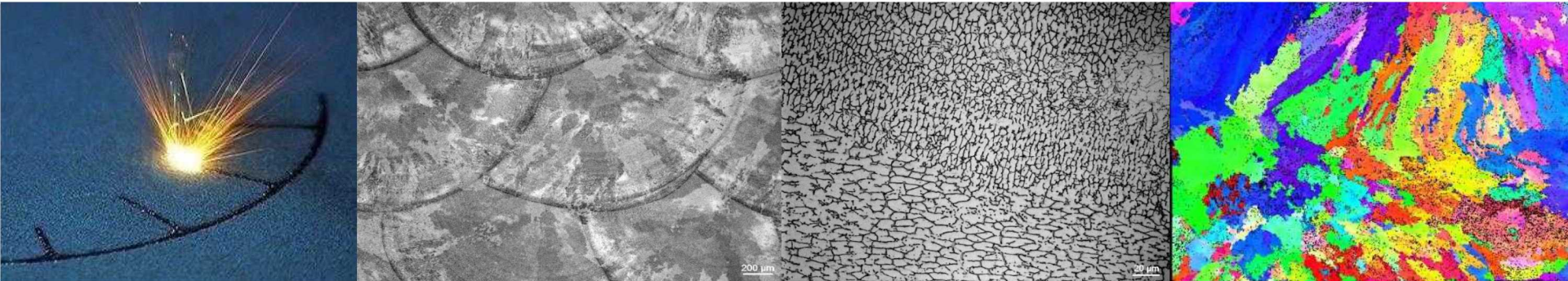


[Redacted text]

[Redacted text]



Preliminary Results of Wire-AM 308L LZH4 Builds

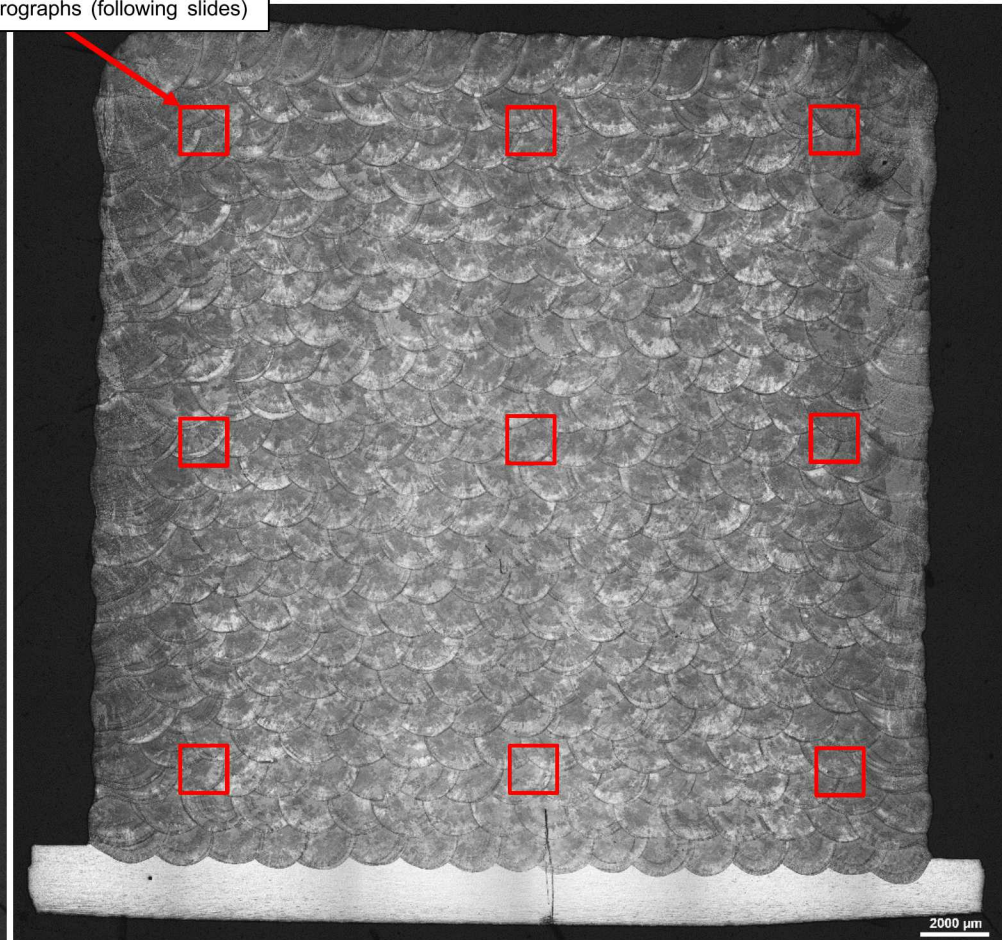
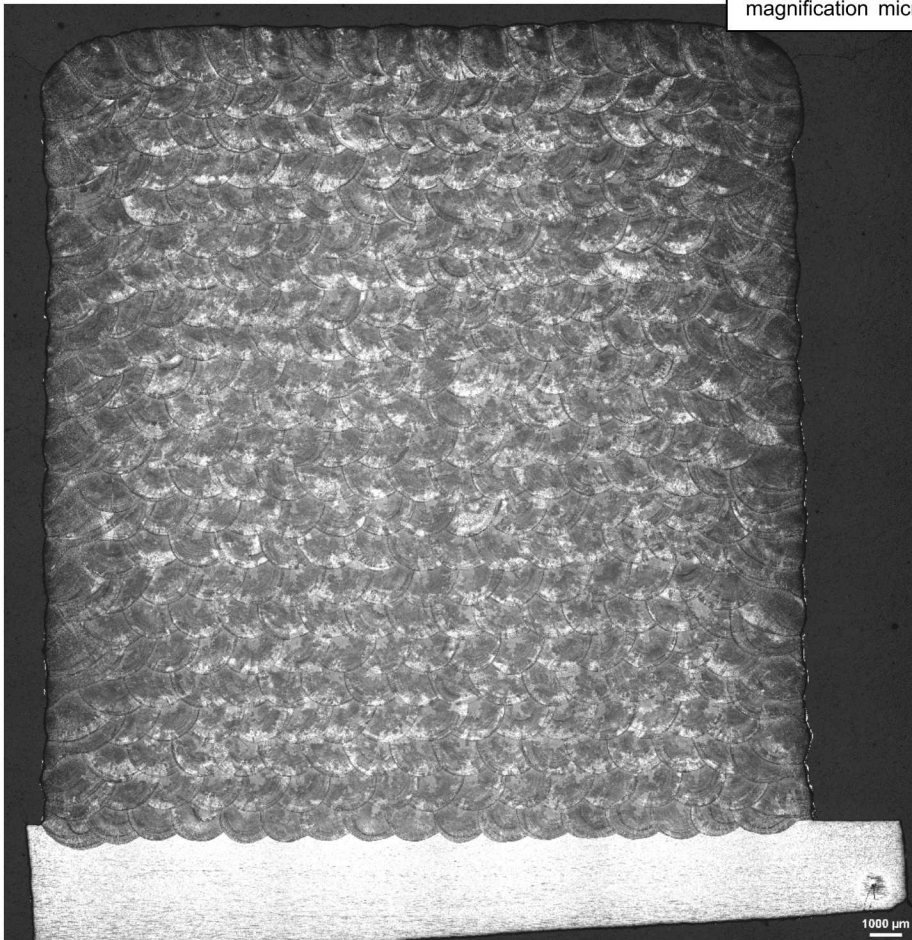
Jeff Rodelas, Michael Heiden
Sandia National Laboratories, Albuquerque, NM

LZH4: Wire Arc AM 308L

LZH4 MK3

Approximate locations of high-magnification micrographs (following slides)

LZH4 MK1



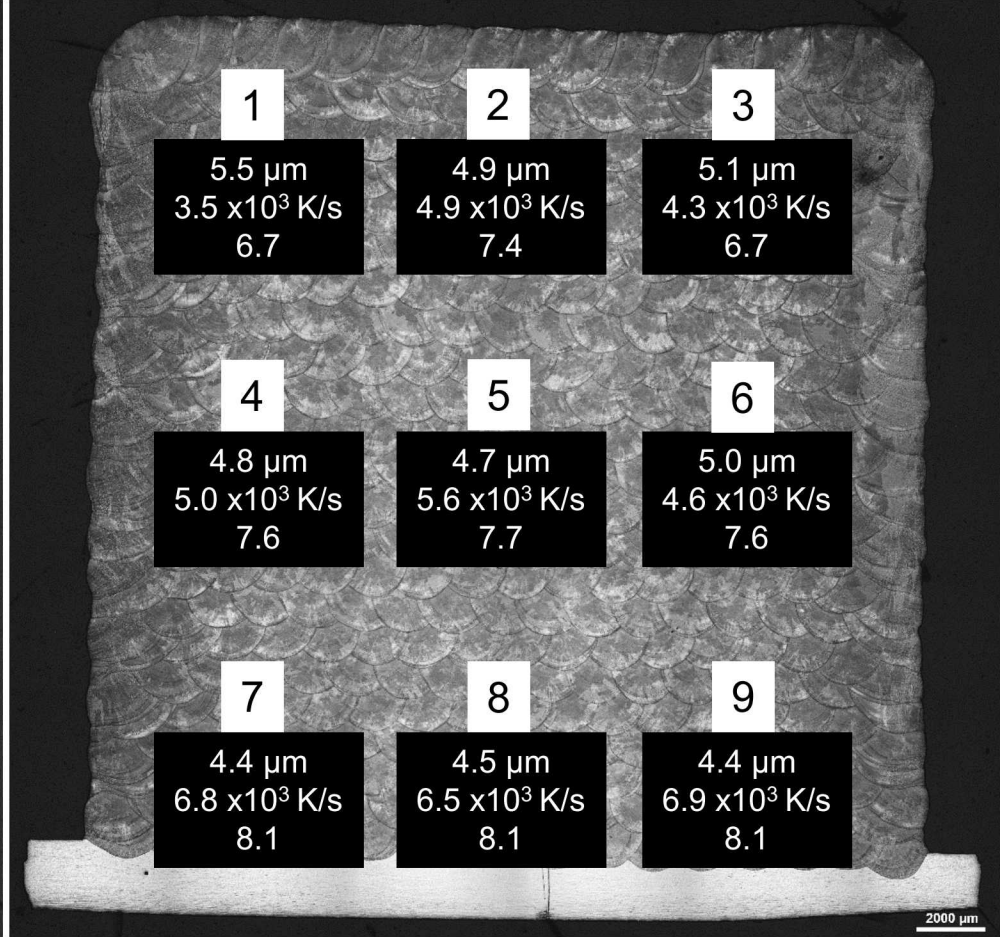
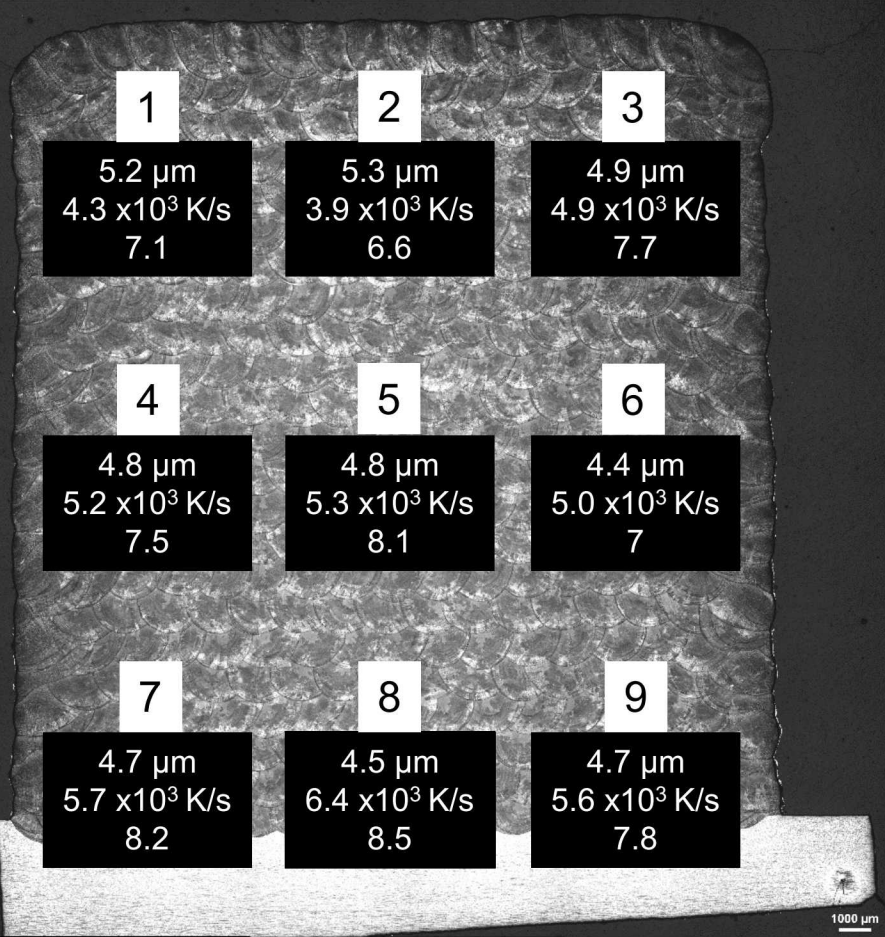
- Both sections of build qualitatively exhibit near full density in plane of section

LZH4 MK1 and LZH4 MK3: Wire Arc 308L Arm/Cell Spacing, Estimated Cooling Rate, Ferrite Content Data

LZH4 MK3

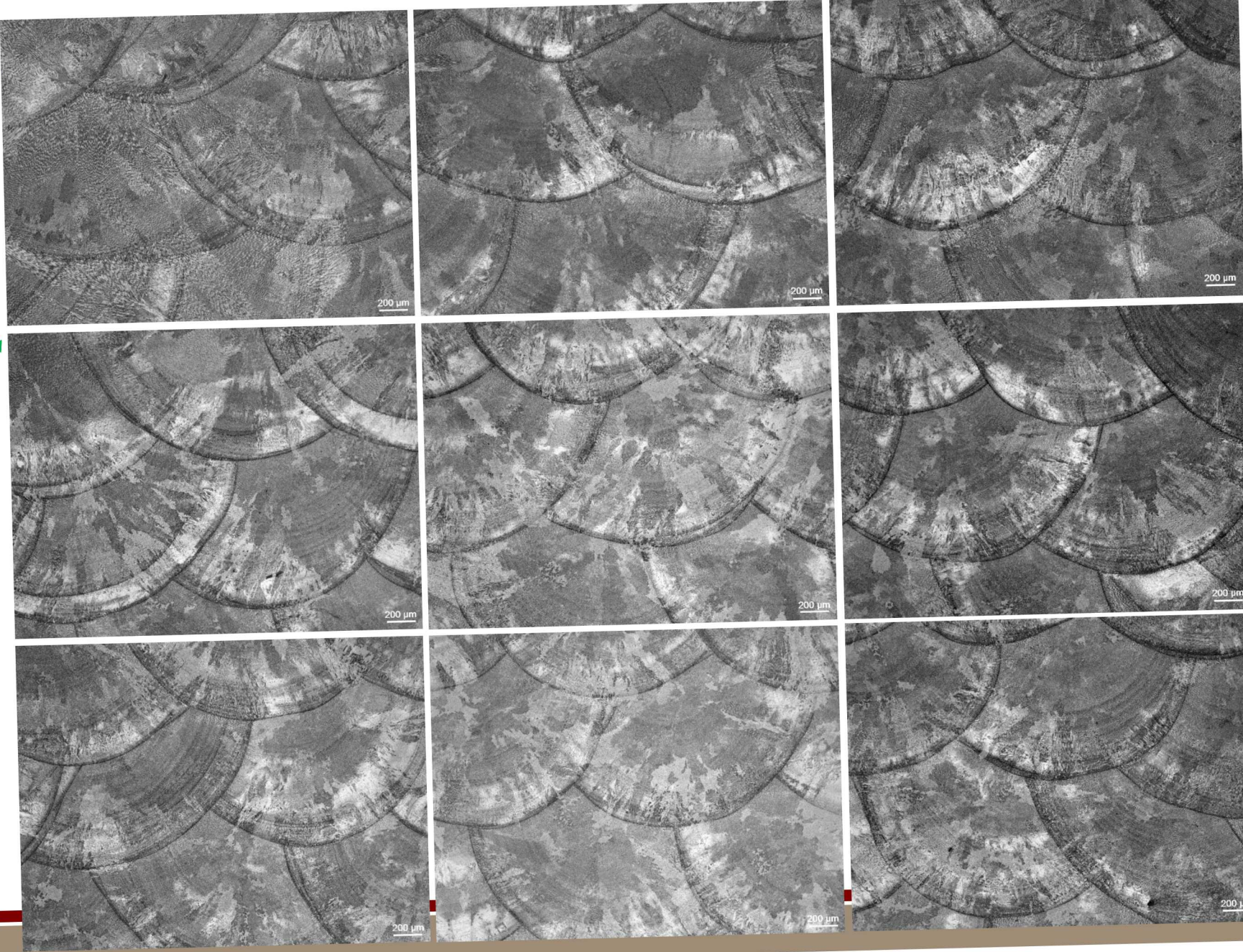
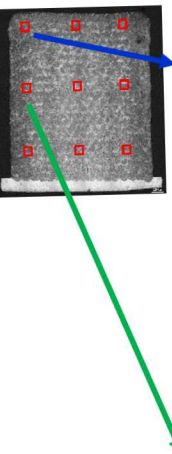
Cell Spacing (μm)
Cooling Rate (K/s)
Vol. % Ferrite

LZH4 MK1

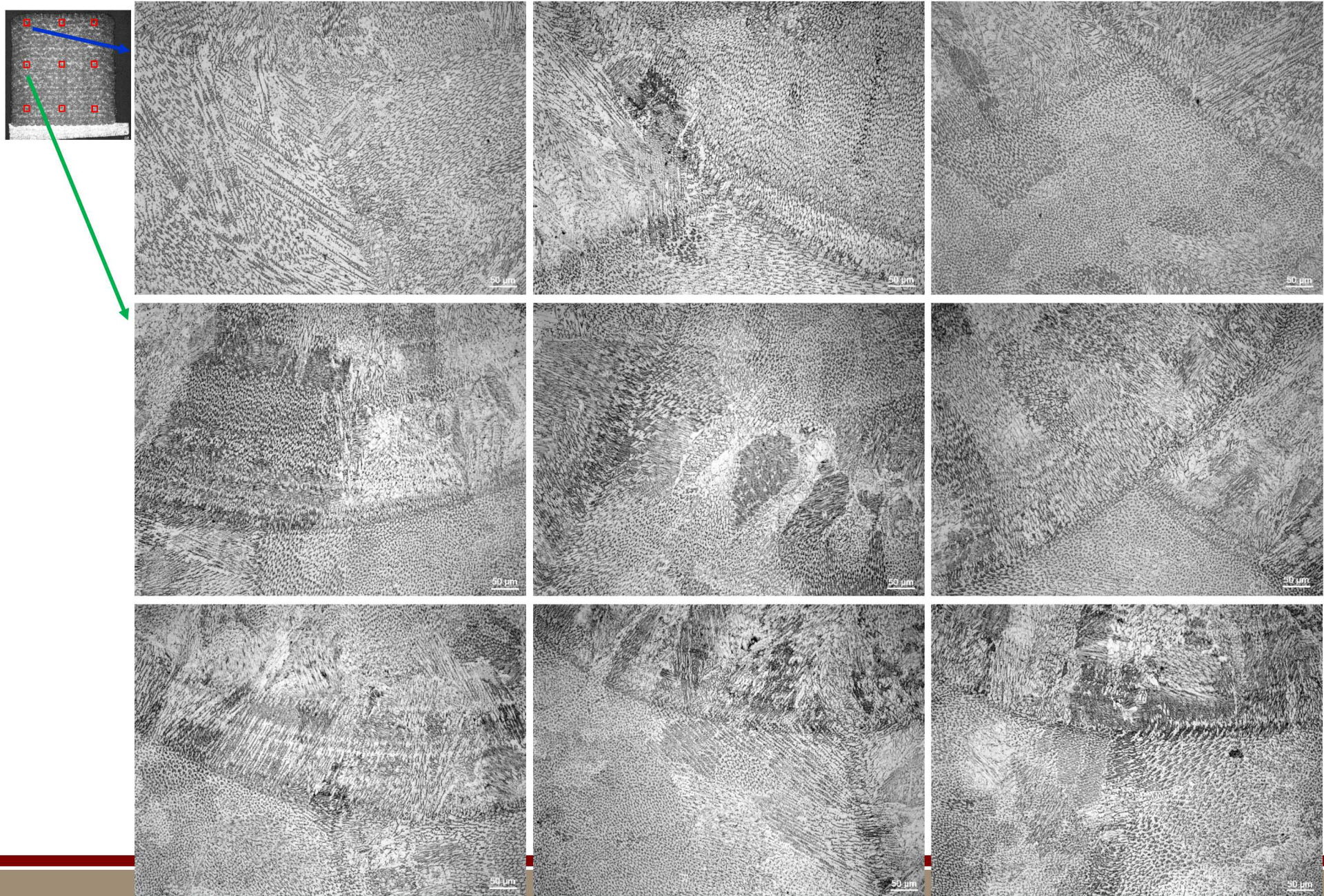


- Region near build plate seems to have cooled faster than the top and formed slightly more ferrite

LZH4 MK1: Wire Arc 308L (detail) 50X

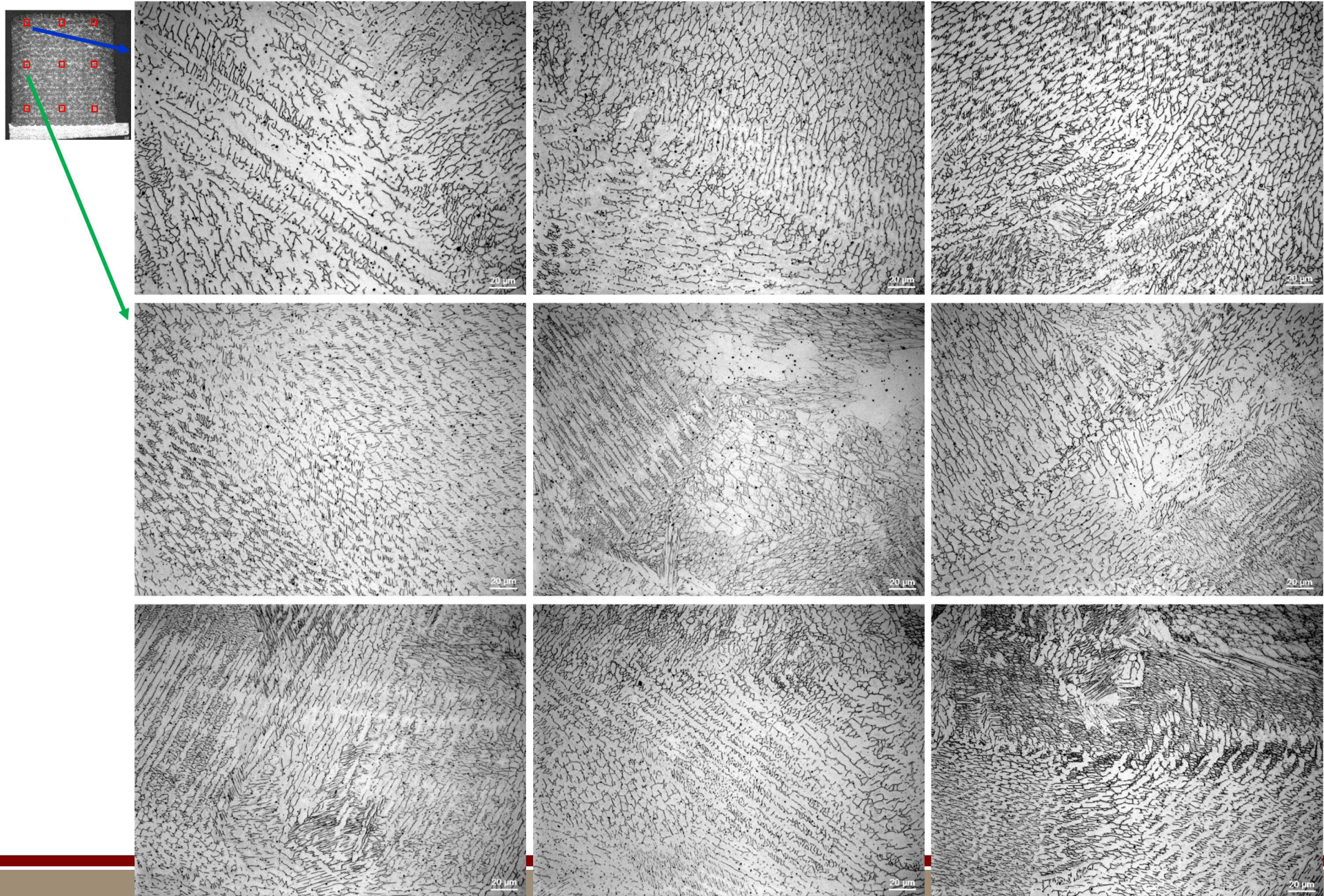


LZH4 MK1: Wire Arc 308L (detail) 200X

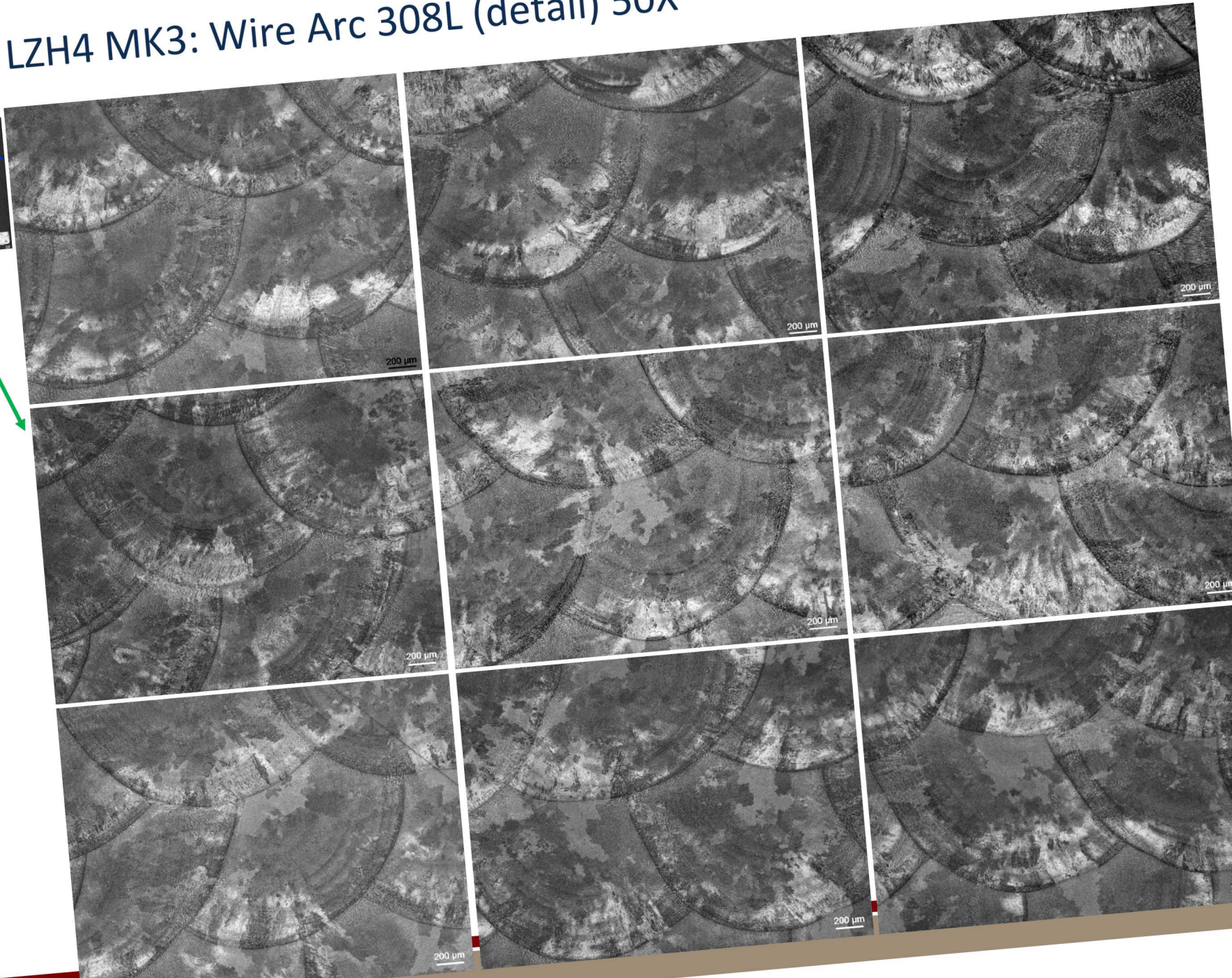
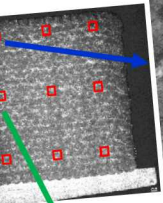


LZH4 MK1: Wire Arc 308L (detail) 500X

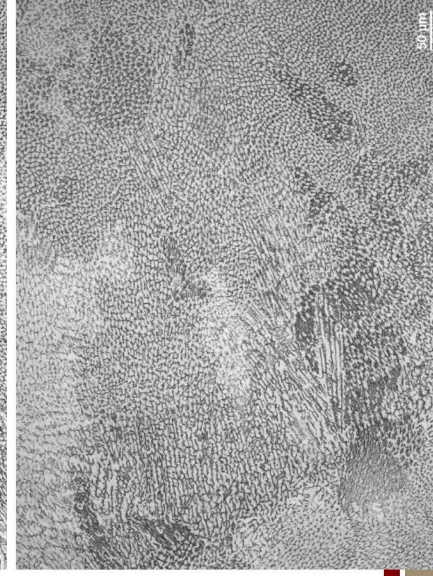
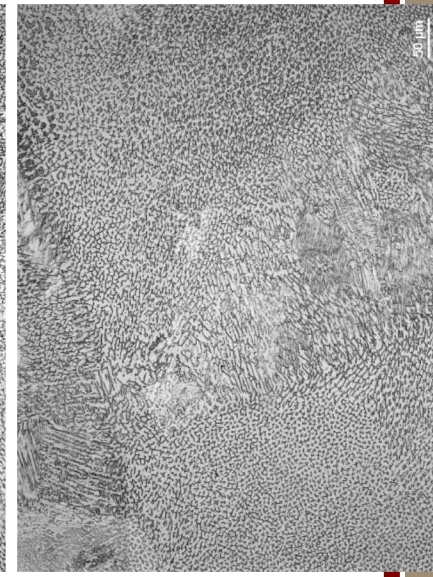
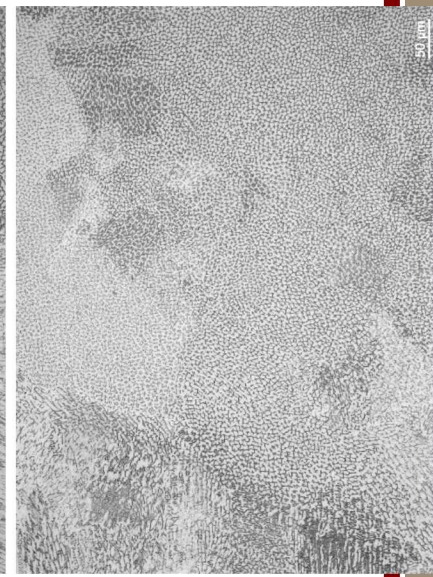
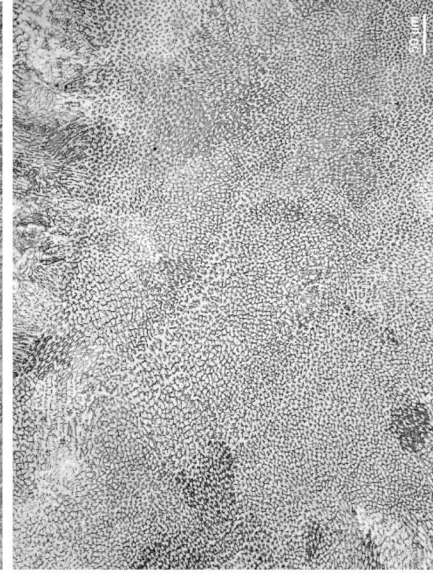
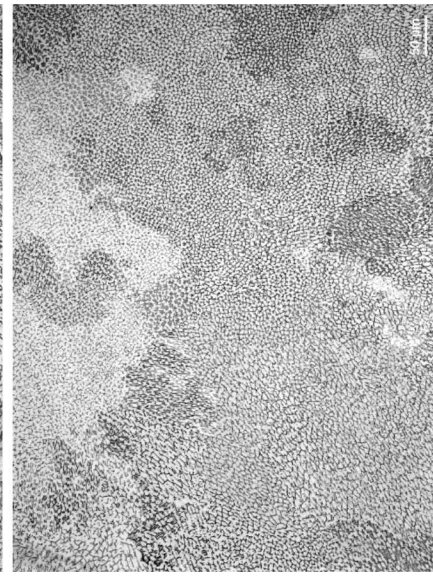
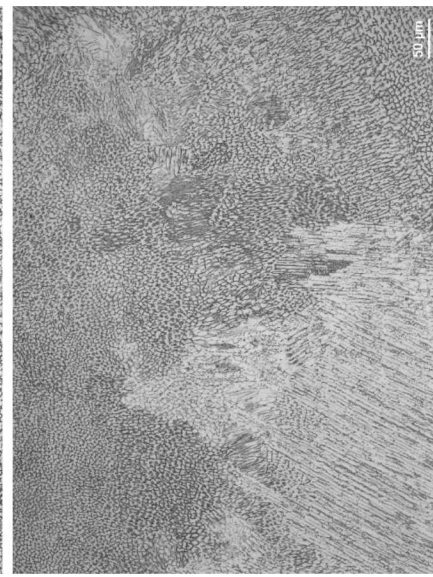
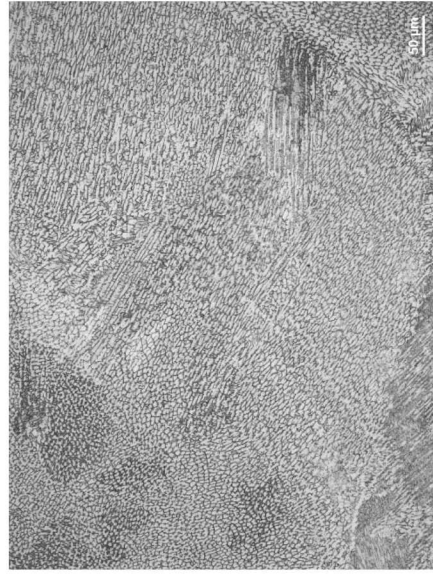
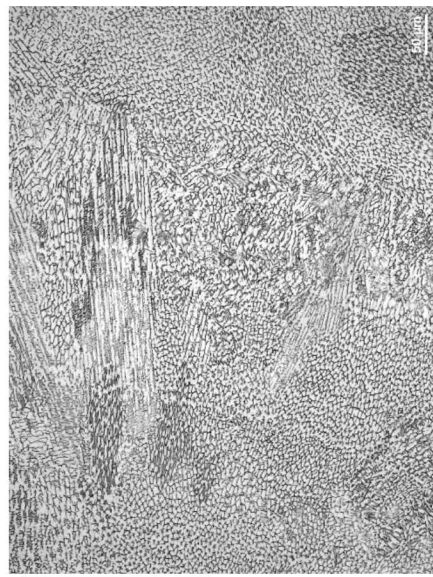
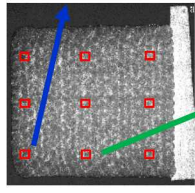
Solidification microstructure shows intradendritic skeletal ferrite consistent with primary ferrite solidification



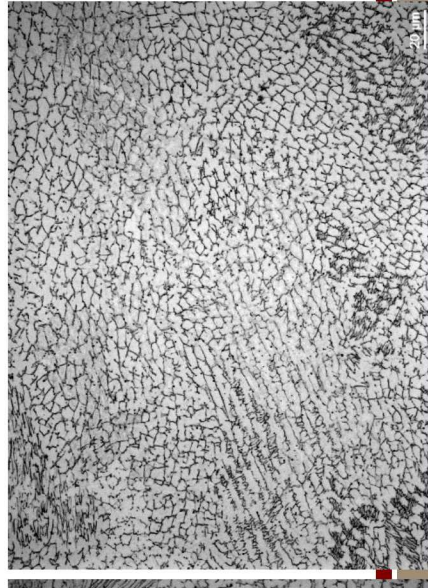
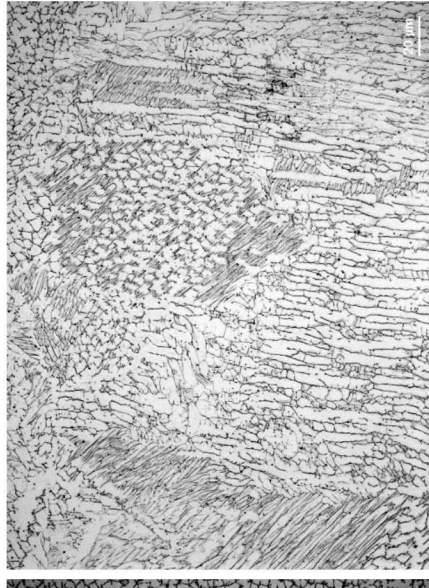
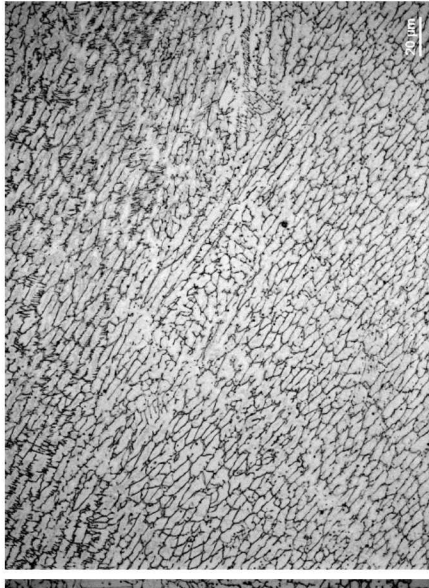
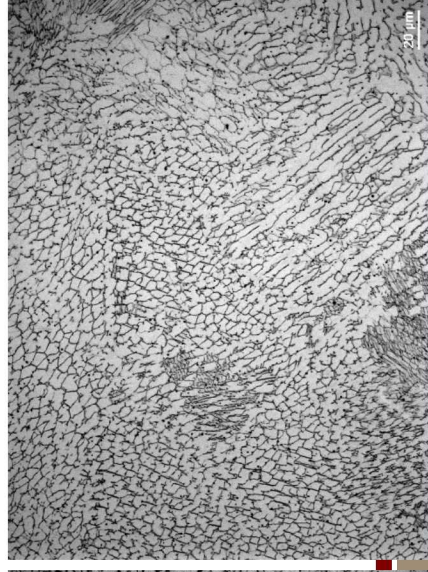
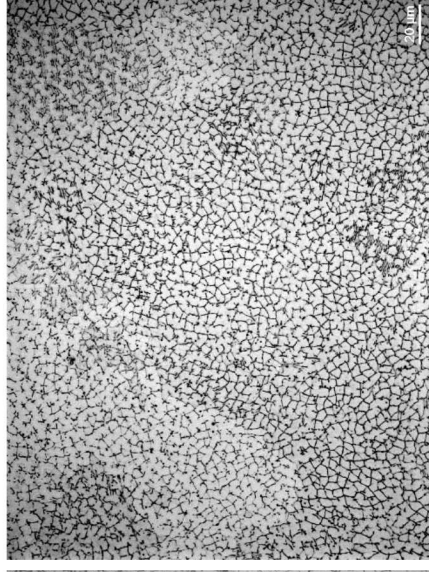
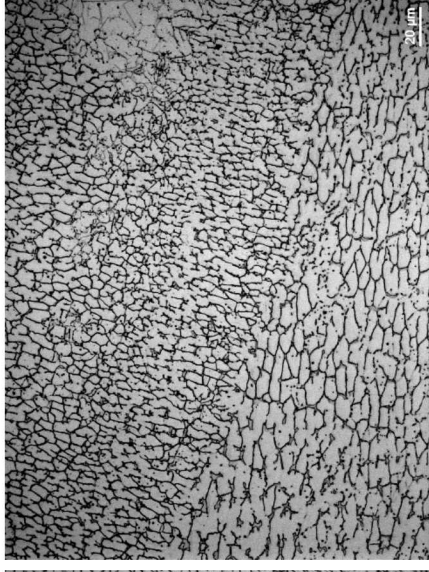
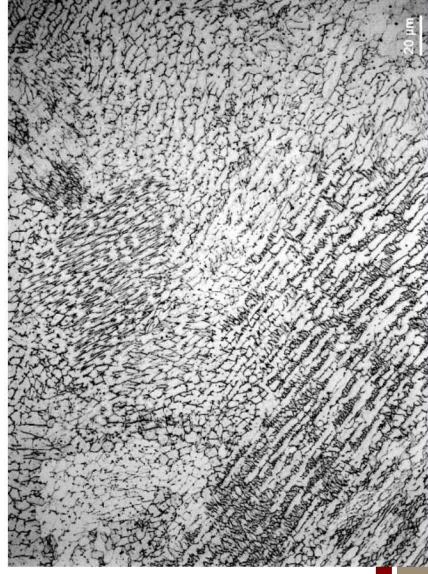
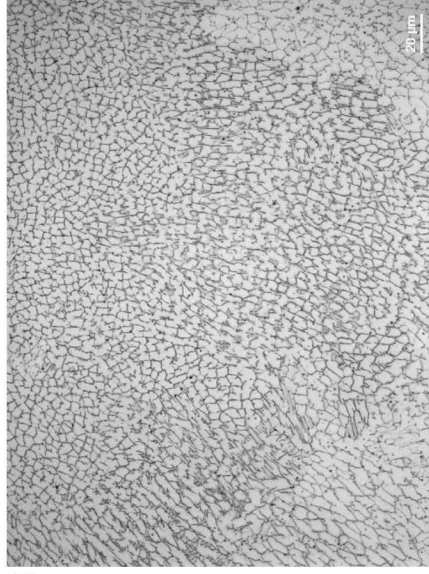
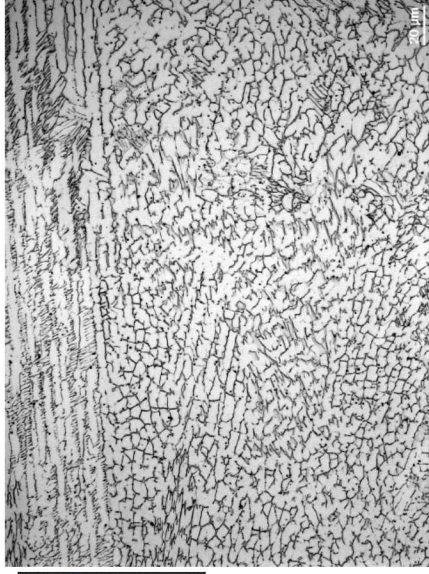
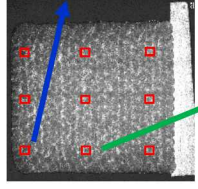
LZH4 MK3: Wire Arc 308L (detail) 50X



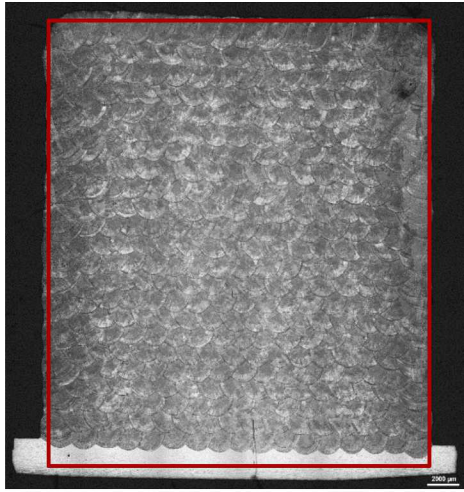
LZH4 MK3: Wire Arc 308L (detail) 200X



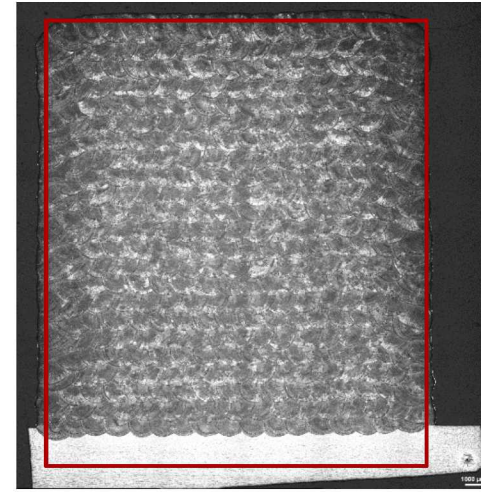
LZH4 MK3: Wire Arc 308L (detail) 500X



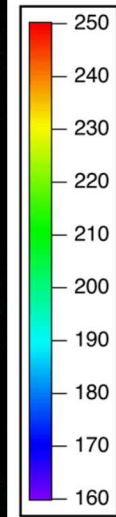
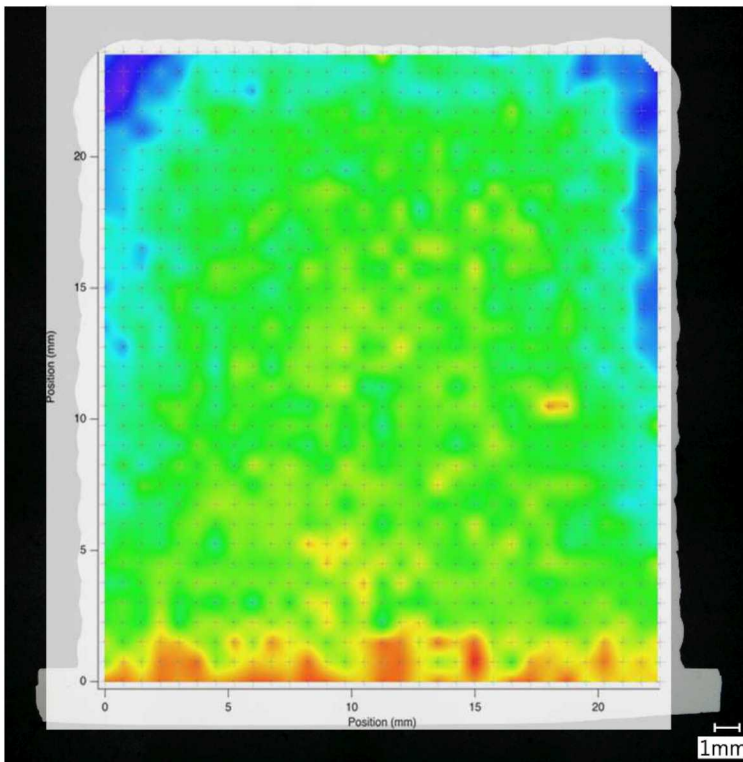
Hardness Maps



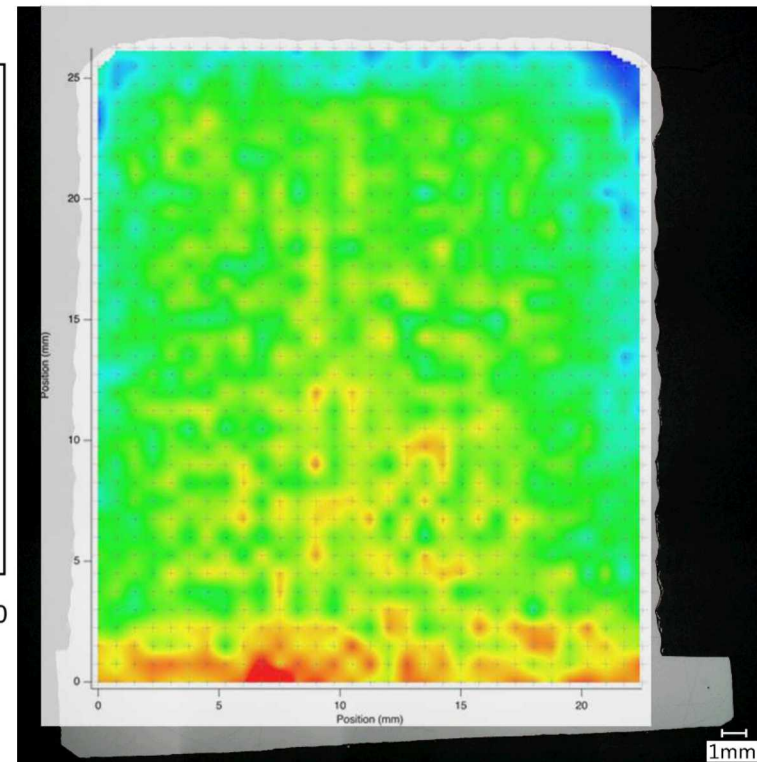
T80053 - LZH4 - MK1



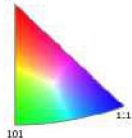
T80053 - LZH4 - MK3



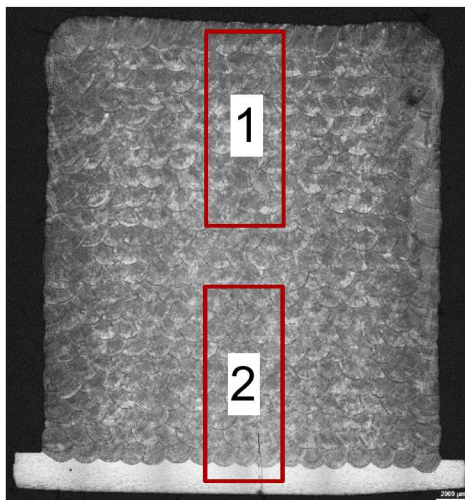
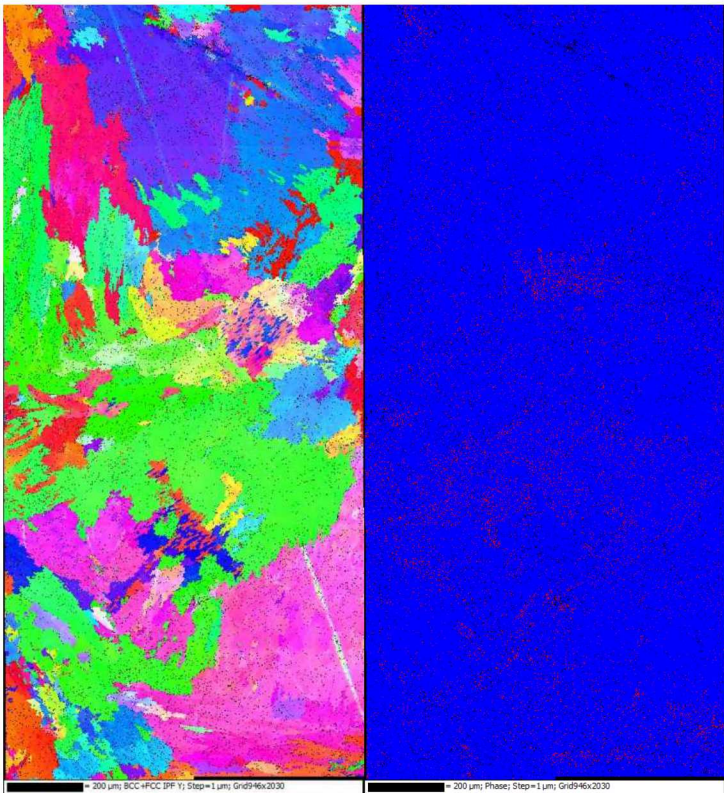
HVN_{1.0}



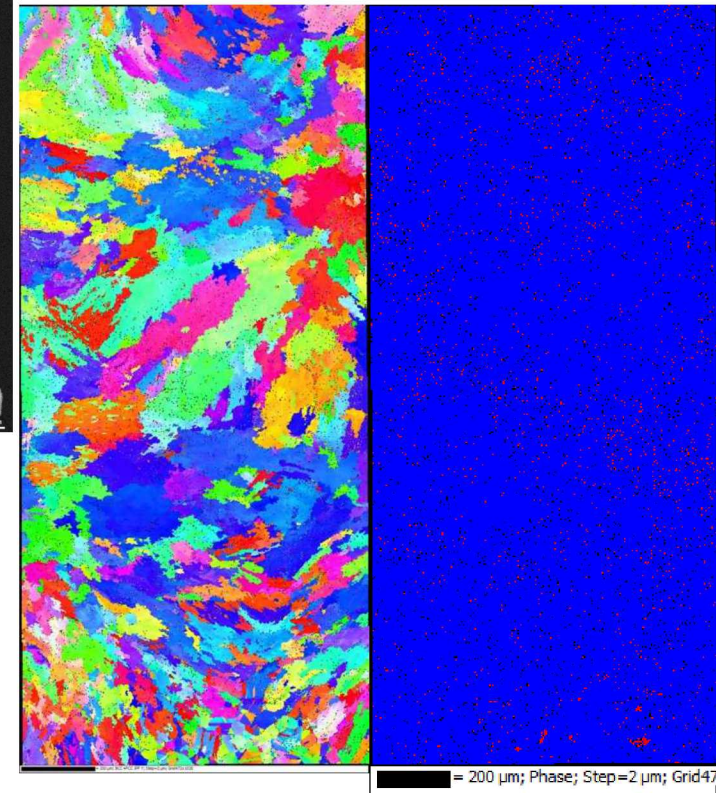
T80053 - LZH4 - MK1 EBSD Maps



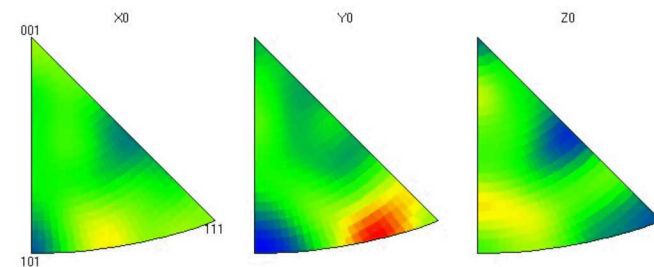
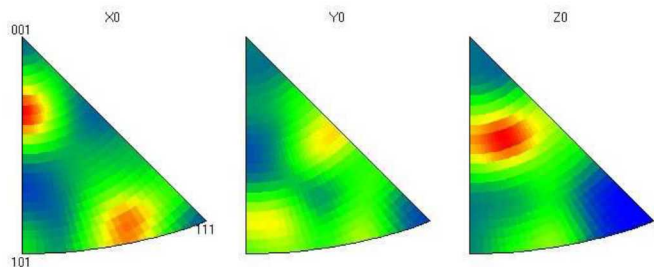
1



2

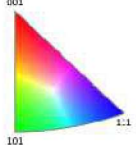


Blue: FCC
Red: BCC

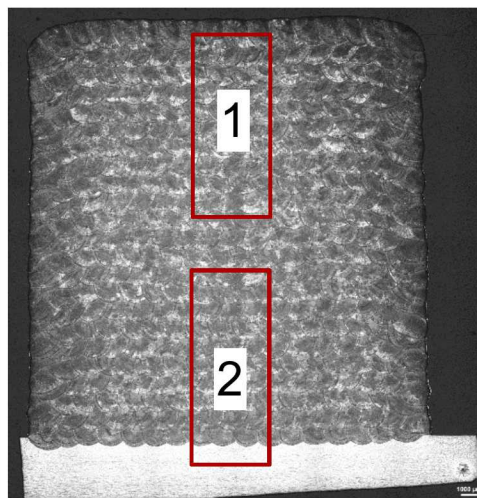
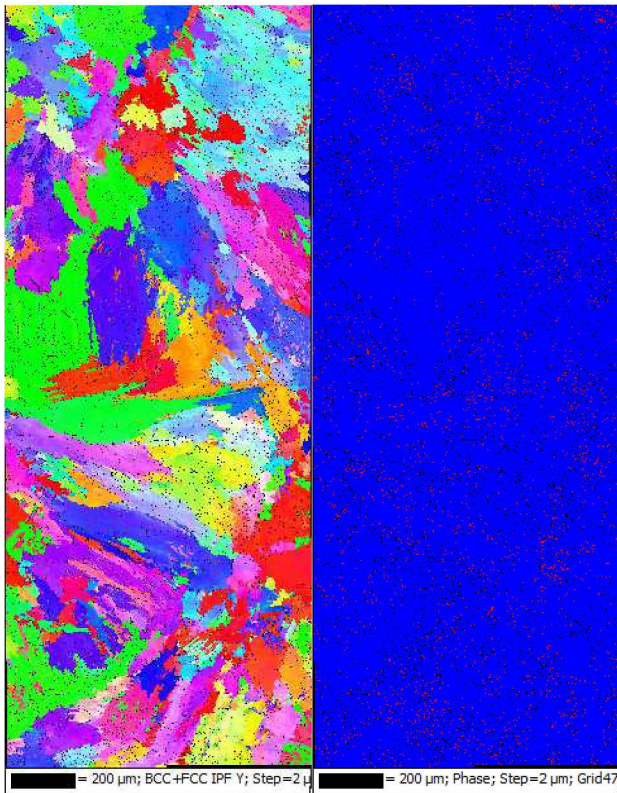


T80053 - LZH4 – MK3 EBSD Maps

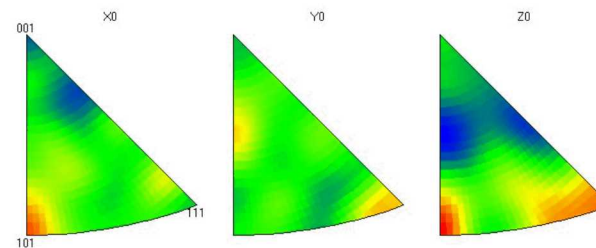
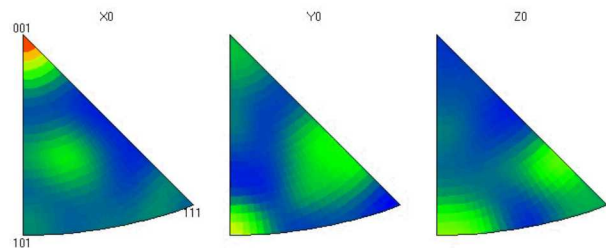
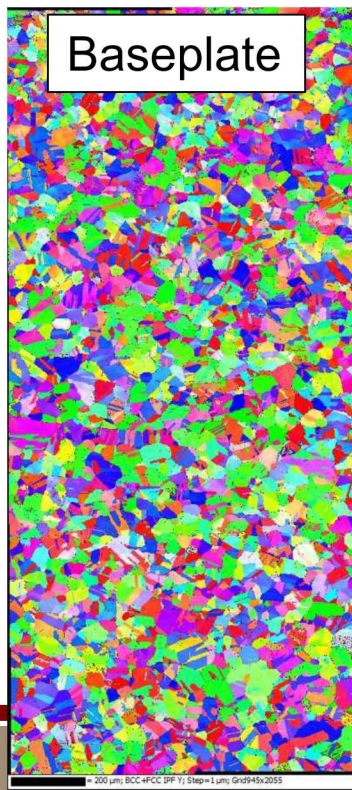
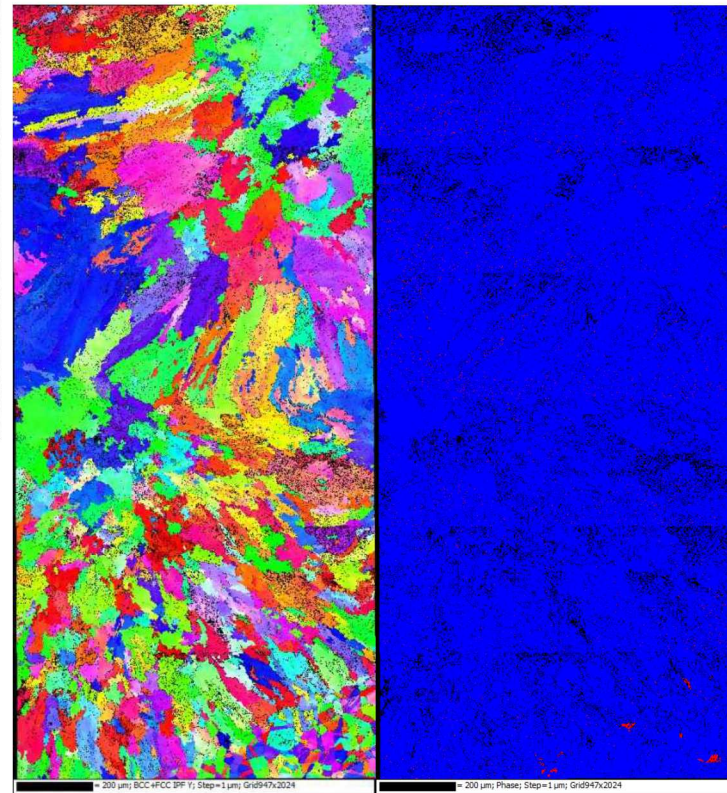
Blue: FCC
Red: BCC



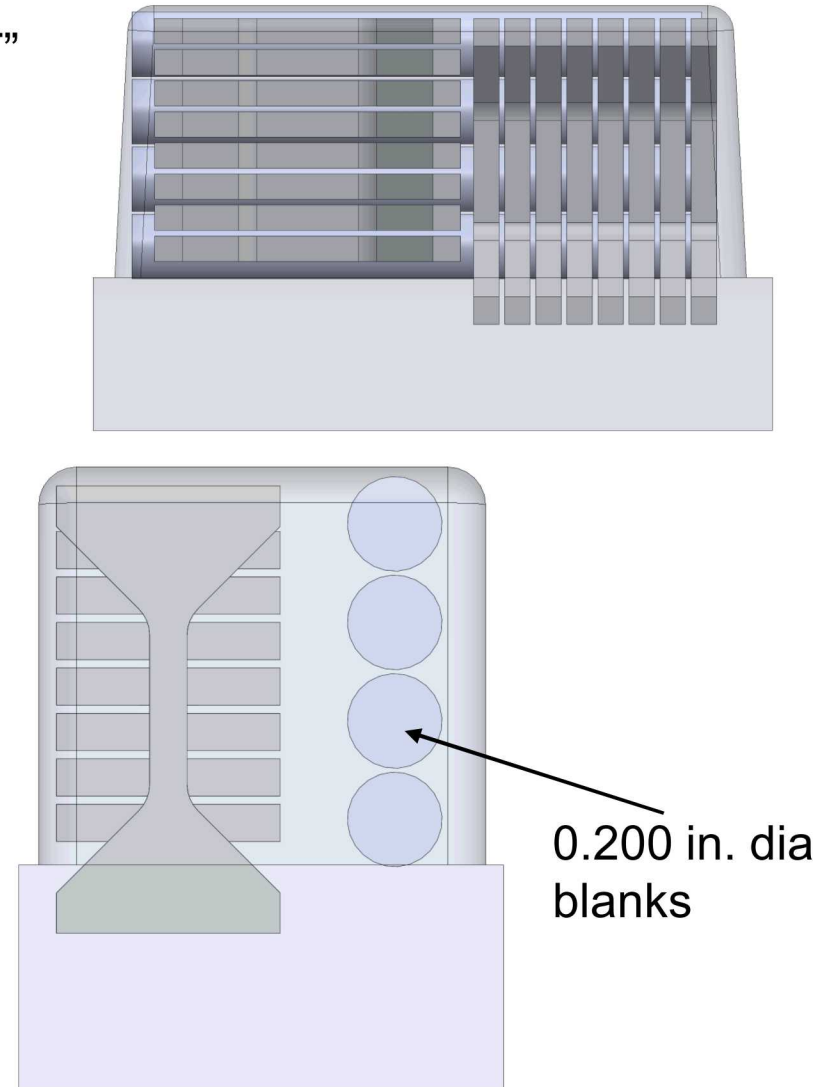
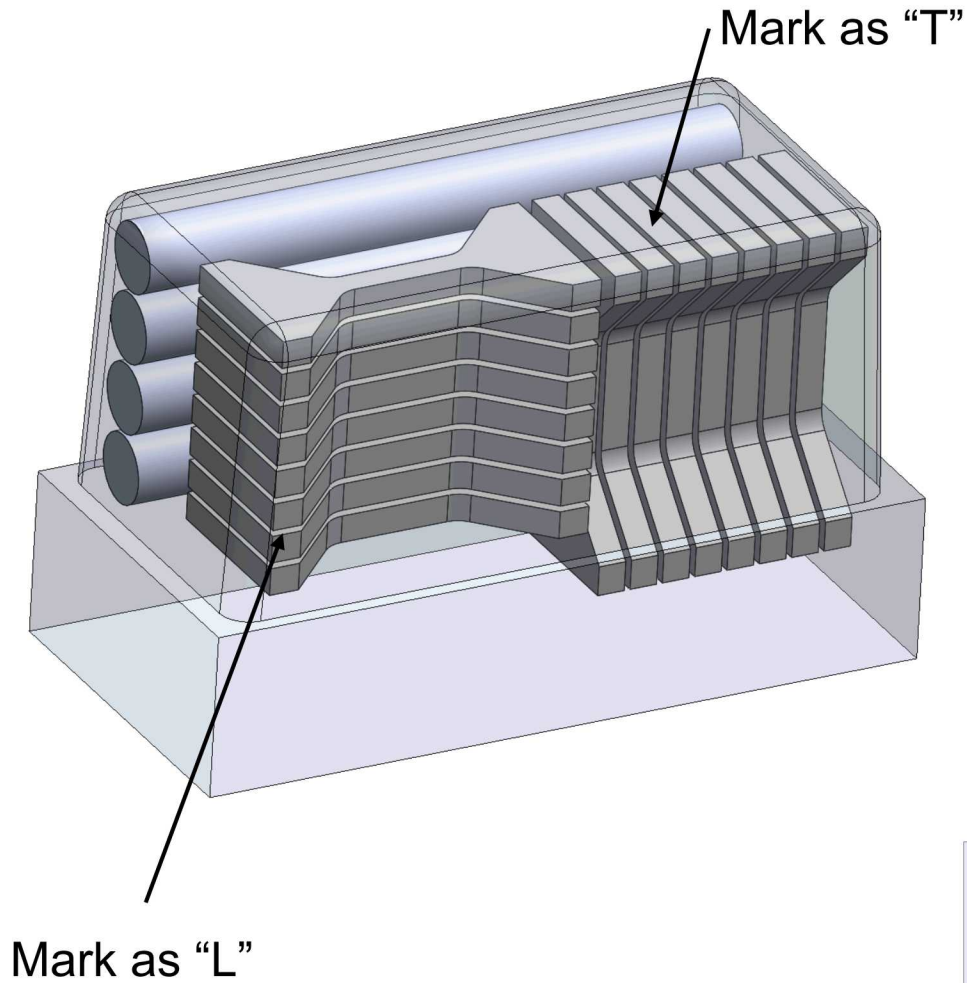
1



2



EDM samples from AM deposit



Appendix:

LZH4 MK1 and LZH4 MK3: Cell Spacing Raw Data

	SDAS (um)		Cooling Rate (K/s)	
	Average	Stdev	Average	Stdev
MK3				
1	5.21	0.73	4.30E+03	1.42E+03
2	5.31	0.46	3.85E+03	8.82E+02
3	4.89	0.30	4.87E+03	9.18E+02
4	4.81	0.41	5.23E+03	1.32E+03
5	4.79	0.41	5.28E+03	1.26E+03
6	4.84	0.28	5.02E+03	8.96E+02
7	4.70	0.48	5.72E+03	1.86E+03
8	4.46	0.25	6.43E+03	1.06E+03
9	4.67	0.30	5.62E+03	1.27E+03
MK1				
1	5.46	0.27	3.46E+03	5.08E+02
2	4.91	0.40	4.88E+03	1.20E+03
3	5.10	0.27	4.25E+03	6.31E+02
4	4.82	0.19	5.02E+03	5.76E+02
5	4.65	0.19	5.60E+03	6.83E+02
6	5.04	0.50	4.62E+03	1.53E+03
7	4.42	0.42	6.77E+03	1.82E+03
8	4.49	0.39	6.46E+03	1.89E+03
9	4.43	0.46	6.85E+03	2.17E+03

PDAS per area (um)

5.21	5.31	4.89
4.81	4.79	4.84
4.70	4.46	4.67

Cooling rate per area (K/s)

MK3

4.30E+03	3.85E+03	4.87E+03
5.23E+03	5.28E+03	5.02E+03
5.72E+03	6.43E+03	5.62E+03

MK1

5.46	4.91	5.10
4.82	4.65	5.04
4.42	4.49	4.43

3.46E+03	4.88E+03	4.25E+03
5.02E+03	5.60E+03	4.62E+03
6.77E+03	6.46E+03	6.85E+03

$$\lambda_1 = 80\dot{T}^{-0.33}$$

$$\dot{T} = \frac{584710}{\lambda_1^{3.03}}$$

λ_1 = Intercellular Spacing (μm)

\dot{T} = Cooling rate, (K s^{-1})

Schubert, *Mater. Sci. Technol.*, 1995

Appendix:

Ferritscope Measurements of Volume % Ferrite Raw Data

Region	LZH4 MK3 - AM 308L Wire				LZH4 MK3 - AM 308L Wire			
	top	middle	bottom	baseplate	top	middle	bottom	baseplate
1,4,7	7.2	7.5	8	0.24	6.8	7.6	8.1	0.48
2,5,8	6.6	8	8.5	0.25	7.5	7.7	8.1	0.36
3,6,9	7.7	6.9	7.9	0.23	6.7	7.4	7.9	0.52
1,4,7	7.1	7.6	8.2	0.24	6.7	7.7	8.1	0.32
2,5,8	6.5	8.1	8.5	0.24	7.4	7.6	8.1	0.33
3,6,9	7.5	7.2	7.7	0.24	6.7	7.6	8.3	0.47
1,4,7	7	7.4	8.3	0.24	6.7	7.5	8.2	0.39
2,5,8	6.8	8.2	8.5	0.24	7.3	7.7	8.2	0.51
3,6,9	7.8	7	7.9	0.24	6.7	7.8	8	0.46
average	7.1	7.5	8.2	0.2	6.7	7.6	8.1	0.4
	6.6	8.1	8.5	0.2	7.4	7.7	8.1	0.4
	7.7	7.0	7.8	0.2	6.7	7.6	8.1	0.5
stdev	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.1
	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1
	0.2	0.2	0.1	0.0	0.0	0.2	0.2	0.0