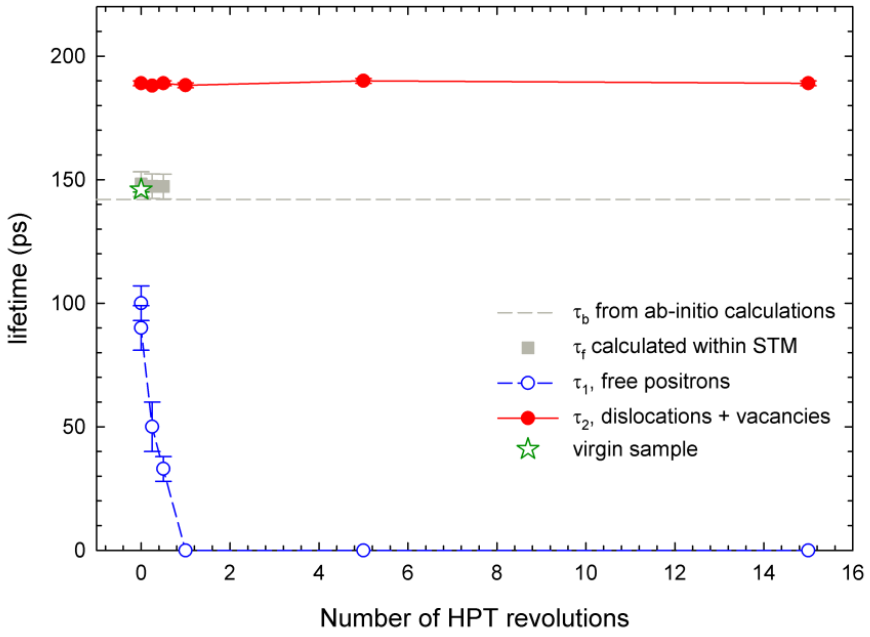
PAS setup

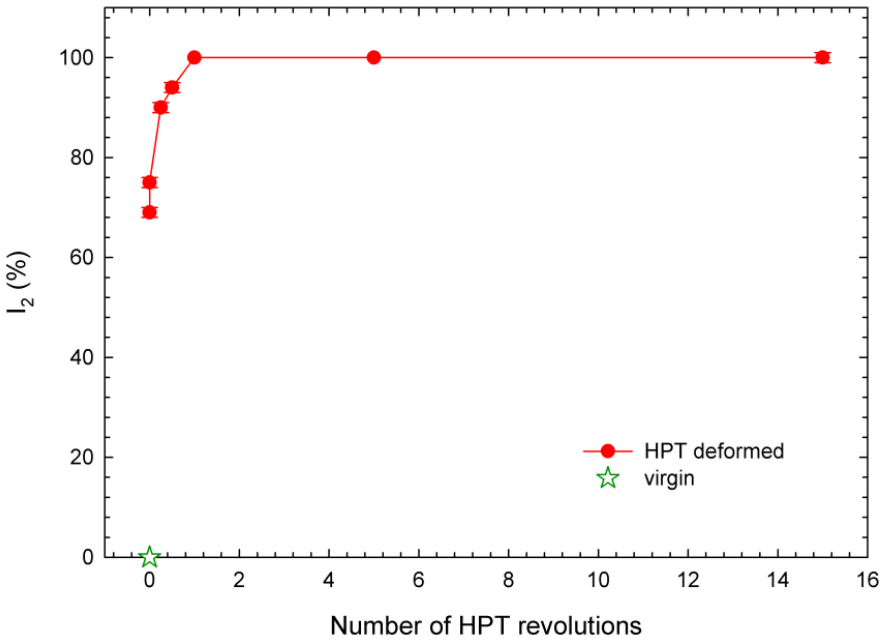
Defects in sintered samples

atomized powder shows defects τ = 165 ps



High pressure torsion in HfNbTaTiZr (previous results)





Defects in sintered samples

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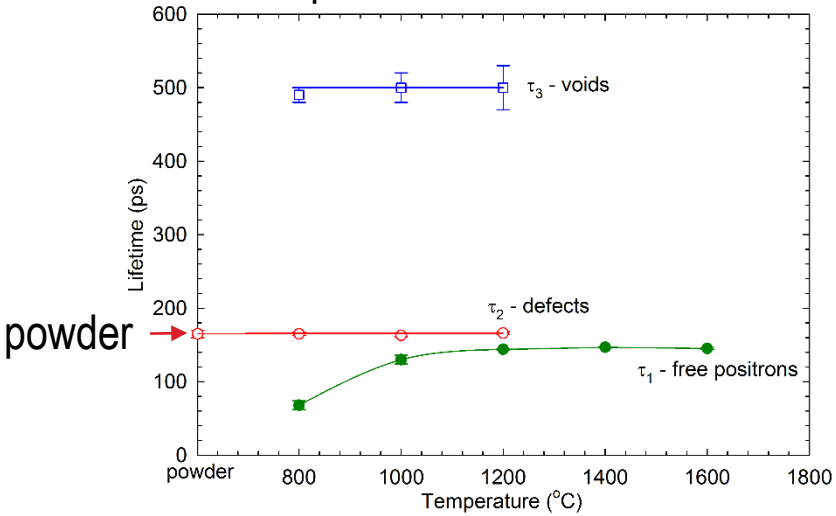
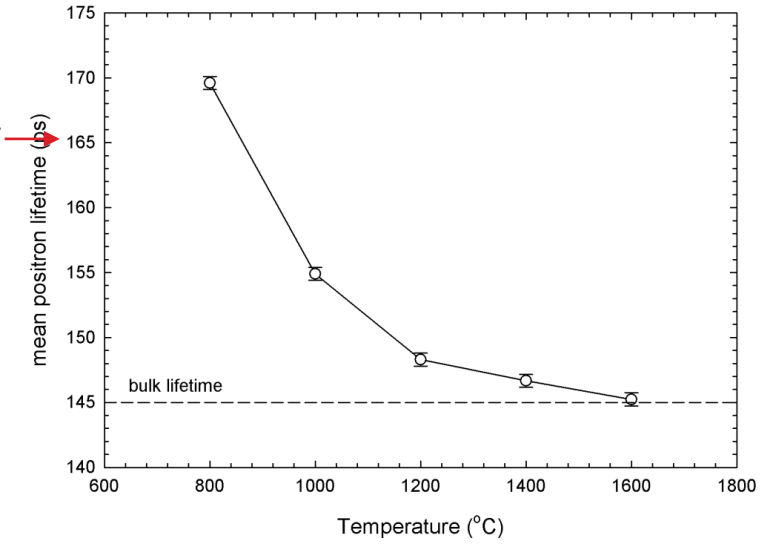
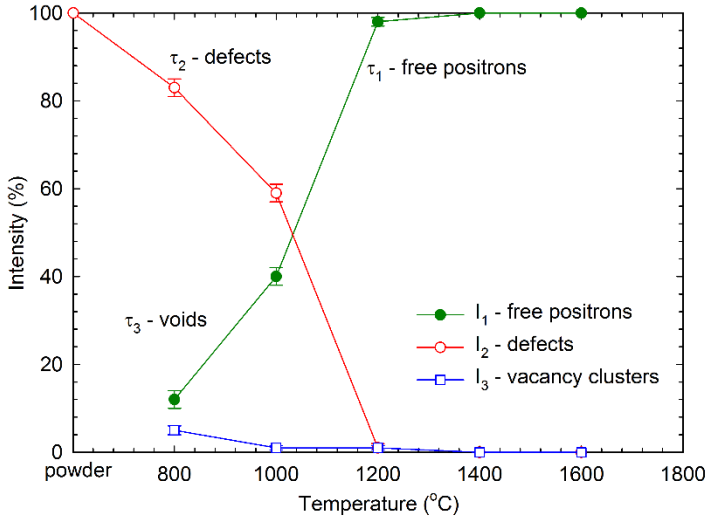


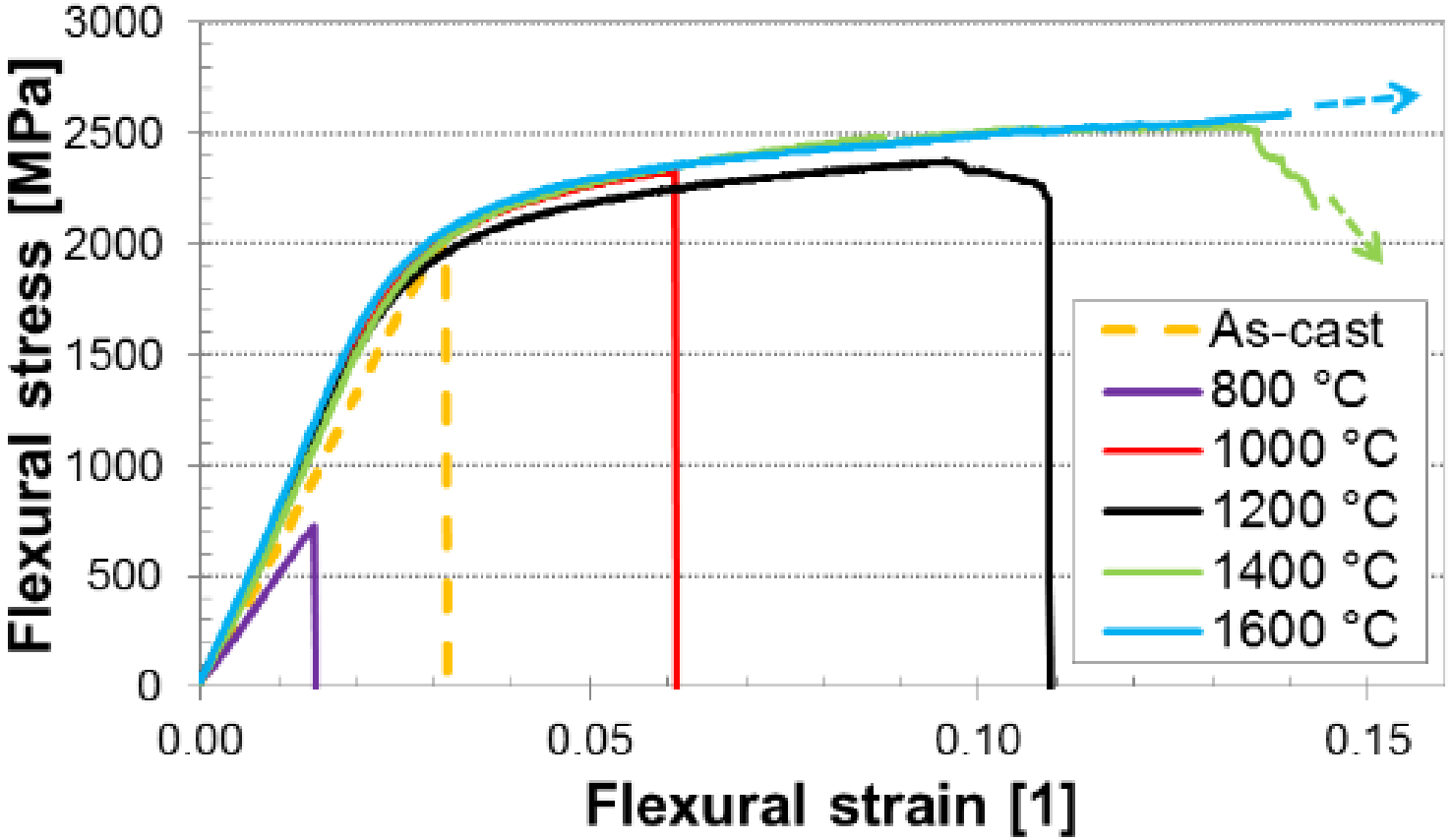
powder





disappearance of defects correlates with number of phases

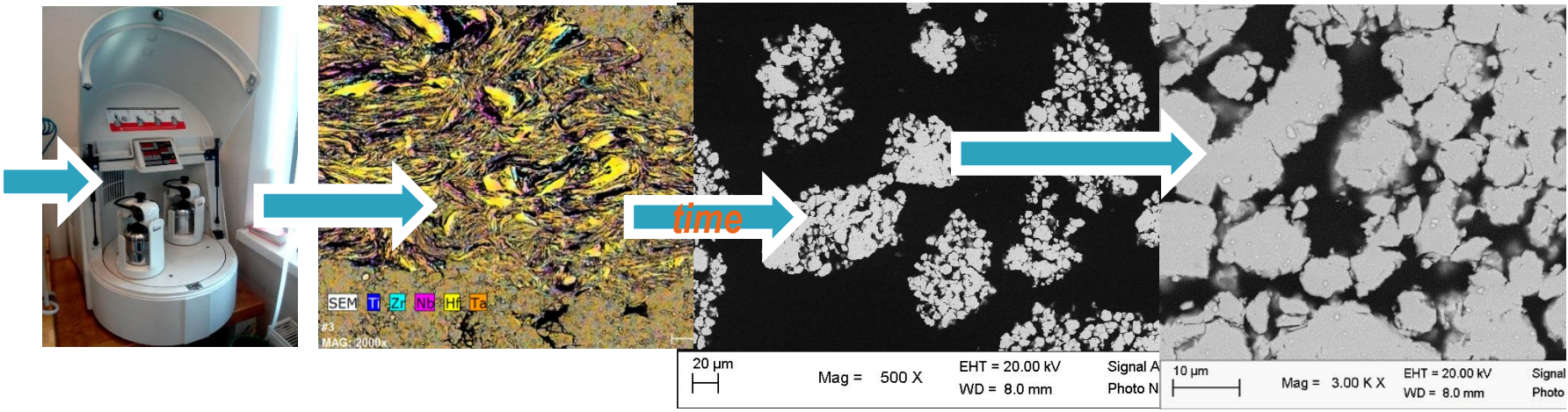
Mechanical properties of SPS

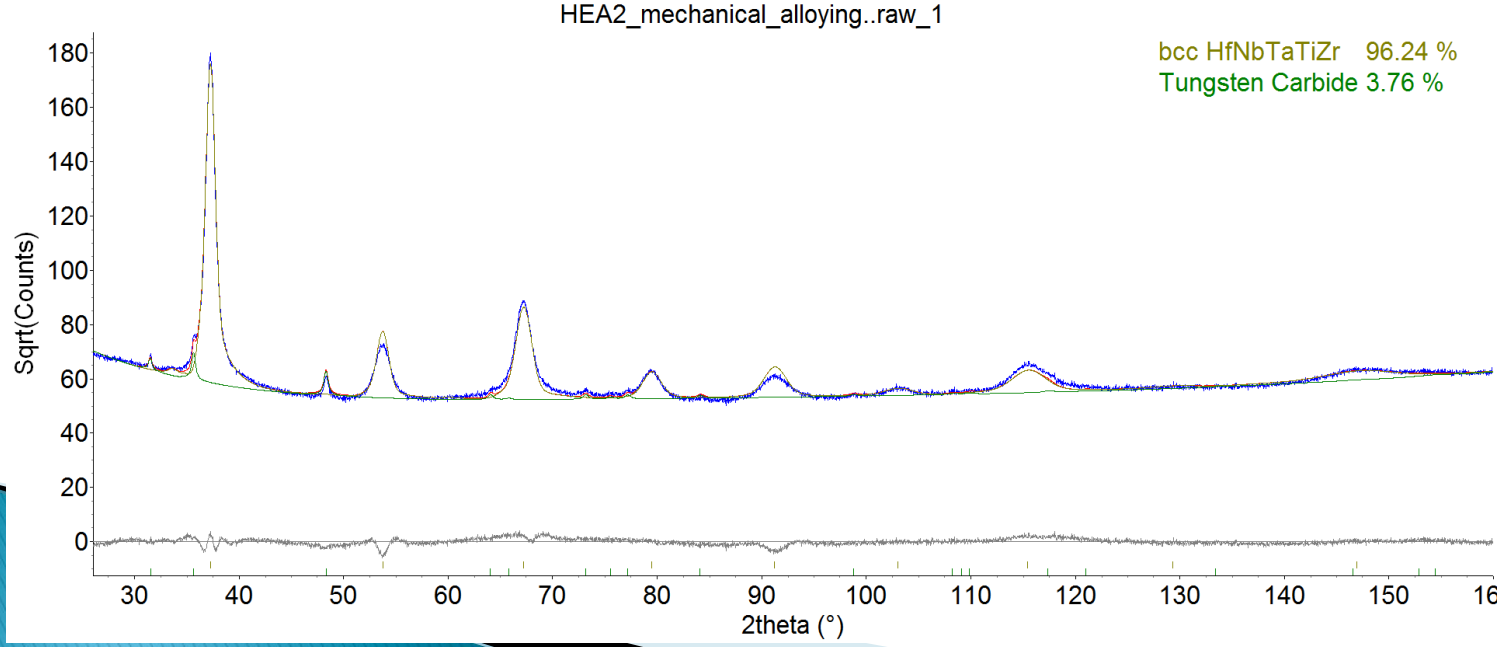


Mechanical alloying - MA powder from pure metals

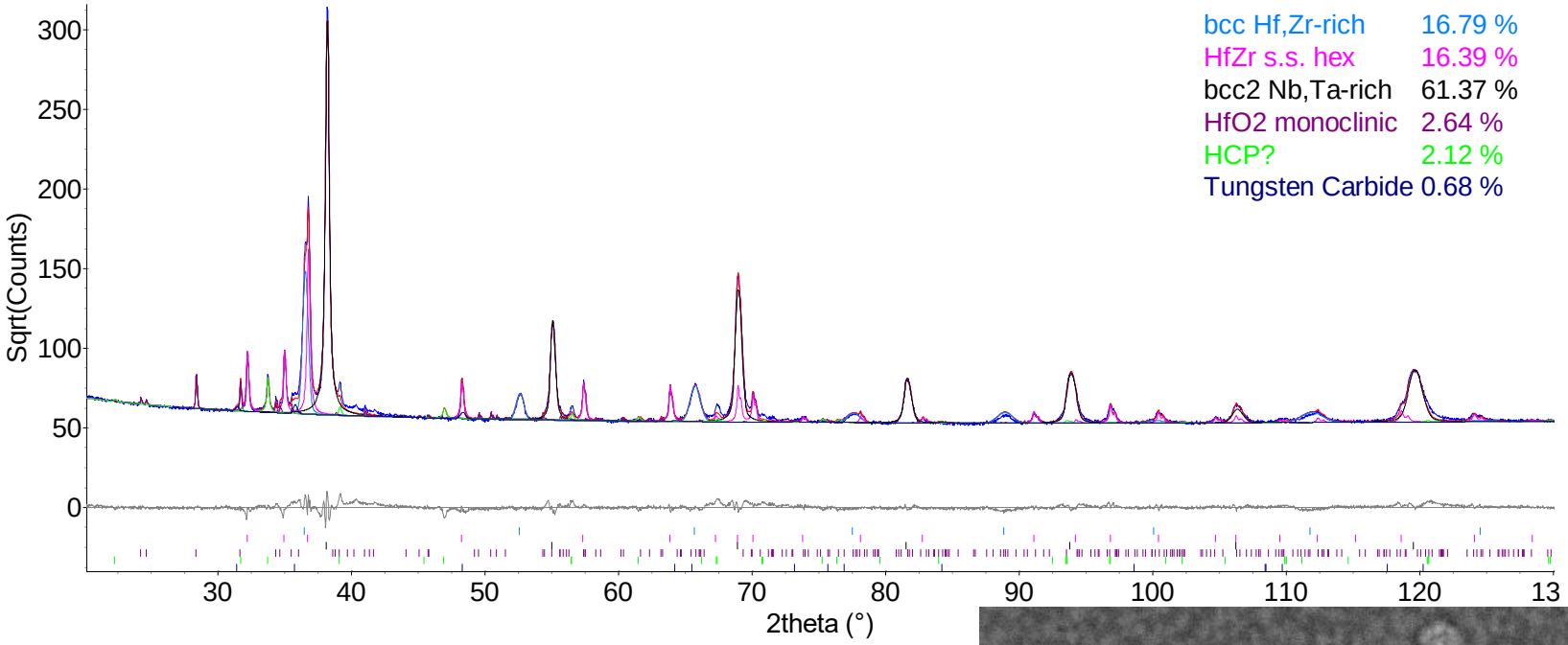
Hf
Nb
Ta
Ti
Zr

POWDERS

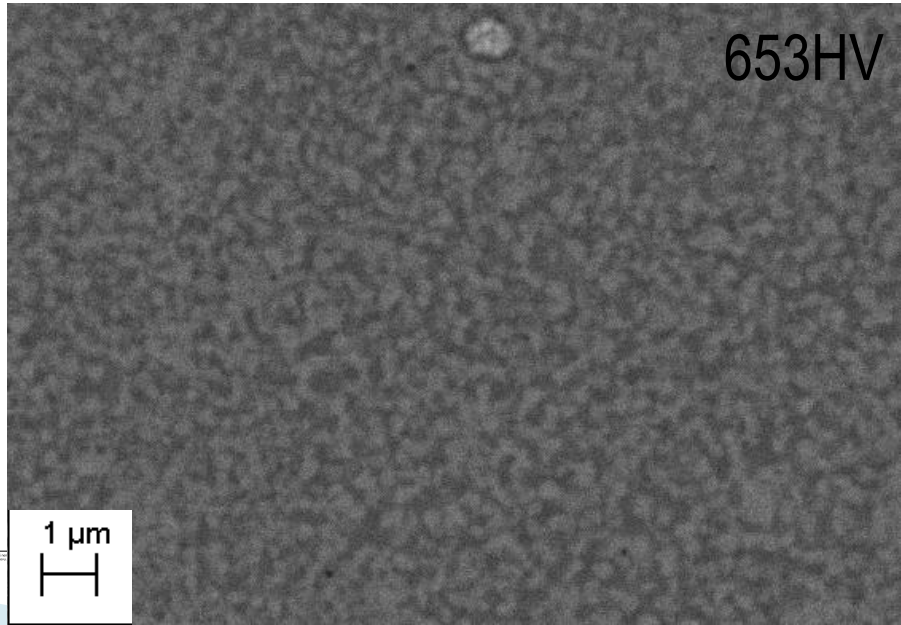




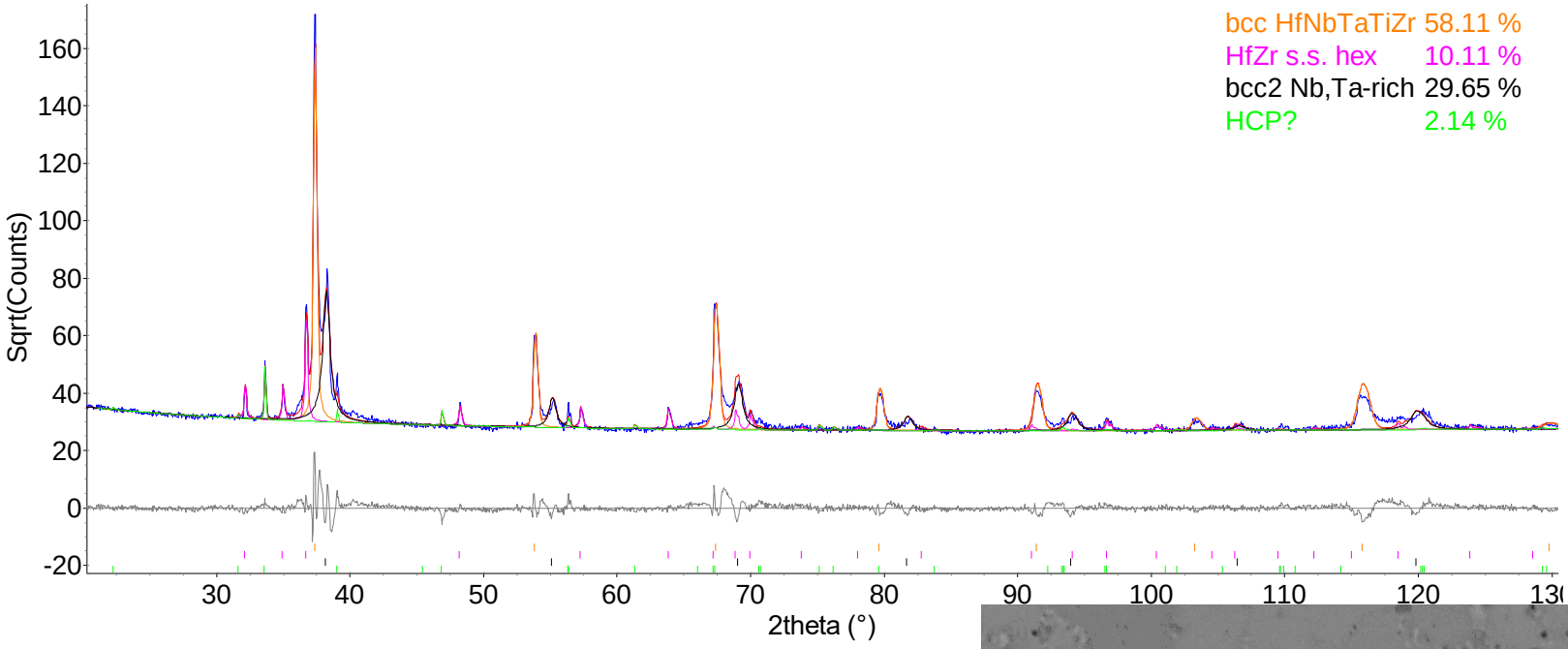
Mechanical alloying (MA) + SPS1000°C / 2min

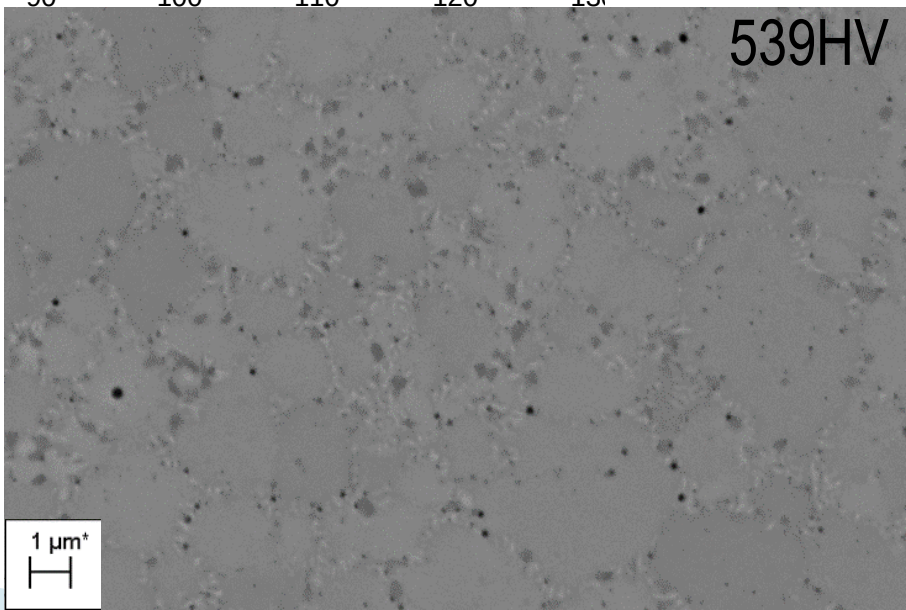


bcc Hf,Zr-rich	16.79 %
HfZr s.s. hex	16.39 %
bcc2 Nb,Ta-rich	61.37 %
HfO2 monoclinic	2.64 %
HCP?	2.12 %
Tungsten Carbide	0.68 %

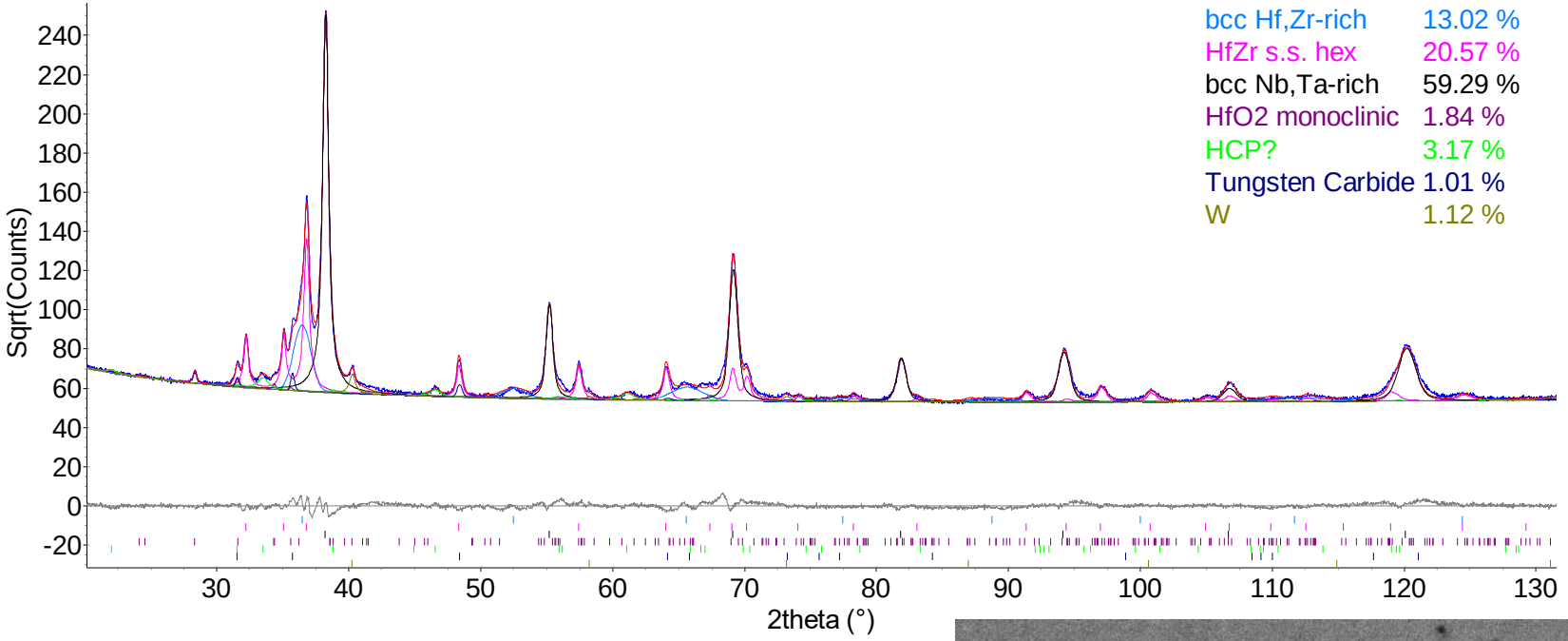


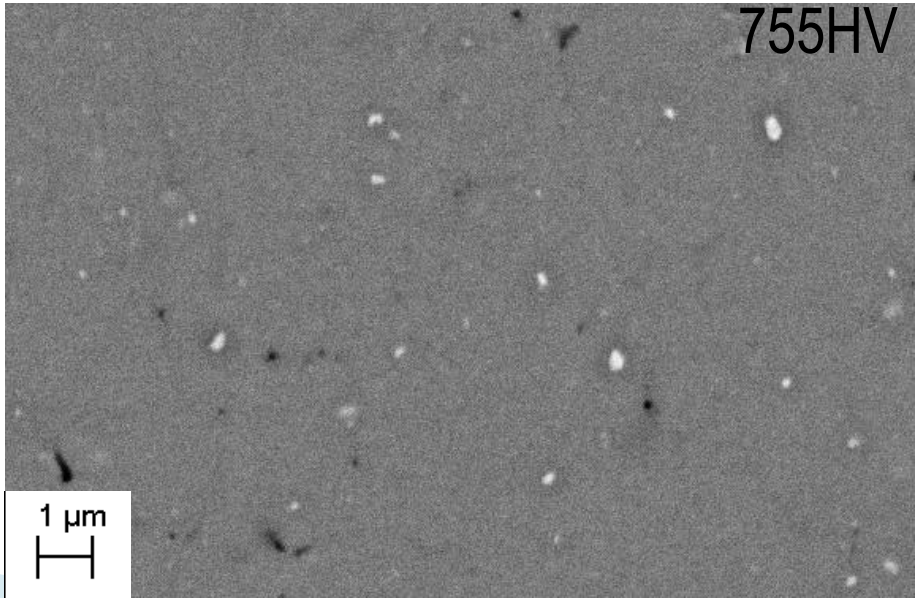
MA + SPS1200°C / 2 min





MA + SPS1000°C / 0 min + quench





Conclusions

- Optimization of SPS parameters was done using PAS
- Sintering produces high entropy single phase alloy when recrystallization occurs
- SPS yield better mechanical properties than arc-casting in significantly reduced time
- Induced deformation in powder significantly accelerates phase transformation during sintering
- Mechanical alloying produce single phase HEA powder
- SPS of MA powder produces nano-sized grains material with improved mechanical properties