Influence of carbide feedstock on properties of protective laser claddings on grey cast iron brake rotors

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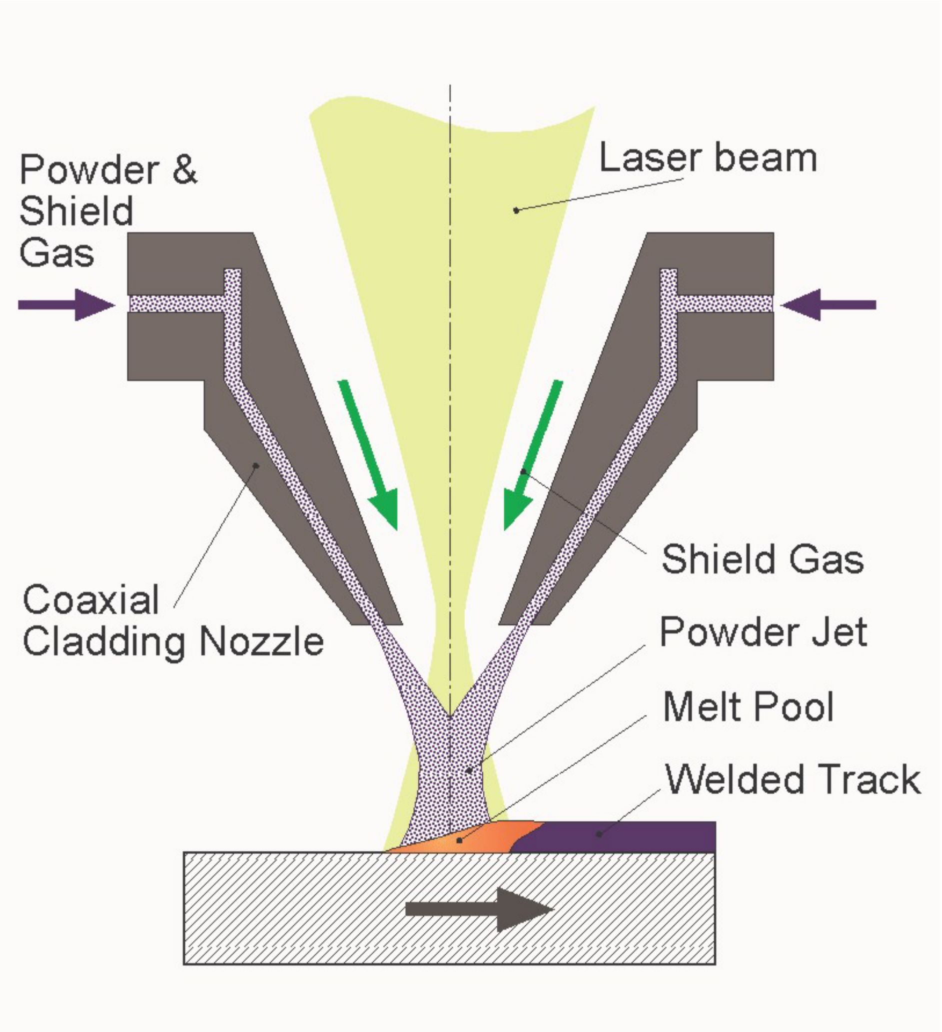
Outline

- Cladding process characteristics
- Cladding design
- Influence of reinforcing phases
  - Spherical fused tungsten carbide
  - NbC / TiC based powders

Cladding process characteristics

- **6-stream powder nozzle**
  tailored particle density distribution
  tailored speed of powder components
- **Up to 22 kW laser power**
- **Up to 300 g/min powder feed rate**
- **Deposition efficiency 87 - 92%**
- **Up to 400 m/min cladding speed**
- **Overlap > 85%**
- **80 - 500 µm layer thickness**
- **Stainless steel + TiC, NbC or W_2C/WC**



Cladding process characteristics

Cladding design

- **Multilayer claddings**

  buffer layer and graded hard phase contents

  reduce residual stresses

  production time, powder consumption and

  distortion increase with cladding thickness

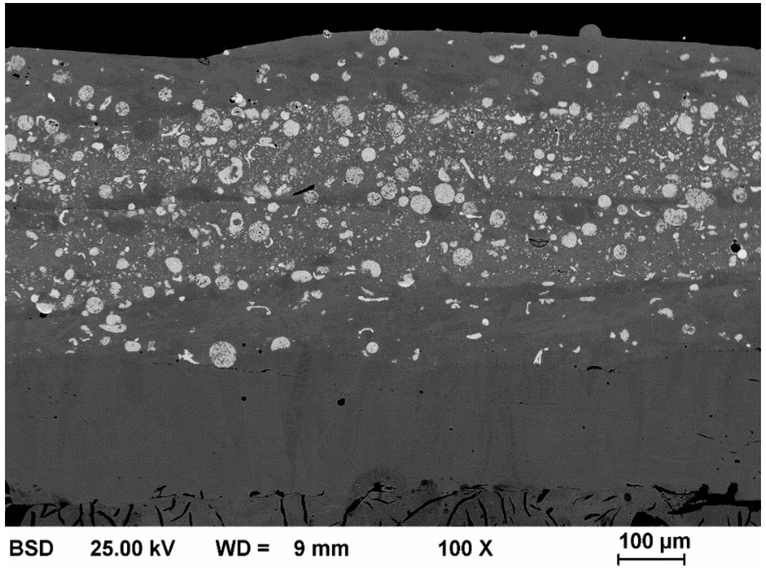
- **Monolayer claddings**

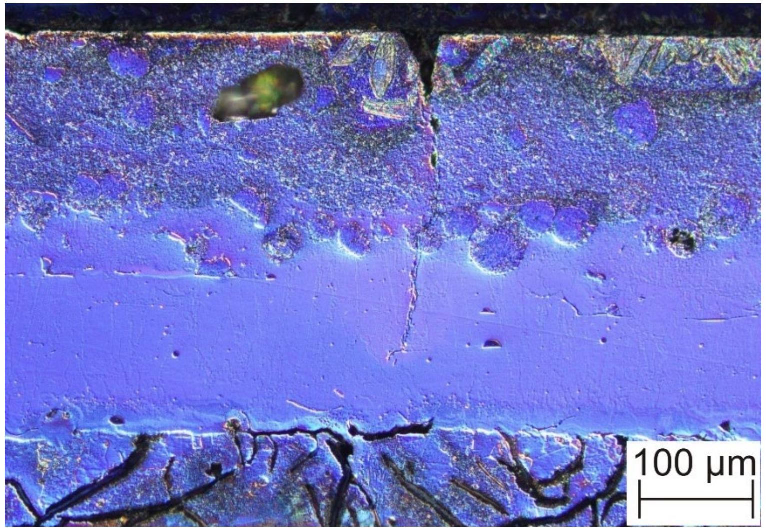
  stricter hard phase content limitations to

  avoid crack formation

  reduced crack propagation resistance

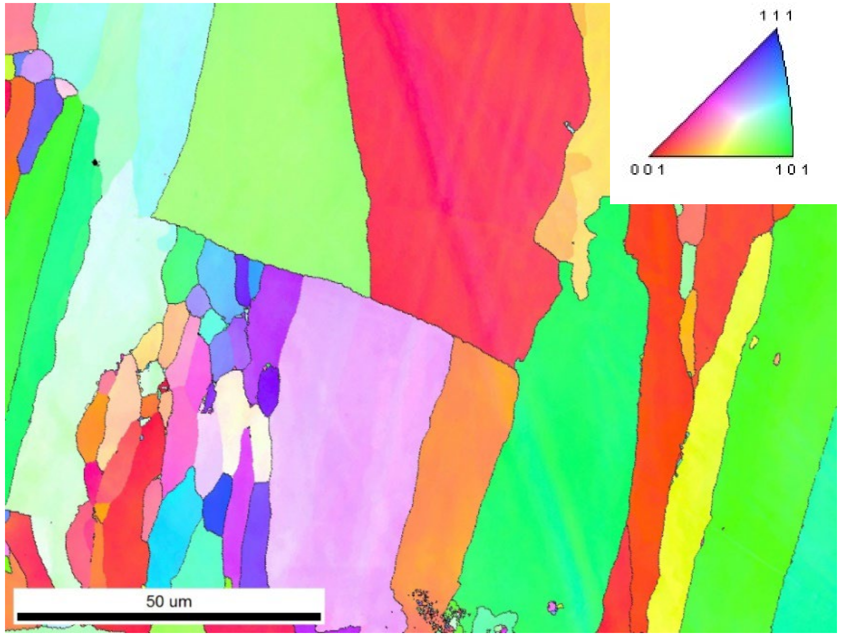
  reduced wear resistance

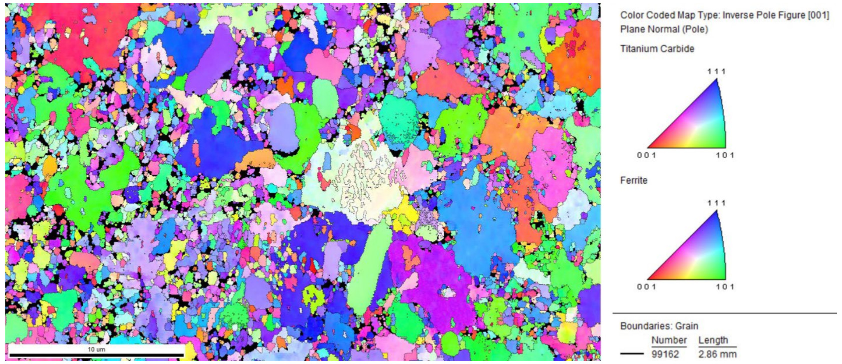




Cladding microstructure

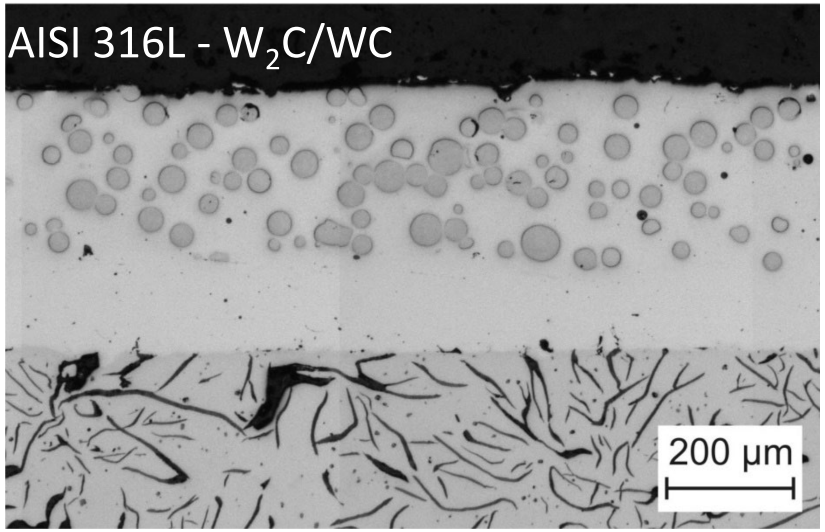
- **Directional solidification**
  stainless steel crystals cover full layer thickness for remelting of previous beads surfaces
  carbide reinforcement causes grain refinement and prevents grain growth due to thermo-mechanical load
- **Crystal structure**
  non-equilibrium phase composition due to high cooling rates; even Schaeffler diagram not applicable; e.g. AISI 318LN fully ferritic





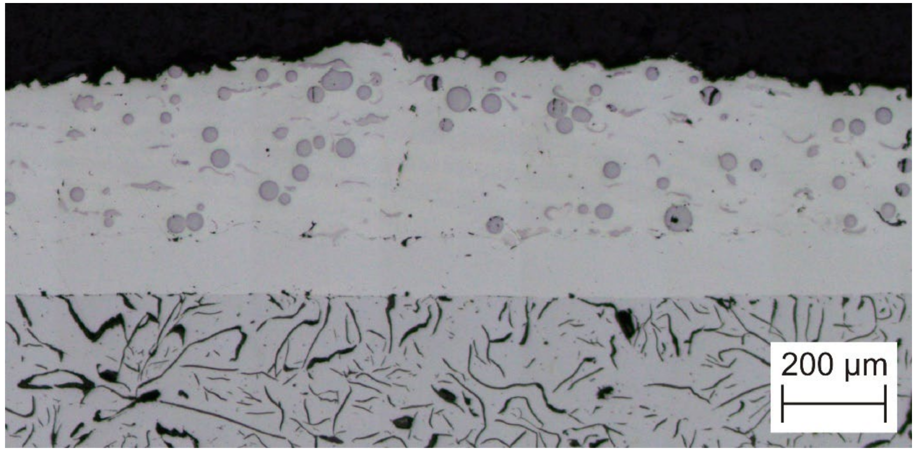
W_2C/WC reinforcement

- **Carbide content**
  Crack free 30 vol.-% W_2C/WC - stainless steel layers only possible without pre-heating for use of buffer layers as well as limitation of friction ring surface area and cladding thickness
- **Microhardness**
  inhomogeneous microhardness distribution; individual values of 400-2,500 HV0.3 with average of 900-1,400 HV0.3 for ten measurements

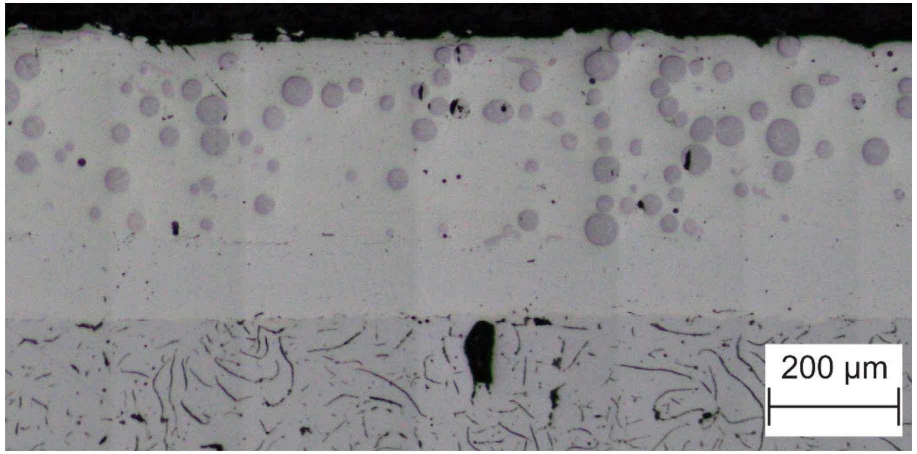


W_2C/WC reinforcement

- **Flattening degree and degree of dissolution in stainless steel melts depend on heat transfer to inflight carbide particles**
- **Heat transfer to carbide particles on their way into the melt pool can be tailored by particle speed / dwell time inside the laser beam**



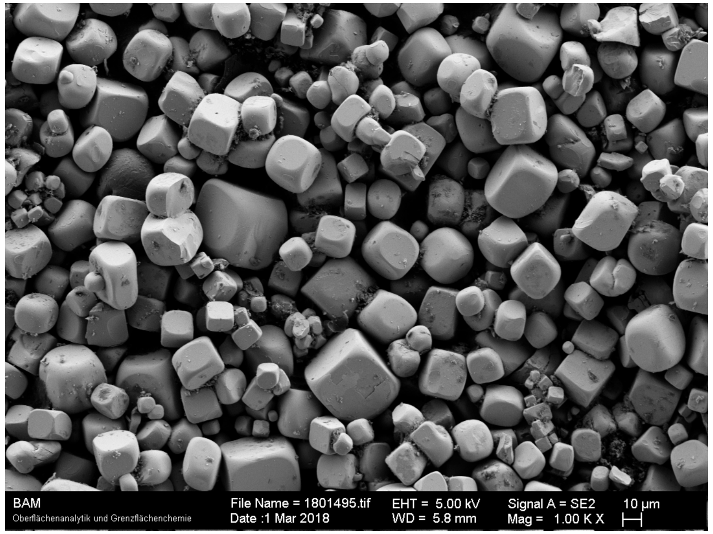
Carrier gas Ar for FTC_s: 2x 4 l/min

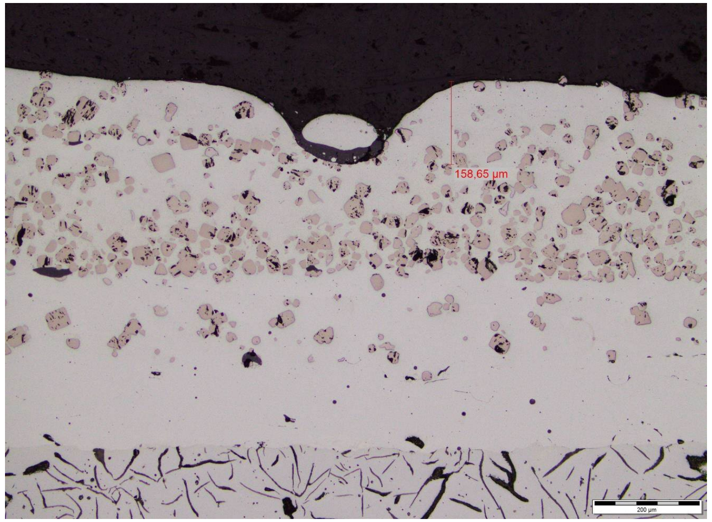


Carrier gas Ar for FTC_s: 2x 6 l/min

NbC cube powder

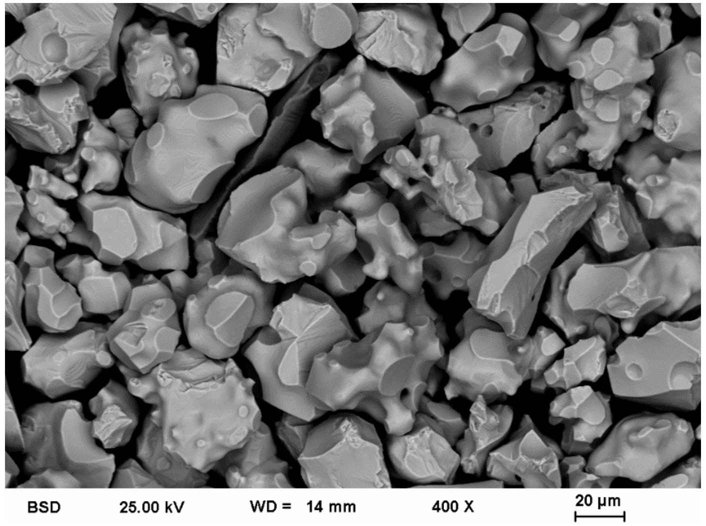
- Route: Leaching
- Good feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Availability: 2 t/a
- Crater formation due to Al_2O_3 contamination arising from powder production process

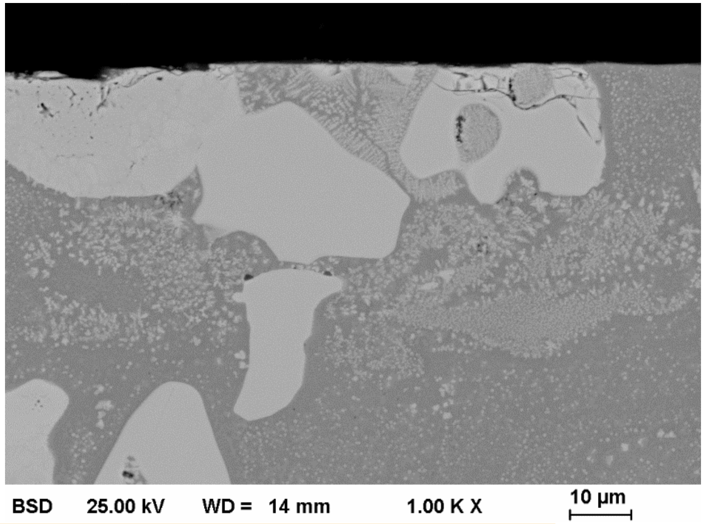




TiC / NbC, sintered & crushed

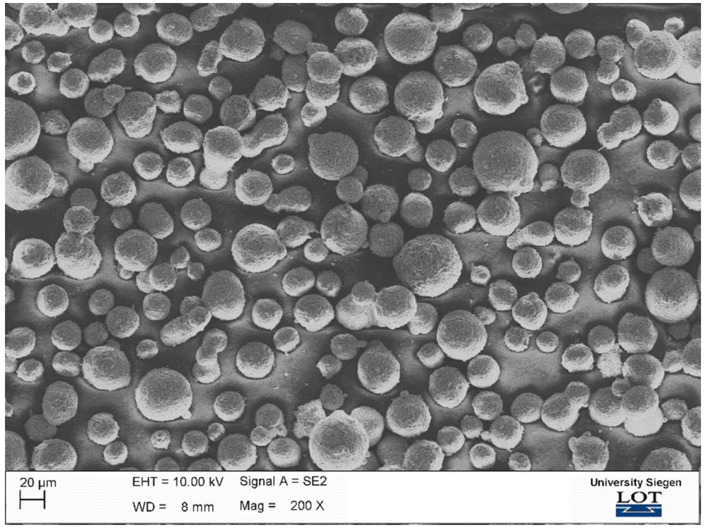
- Acceptable feed rate stability only for sufficiently coarse particle size
- Large specific surface area
- Strong dilution in stainless steel matrix
- Precipitation of dendritic carbides, embrittlement of matrix material
- Long cracks in as clad state due to lack of penetration of cracks originating from crushing process or crack formation during grinding procedure

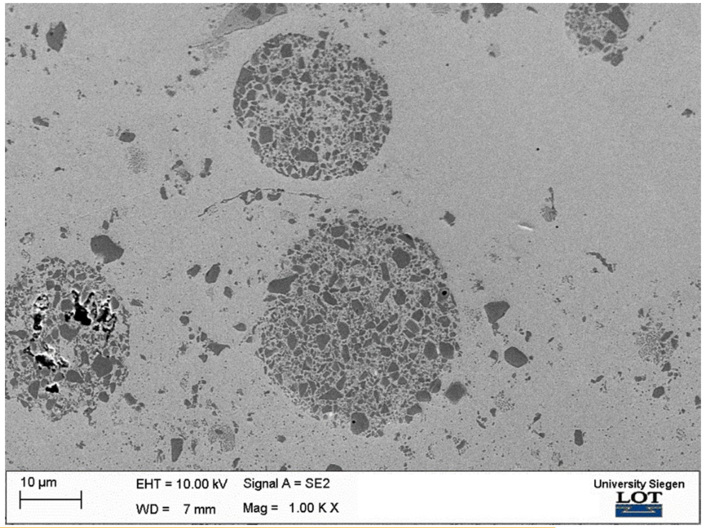




TiC/FeCr / NbC/FeCr, aggl. & sintered

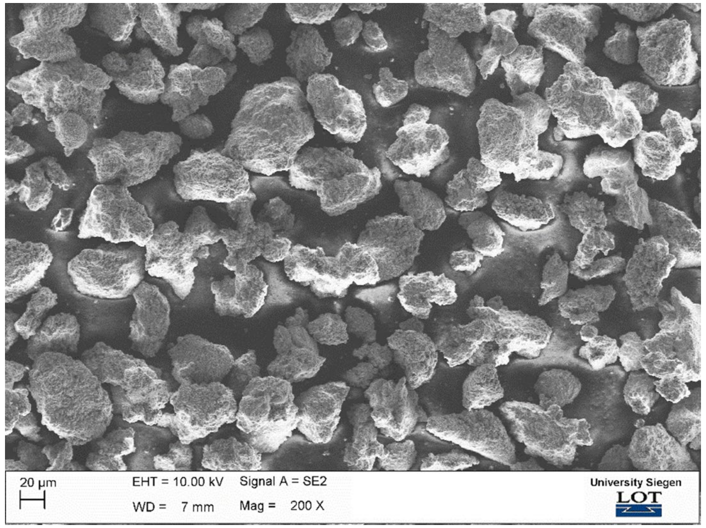
- Excellent feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Formation of microcraters during grinding procedure or braking events possible, if porous composite particles are not fully penetrated by matrix material

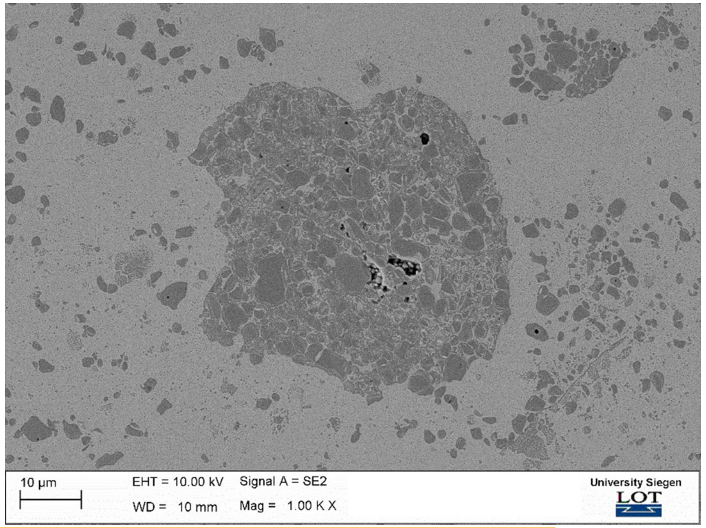




TiC/FeCr / NbC/FeCr, sintered & crushed

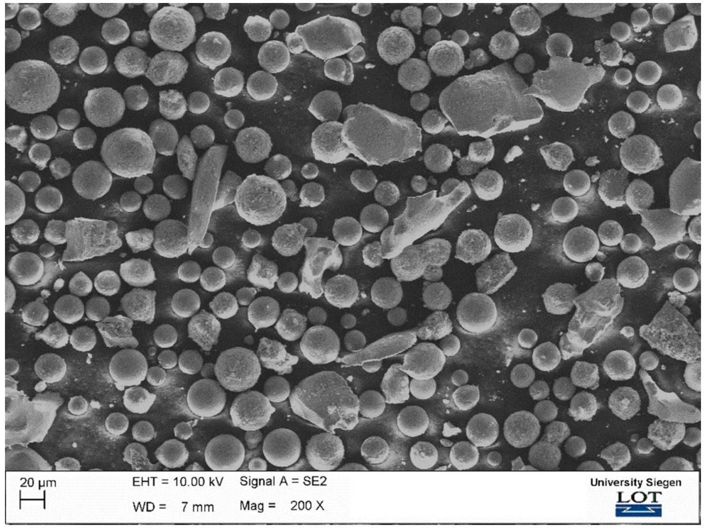
- Good feed rate stability for use of sufficiently coarse particle size
- Large specific surface area
- Limited dilution in stainless steel matrix
- High cohesion even within large composite particles that are not fully penetrated by stainless steel melt

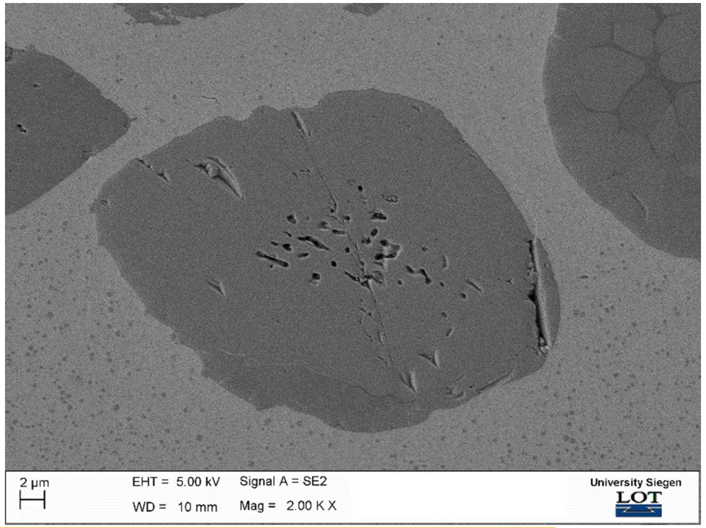




TiC, plasma spheroidized

- Only < 35 µm particles got fully melted
- Excellent feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Actually limited availability and low production rate of plasma spheroidizers





Carbide feedstock evaluation

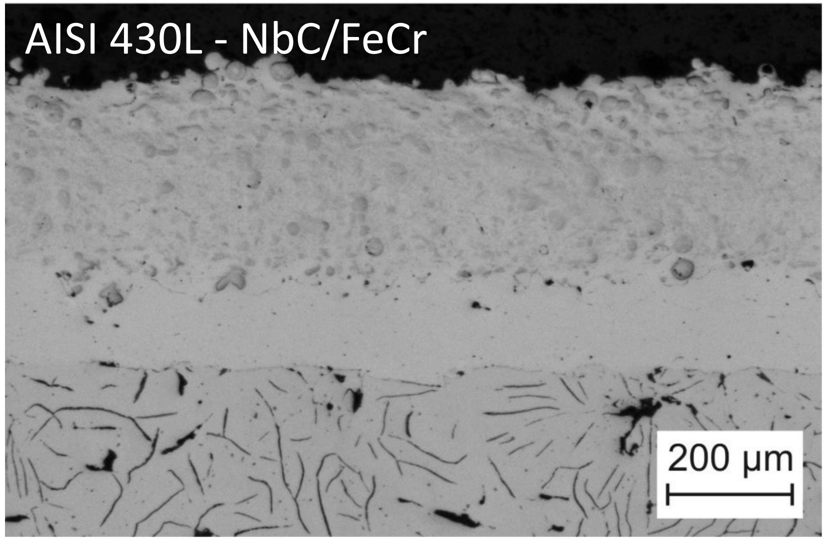
production route	feed stability	dilution in matrix	carbide crack resistance	cladding strength	availability
leached	+	+	+	+	--
sintered and crushed	-	-	-	0	+(+)
agglomerated and sintered composite	++	+	++	0	+(+)
sintered and crushed composite	+	+	++	+	+(+)
plasma spheroidized	++	+	+	+	-

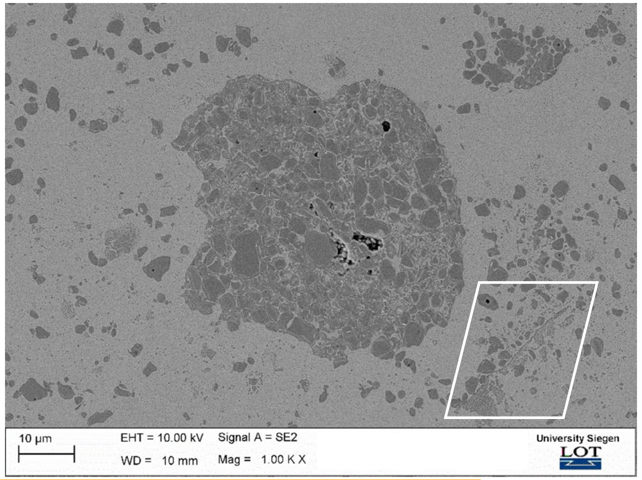
TiC/FeCr / NbC/FeCr reinforcement

- **Carbide content**

  Crack free 30 vol.-% TiC/FeCr / NbC/FeCr - stainless steel layers possible without pre-heating for use of buffer layers
- **Microhardness**

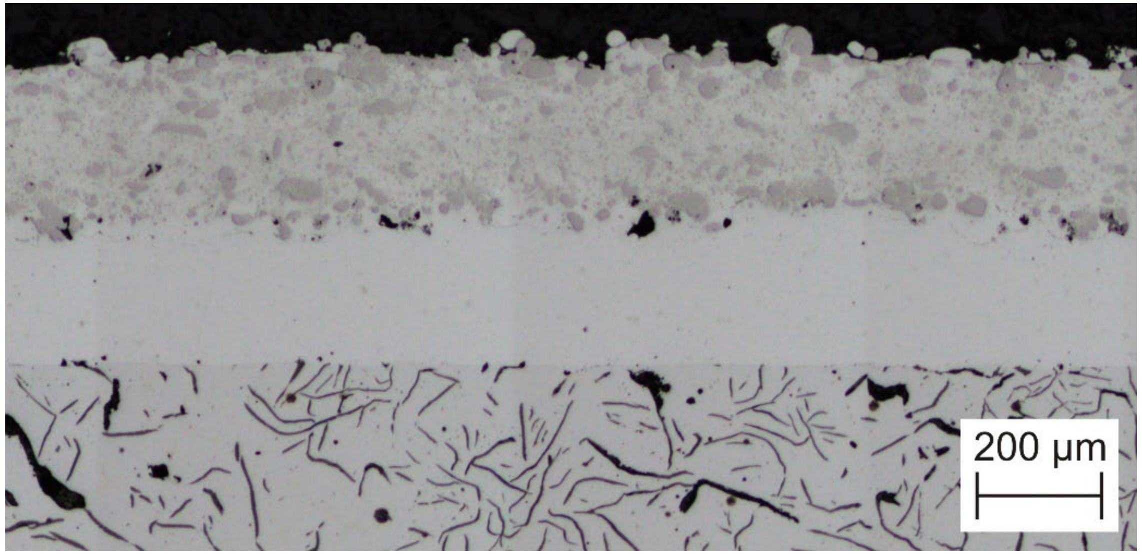
  homogeneous microhardness distribution; depending on matrix material average microhardness 450-700 HV0.3 with standard deviation < 100 HV0,3 for ten measurements
- **Carbide band formation only for TiC observed**



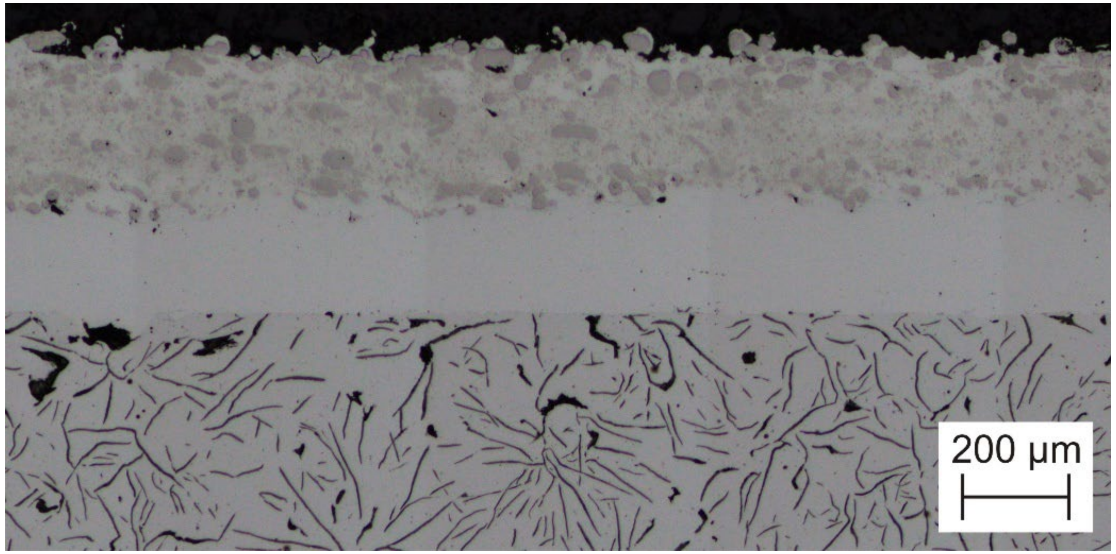


Effect of particle density distribution

- **Control of local particle density permits influence on local laser interaction with substrate / previous cladding layer surface**



28/29/27/27 g/min AISI 430L steel
17/17 g/min TiC/FeCr 70/30



32/32/24/23 g/min AISI 430L steel
21/13 g/min TiC/FeCr 70/30

Conclusions / Key takeaways

- High reproducibility brake disk cladding processes at 22 kW laser power available
- Choice of reinforcing carbide powder takes influence on process stability, coating properties, availability and costs
- Cheap machinery solutions might be costly due to lack of process control

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