In-situ alloying of low alloyed steel with WC and C in PBF-LB/M

Maximilian Marschall *[1,3,4]· Dominic Bartels [1-4] · Katja Tangermann-Gerk [1], Stephan Roth [1,3,4] · Michael Schmidt [1-4]

1 Bayerisches Laserzentrum GmbH, 91052 Erlangen, Germany
2 Institute of Photonic Technologies (LPT), Friedrich-Alexander-University Erlangen-Nuremberg, 91052 Erlangen, Germany
3 Collaborative Research Center (CRC) 814 "Additive Manufacturing", 91052 Erlangen, Germany
4 Erlangen Graduate School in Advanced Optical Technologies (SAOT), 91052 Erlangen, Germany

* Email: m.marschall@blz.org

Introduction and Motivation

- Laser-based powder bed fusion of metals (PBF-LB/M) enables to generate complex parts of usually one powder source
- Choosing local composition and modifying properties like working with a spice rack is called local in-situ alloying
- **Guiding hypothesis:** Can a low alloyed steel be tailored to a hardness comparable to case hardening treatment but in PBF as-built condition
- **Goal:** Ensuring global and local in-situ alloyed samples to achieve desired hardness and defect free samples

Materials and Methods

- low alloyed PBF steel powder Bainidur® AM developed on the base of 1.7980 (18MnCrMoV4-8-7) and 1.7979 (18MnCrMoV6-4-8)
- carbon black ASTM N550; 2.5 wt.%WC particles of different sizes FSSS 0.9/2.5/8.0 µm; Bainidur dry blended for two hours in a tumbler mixer
  → sample labeling according carbon and WC content: (0.25 wt.% C) 25B for Bainidur and (0.35 wt.% C) 35BWC0.9/2.5/8.0
- Aconity Mini PBF-LB/M machine setup: laser spot size 71.9 µm with Z_r = 2.3 mm; various VED; layer height 60 µm; hatch rotation 67.5°
- multi material sample prepared with layers of different powder in the powder feeder cylinder
- analyses: density, hardness testing, microscopy, OES, REM, EDX, EBSD

Results

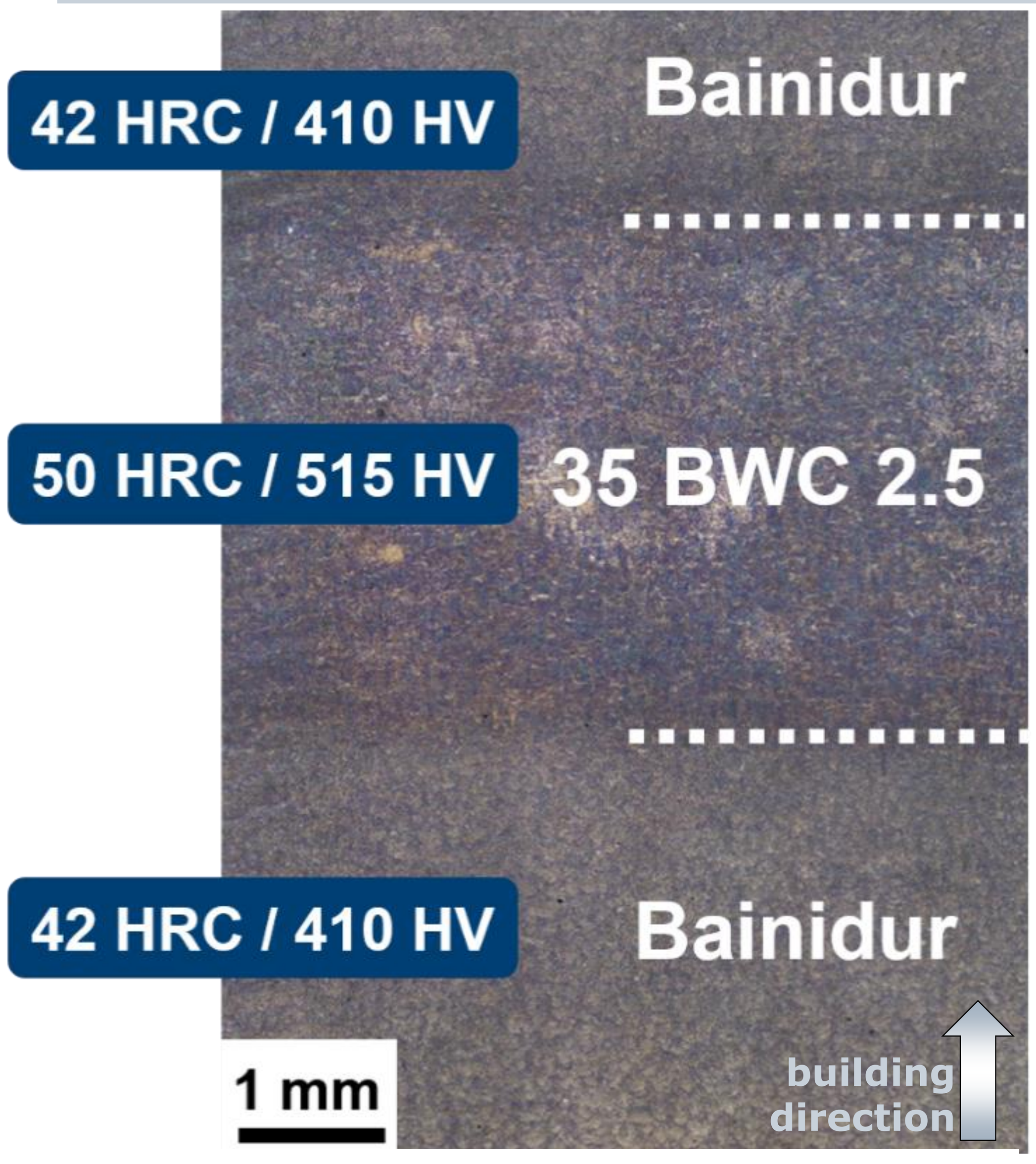

Figure 1: Overview of in-situ alloyed layer sandwiched by Bainidur with resulting hardness; sample was etched with Nital.

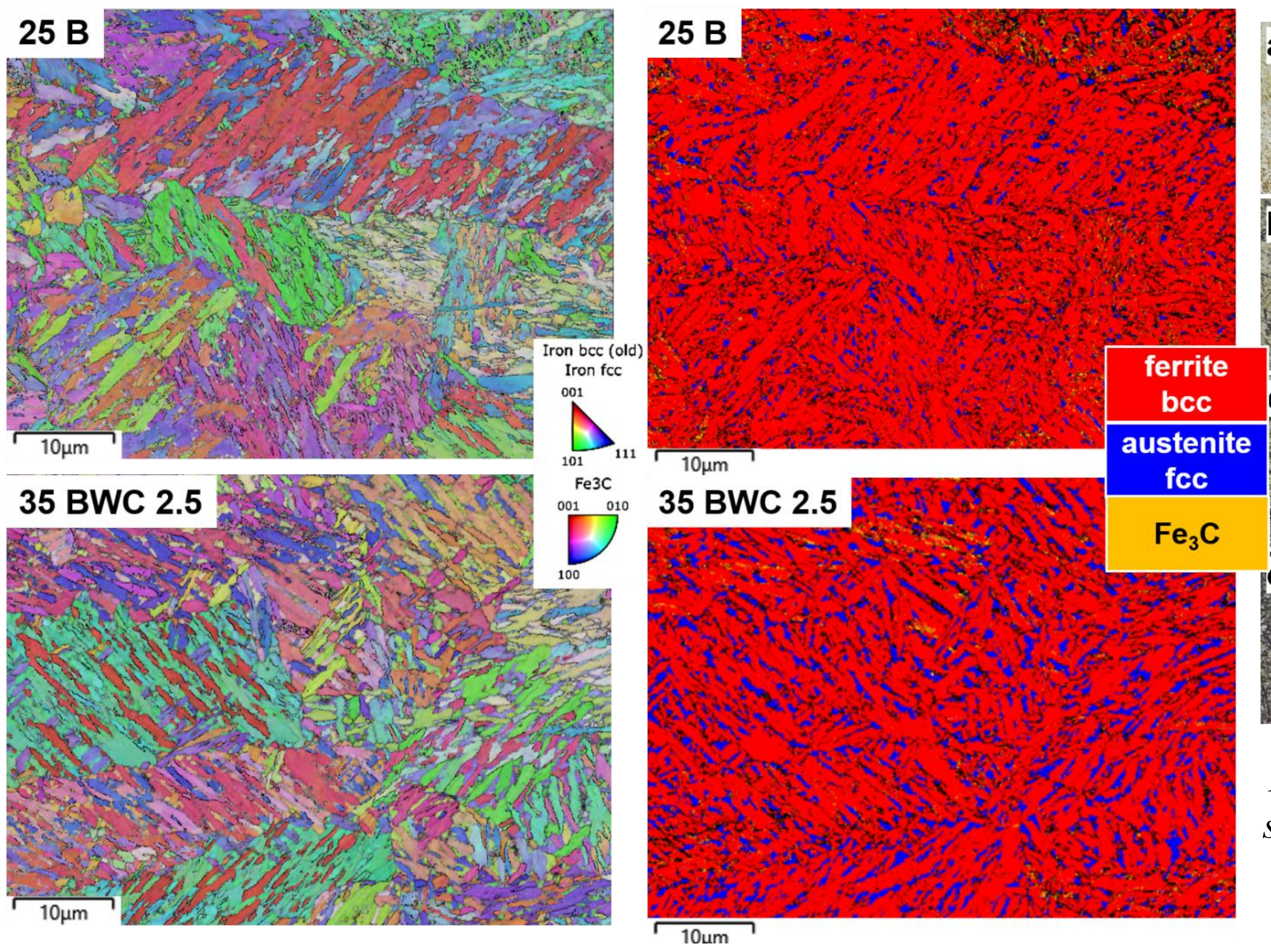

Figure 2: (left) EBSD grain orientation map in Y-direction based on inverse pole figures of regions in Figure 1 and (right) the correlating phase analyses map.

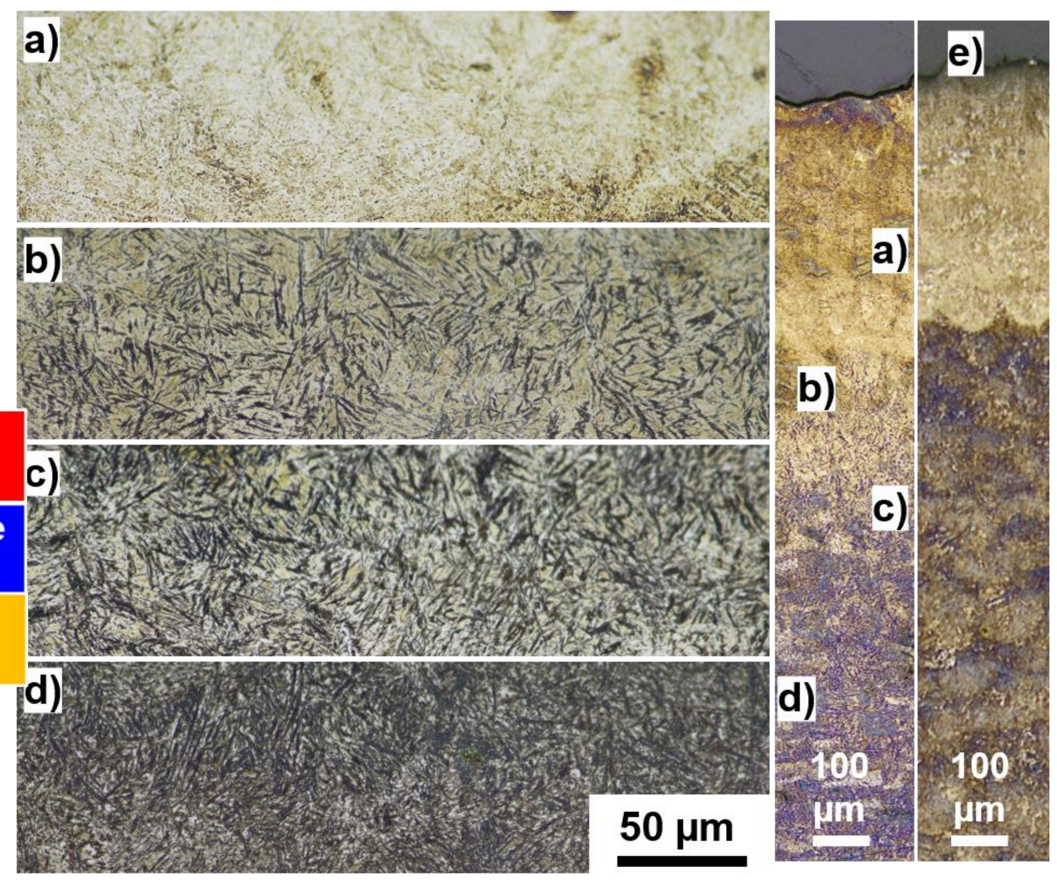

Figure 3: Microstructure development in global in-situ alloyed 35 BWC 2.5 from a) last weld tracks (up to 500 µm depth) over the transition zone b)+c) to the bulk microstructure in d); (right) correlating overview and e) 25B overview for reference.

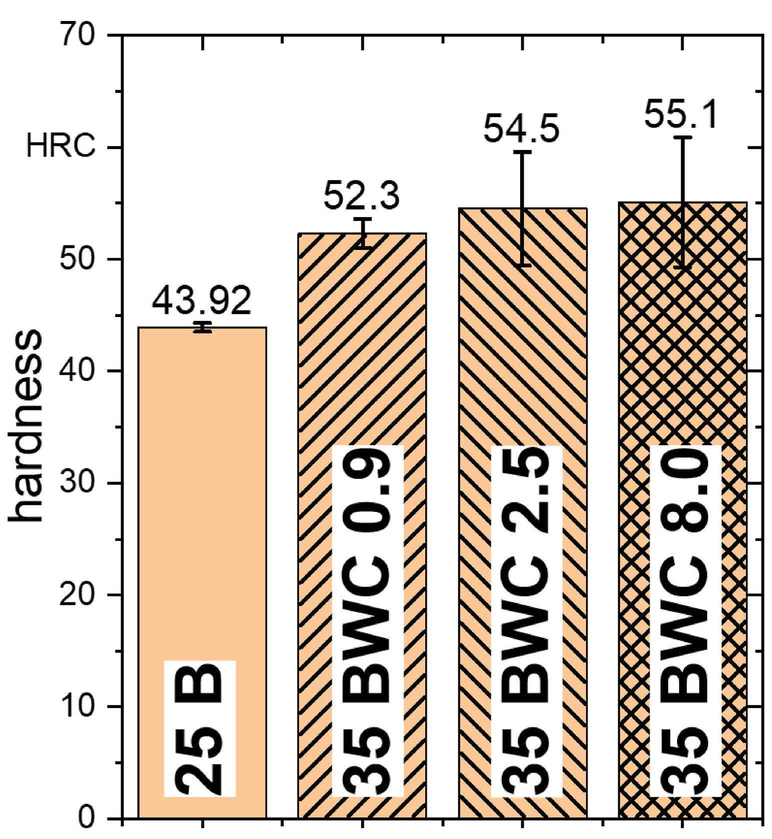

Figure 4: achieved hardness in global in-situ alloying with different WC particle sizes

- Low alloyed bainitic steel was modified with carbon black and tungsten carbide in global and local in-situ alloying
- Bainidur shows a pronounced separation in bulk microstructure to the last printed layer reaching down from top surface one laser welding depth deep – microstructure is predominantly bainitic without notable hardness change on the surface that etches brighter with Nital
- The modified alloy shows a development with bainitic/martensite like microstructure reaching down from top 0.5-1 mm until a stable microstructure is present for the rest of the sample → Figure 3
- Multi material samples were prepared successfully without interface defects → Figure 1
- Reuse of powder blends reduced carbon content by 0.03% points, resulting in lower hardness compared to global in-situ alloyed samples in Figure 4
- The additional carbon is available for alloying as the austenite phase increases in Figure 2 (right) correlated to the nickel-equivalent of austenite stabilisation of carbon

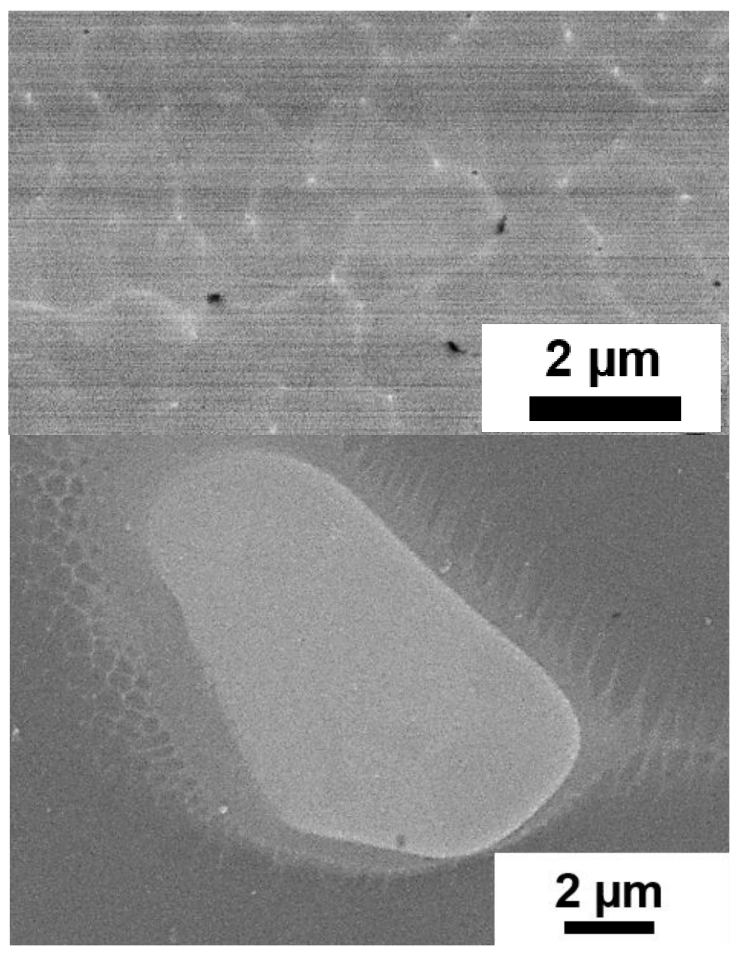

Figure 5: REM with AsB detector revealing homogenous distribution of W at grain boundaries / interdendritic phase (top) and distinct diffusion zone around remaining WC particle cores (bottom)

Conclusions

- Best hardness with the most homogenous microstructure was achieved by using the medium sized WC with FSSS 2.5 µm
- Depending on WC size and process parameters, WC can obtain good integration into the alloy matrix with distinct diffusion zones, while smaller particles dissolve with observable tungsten at grain boundaries without presence of nearby remaining particle cores
- Hardness enhancement was achieved, however, carbon loss on reusing powder must be taken into account for precise as-built hardness tailoring

Acknowledgements

The authors gratefully acknowledge funding of the Collaborative Research Center 814 (CRC 814), sub-project T5, by the German Research Foundation (DFG)-Project No. 61375930 and of the Erlangen Graduate School in Advanced Optical Technologies (SAOT) by the Bavarian State Ministry for Science and Art. And Kennametal Deutschland GmbH for providing a variety of WC particles.