Innoculated High-Speed Steel

Alexander S. Chaus

Slovak University of Technology

http://www.mtf.stuba.sk/
alexander.chaus@stuba.sk

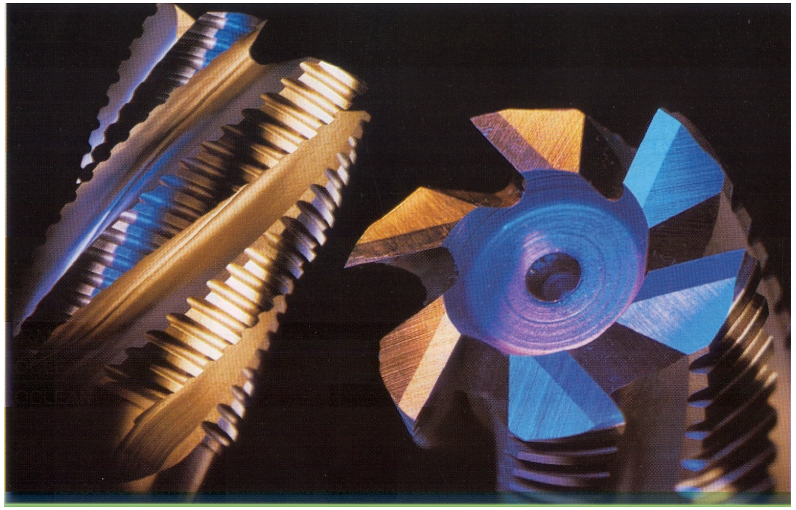
Acknowledgements:

Project VEGA No 1/2594/12
Professor Ľ. Čaplovič, Dr P. Úradník,
Dr M. Boháčik and Dr J. Porubský

STU MTF
SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA

Production of cutting tools by machining of HSS wrought bars

Turning, drilling, milling



Production of cutting tools by precision casting

Cast near-net-shape work-piece

Chemical composition of parent steel of AISI M2 grade, wt. %										
Fe	C	Si	Mn	Ni	P	S	Cr	Mo	W	V
Bal.	0.88	0.26	0.29	0.26	0.023	0.028	4.03	5.34	5.95	1.89

The parent steel *was inoculated* with powder additions of W (0.3 and 0.6 vol.%) and WC (0.1, 0.3 and 0.6 vol.%). The melt was poured into ceramic moulds, ingots were 1.2 kg in mass.

Heat treatments of the specimens fabricated from ingots included annealing, austenitising, quenching and tempering.

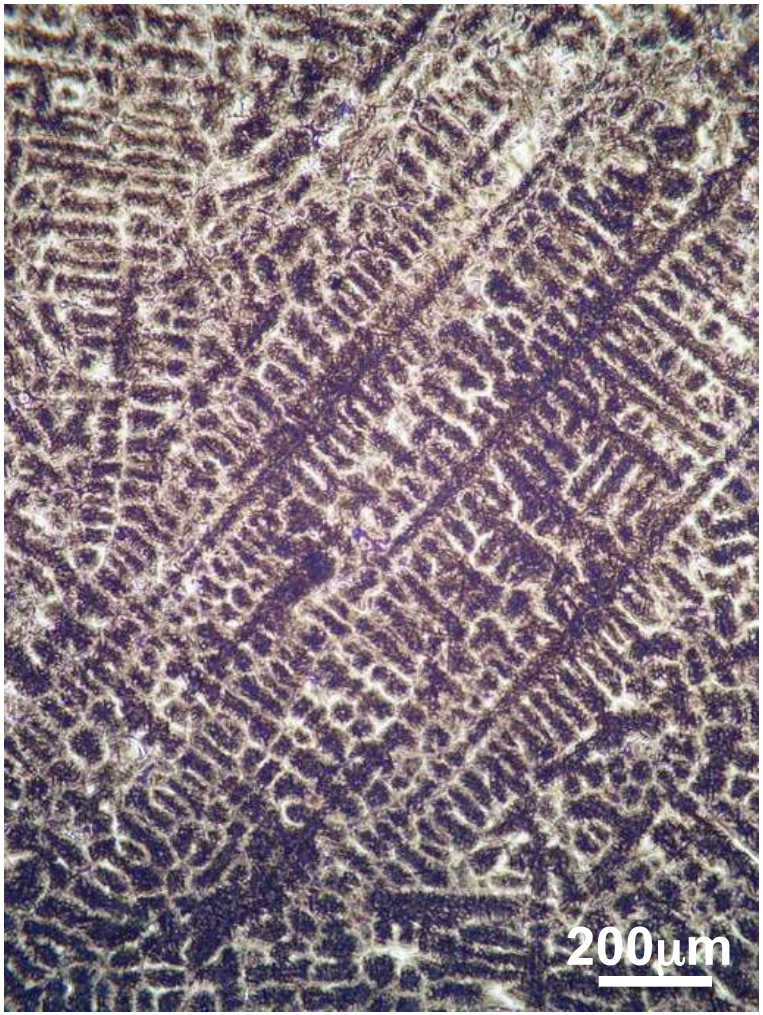
Annealing was carried out at 850°C for 2 h followed by slow cooling to 720°C and holding at this temperature for 4 h.

For *austenitising*, the specimens were heated to temperature 1220°C, and held at this temperature for the same soaking time (10 s per 1 mm of the specimen cross section).

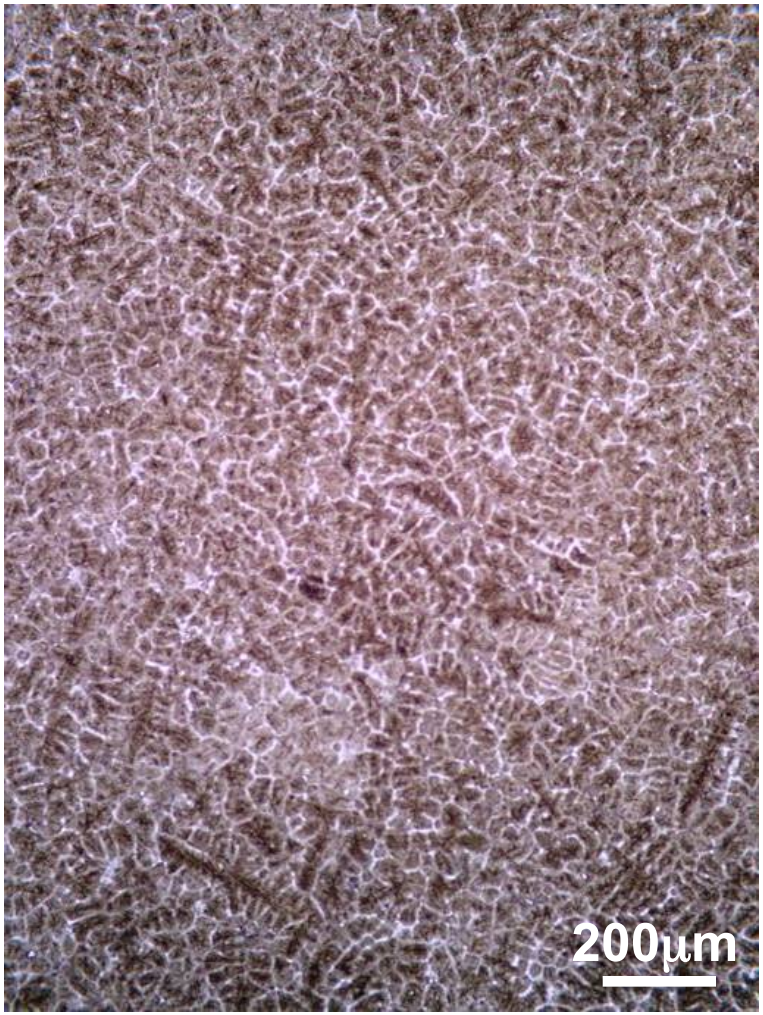
Quenching of the specimens was done in a salt bath at 550°C followed by cooling to room temperature in still air.

Triple tempering at 560°C for 1 h completed the heat treatments.

Overall microstructure in parent and inoculated steel after casting

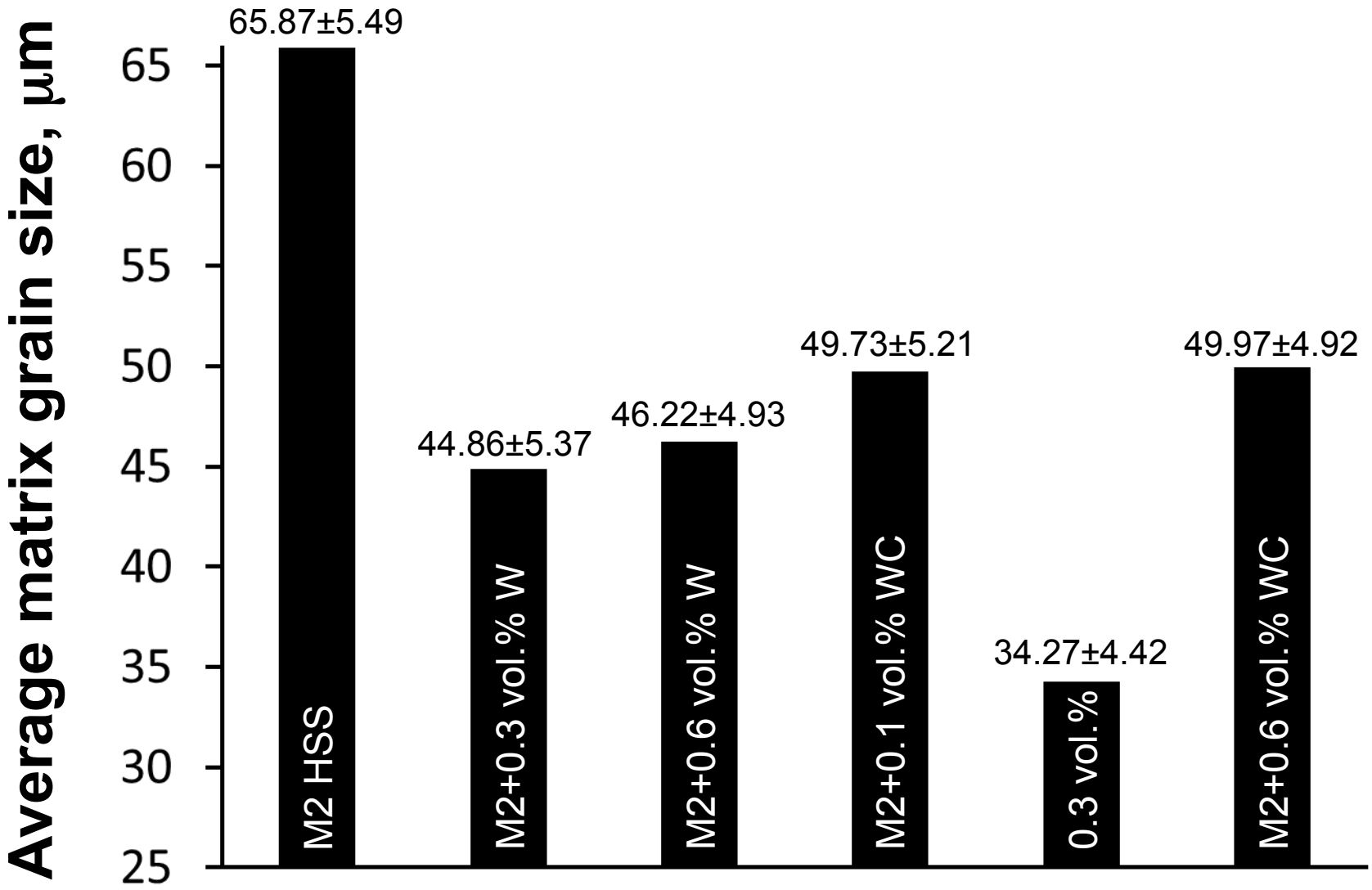


M2 HSS

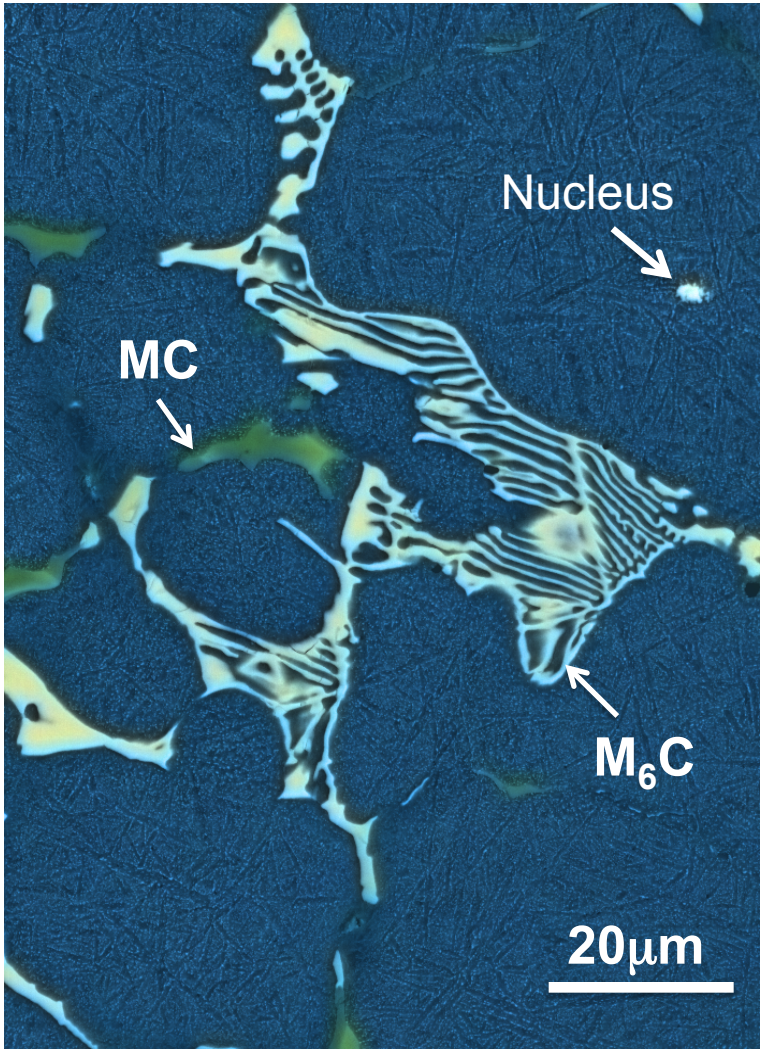


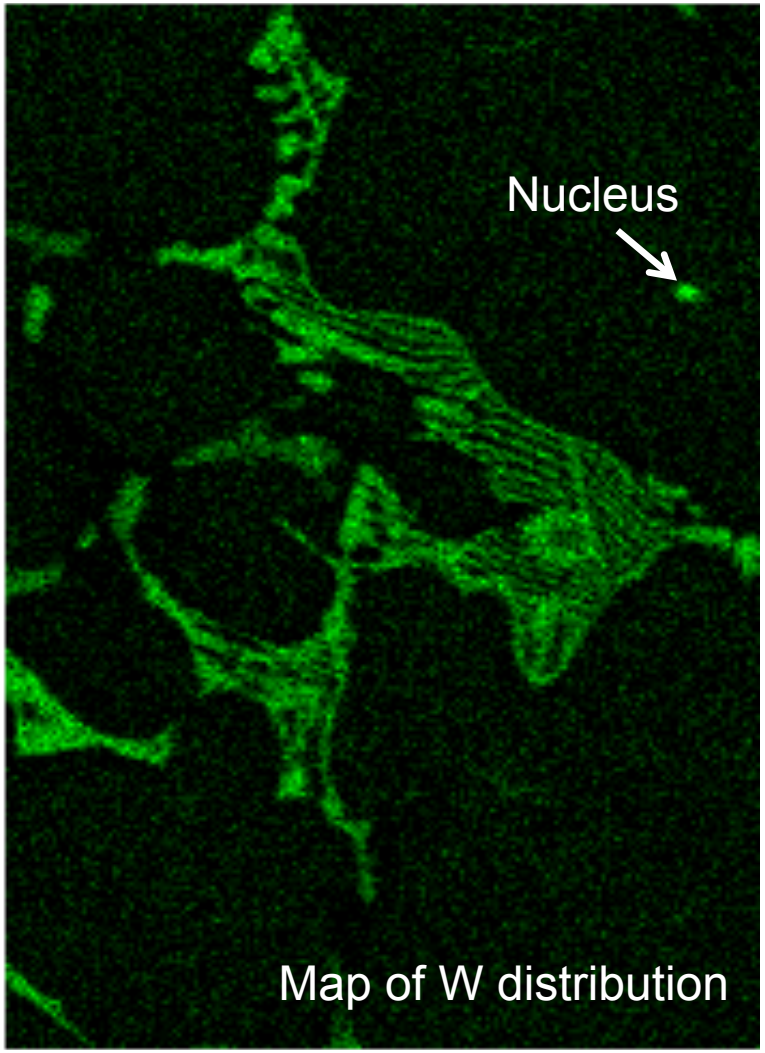
M2+0.3 vol.% WC

Effect of inoculating agents on matrix grain size

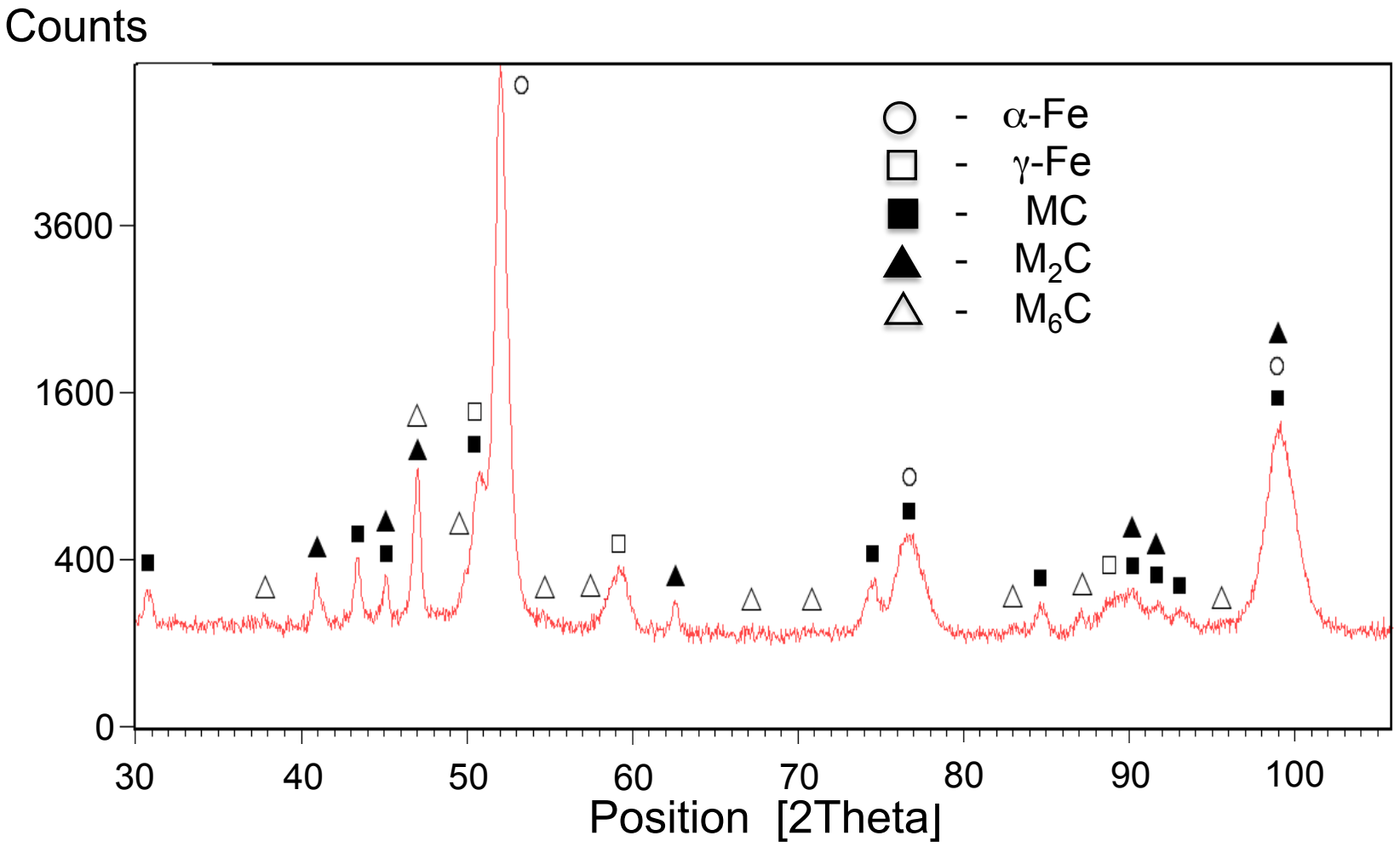


Tungsten containing nucleus in as cast microstructure in steel inoculated with W

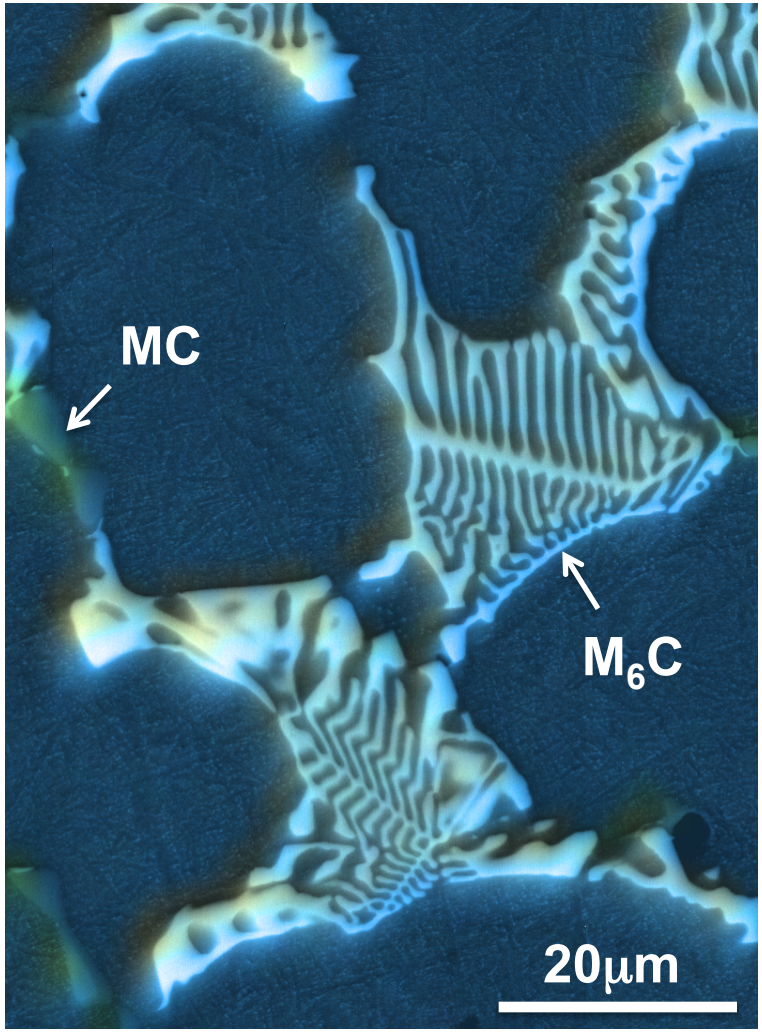


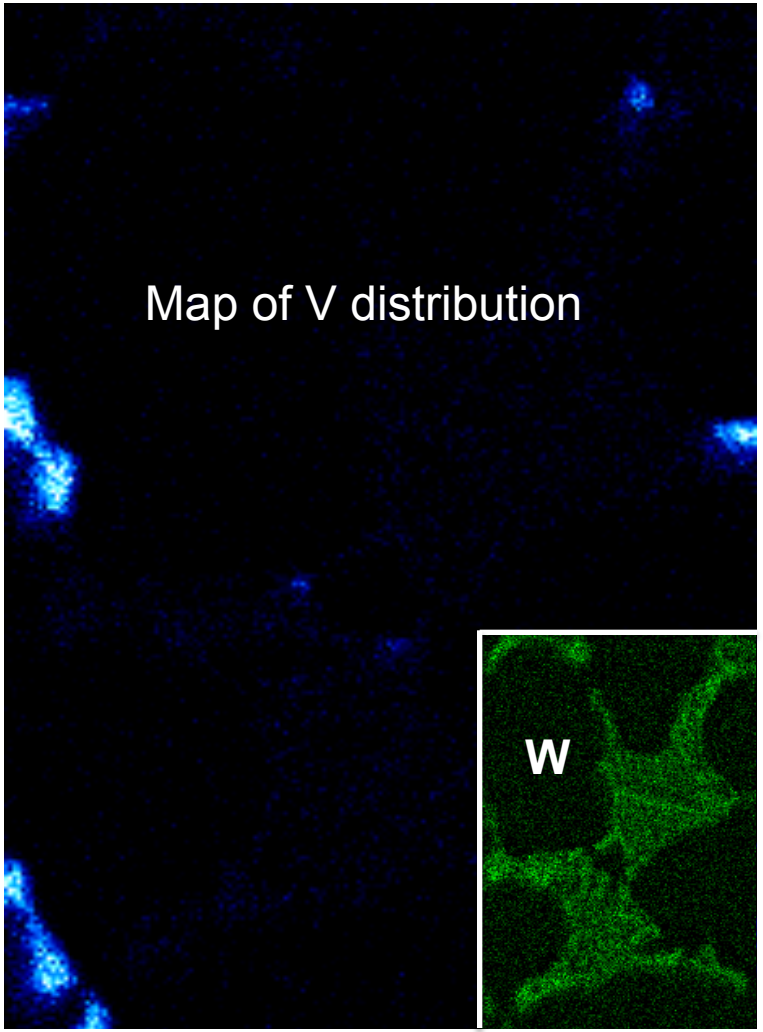


XRD pattern for parent steel

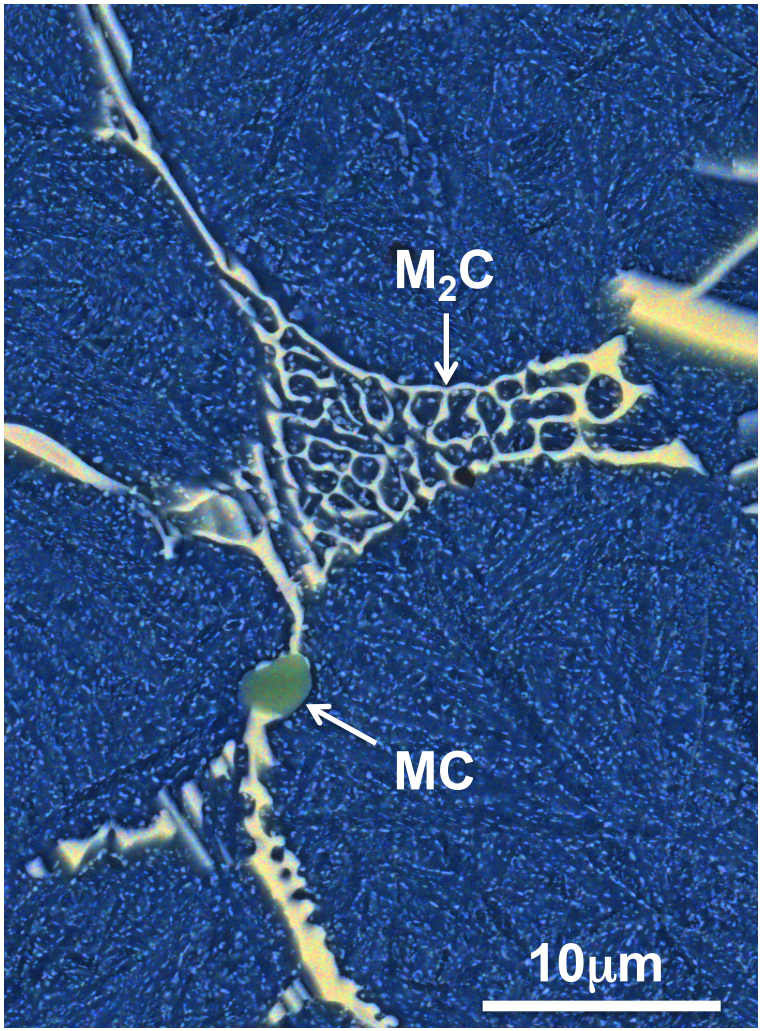


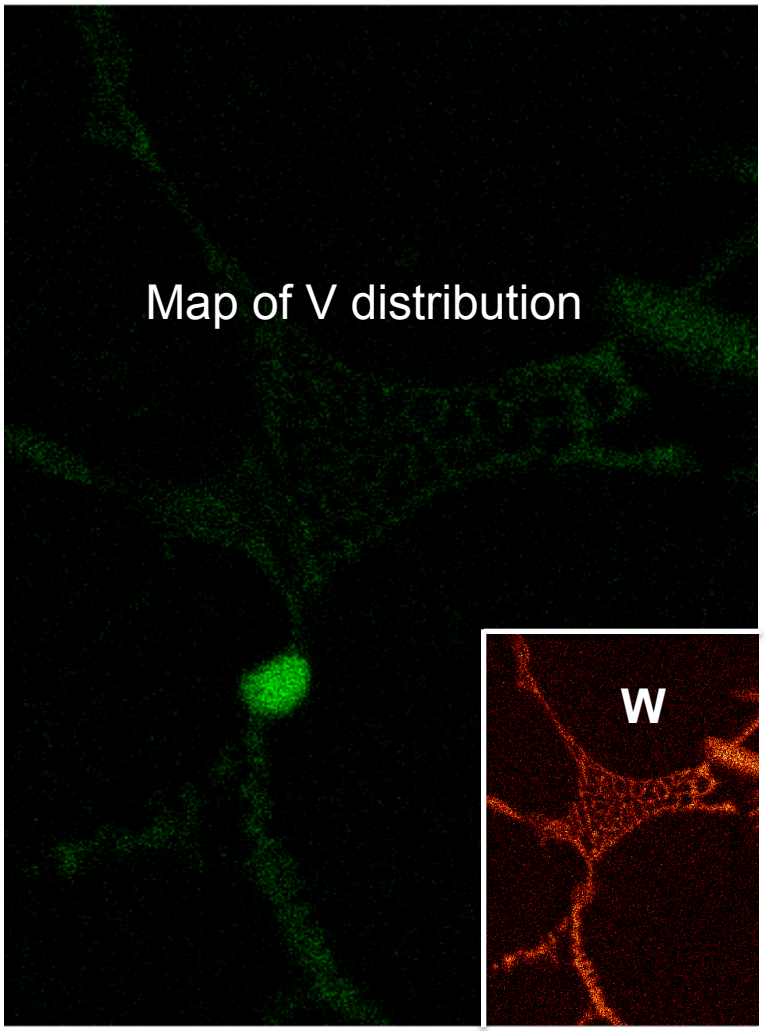
M_6C carbide and distribution of V and W after casting



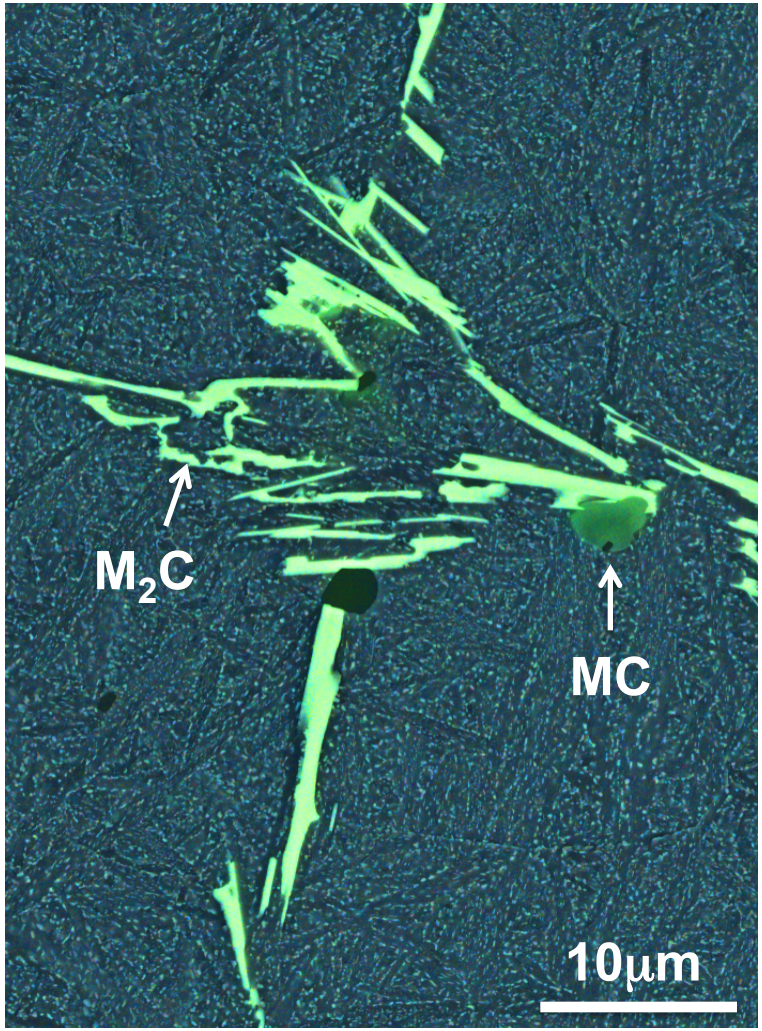


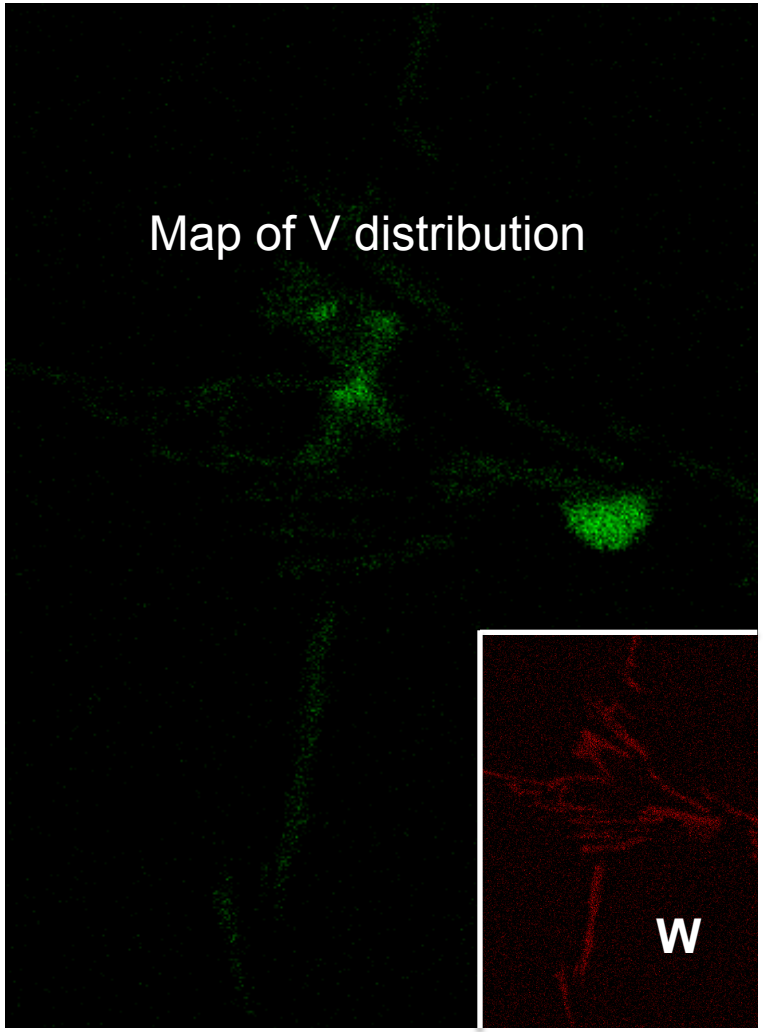
Rod-like M_2C carbide and distribution of V and W after casting





Lamellar M_2C carbide and distribution of V and W after casting

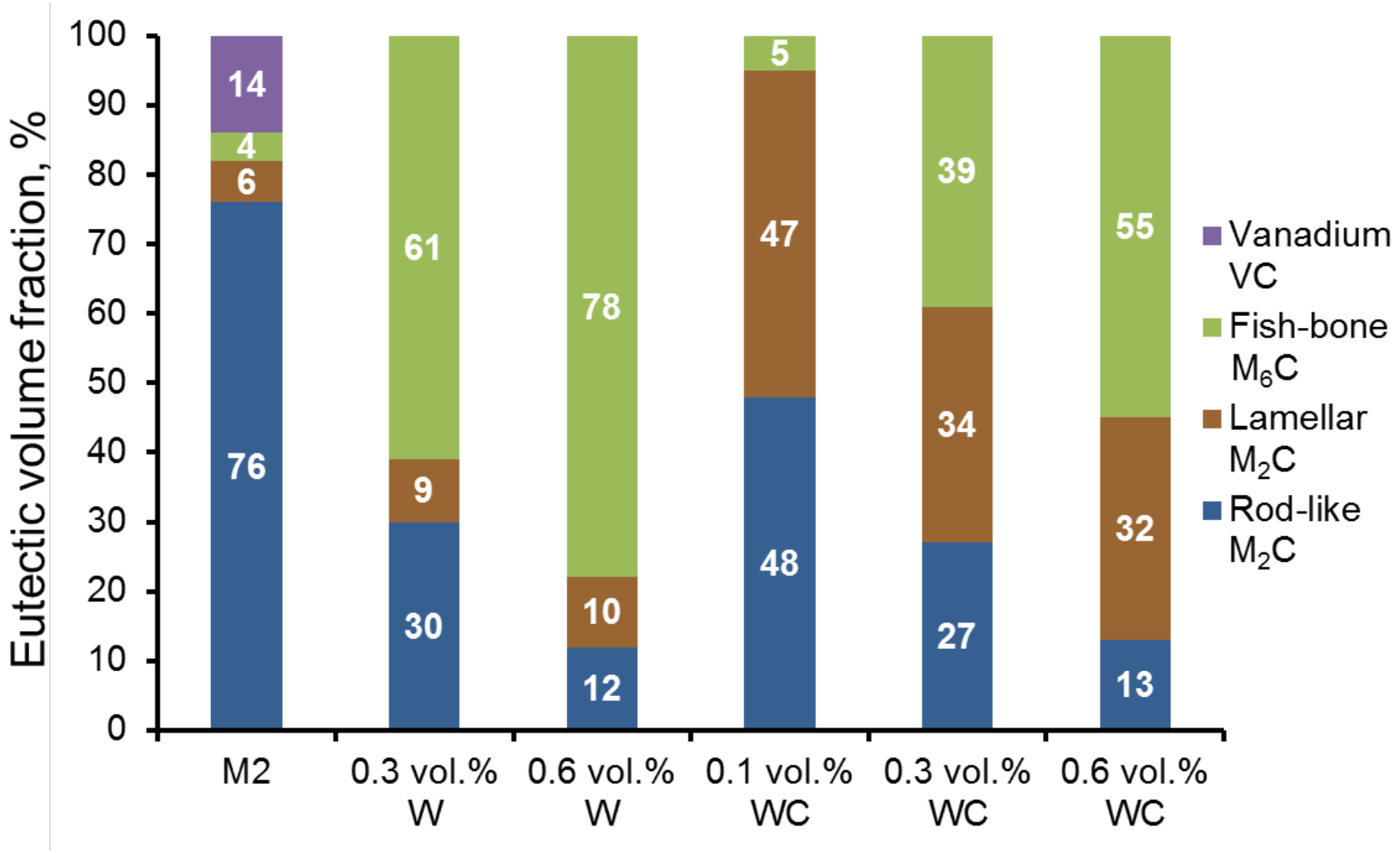




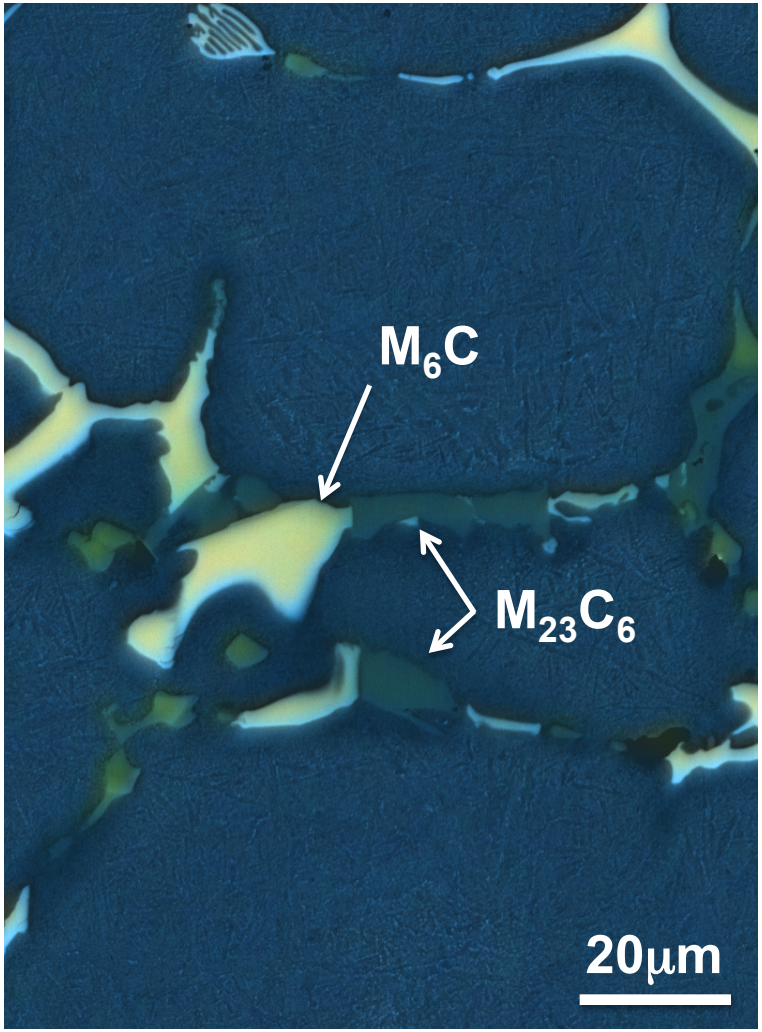
Chemical compositions of M_6C, M_2C and MC eutectic carbides

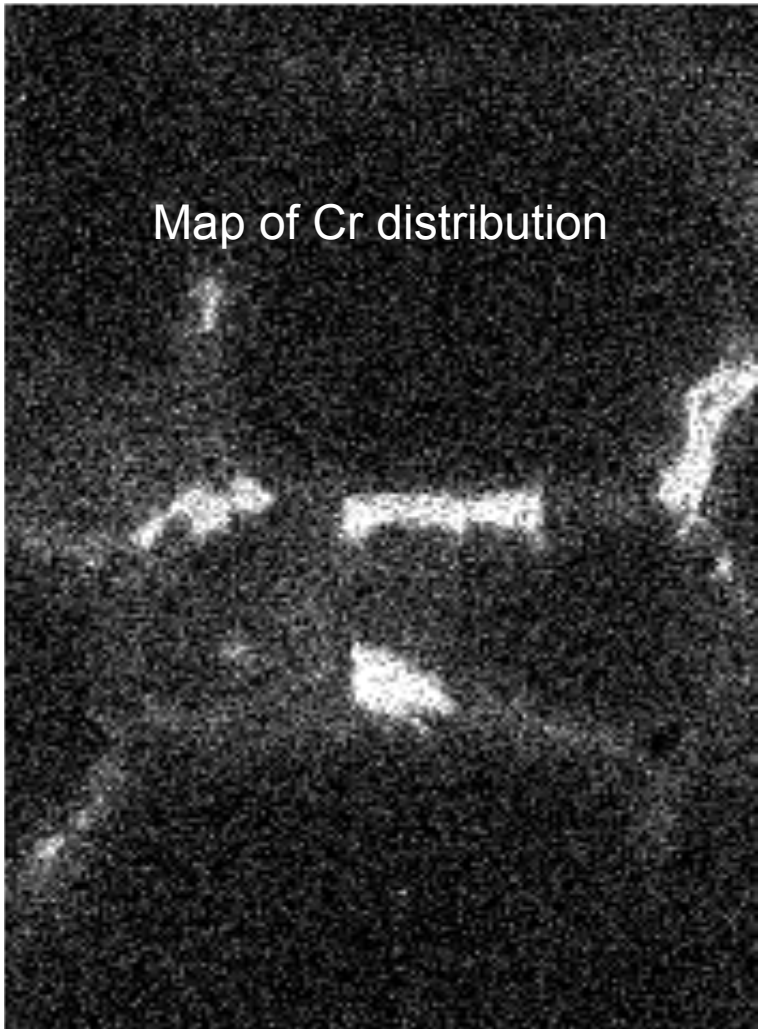
Carbide	Chemical composition, wt.%				
	V	Cr	Fe	Mo	W
M_6C, fishbone	3.01	3.84	39.73	15.61	37.81
M_2C, lamellar	11.96	5.98	12,04	25.72	44.30
M_2C, rod-like	7.66	5.14	14.64	29.79	42.77
MC, petal-like	42.35	3.59	12.17	10.82	31.07

Effect of inoculating agents on volume fractions of eutectics

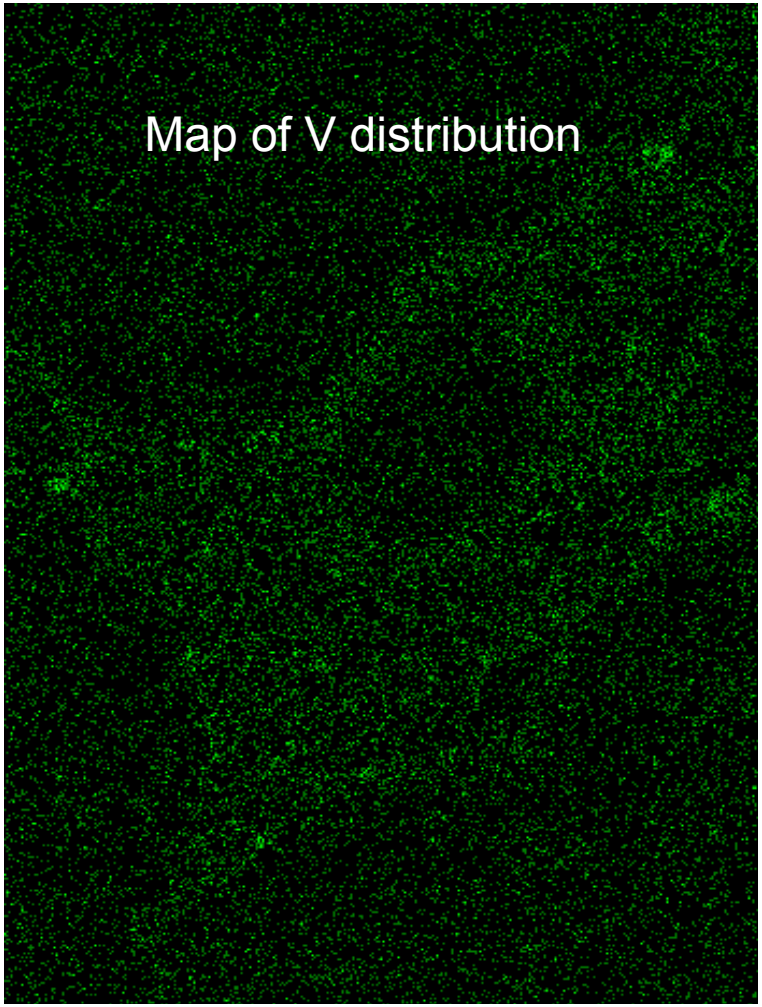


$M_{23}C_6$ carbide and distribution of Cr after casting

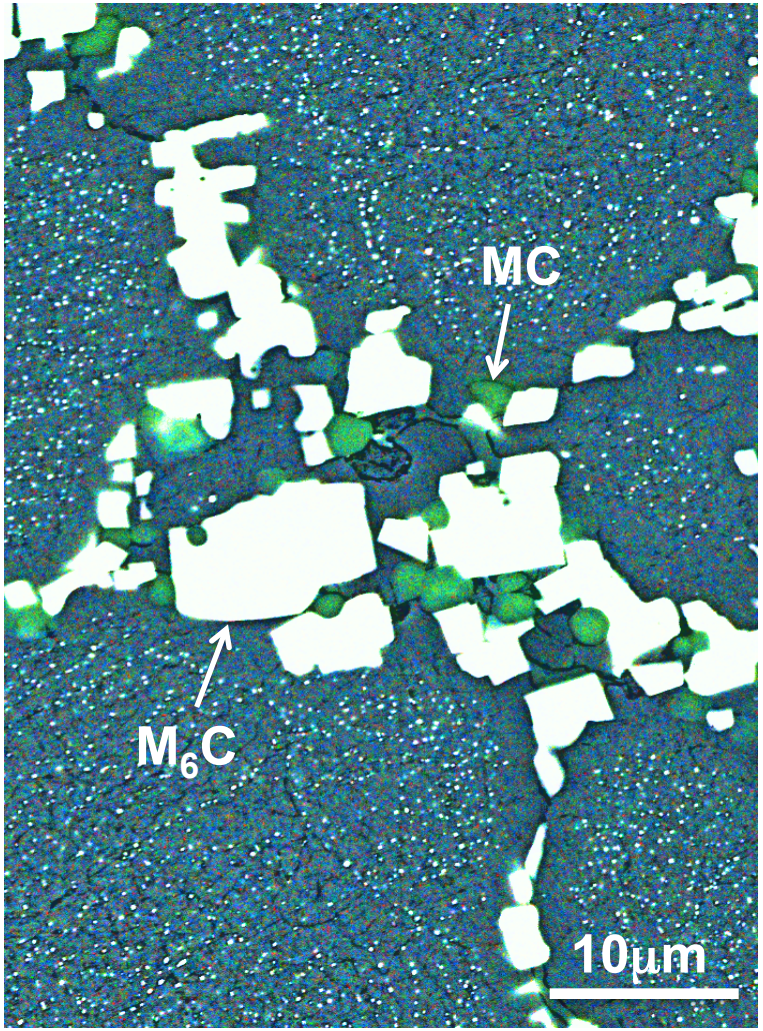


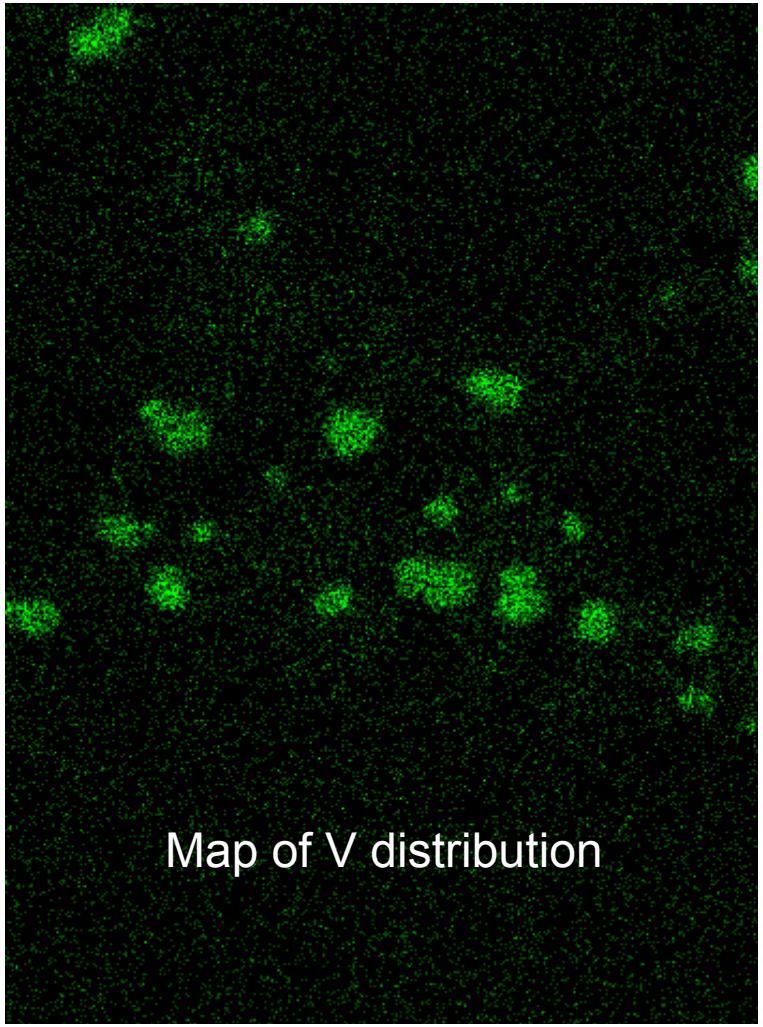


M_6C carbide and distribution of V after heat treatment

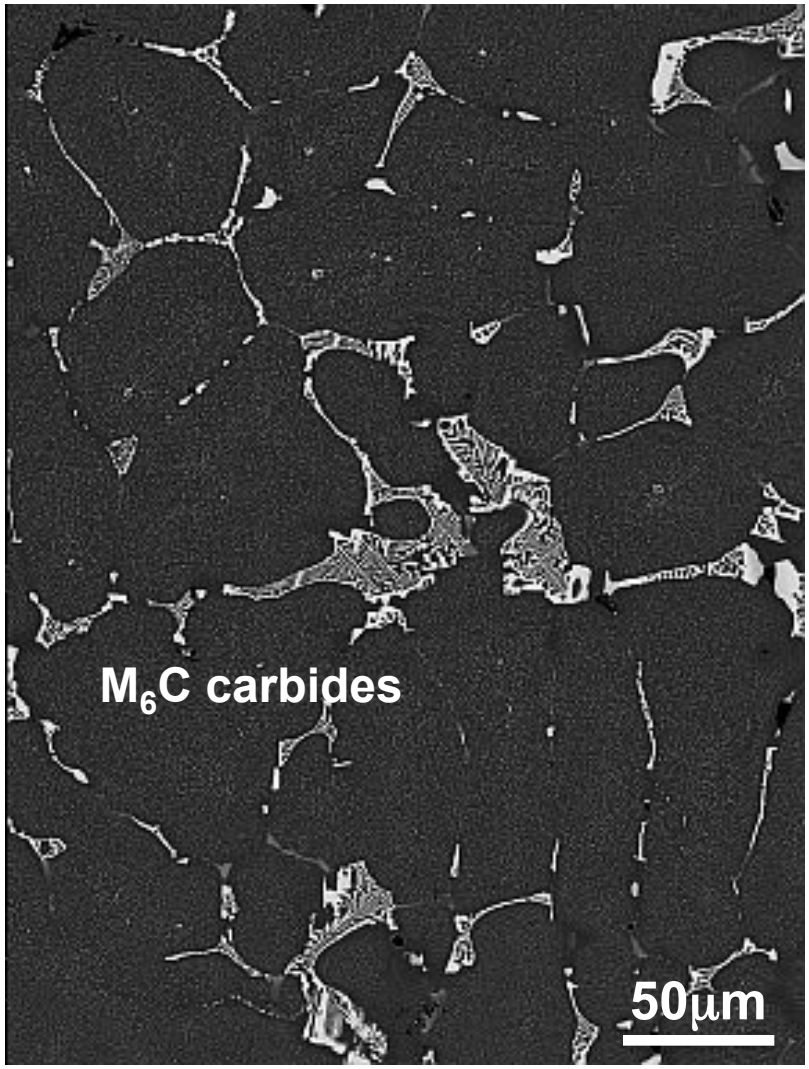


MC and M_6C products of M_2C decomposition and distribution of V after heat treatment

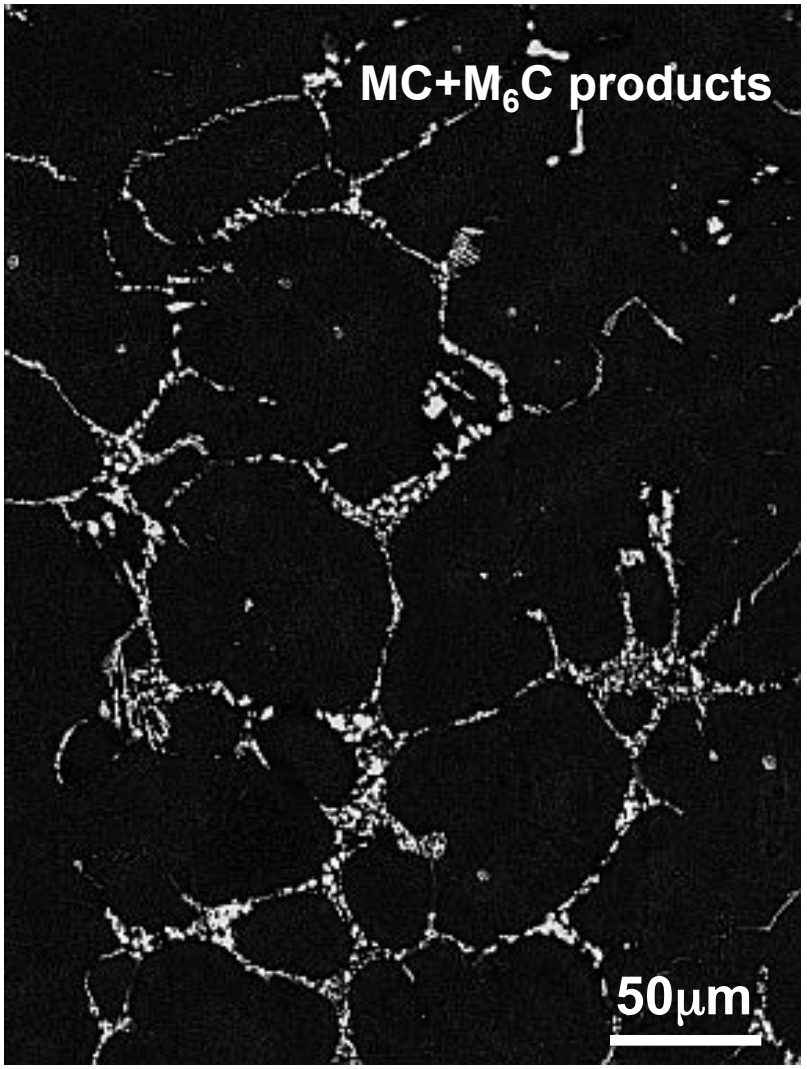




Overall microstructure in inoculated steels after heat treatment

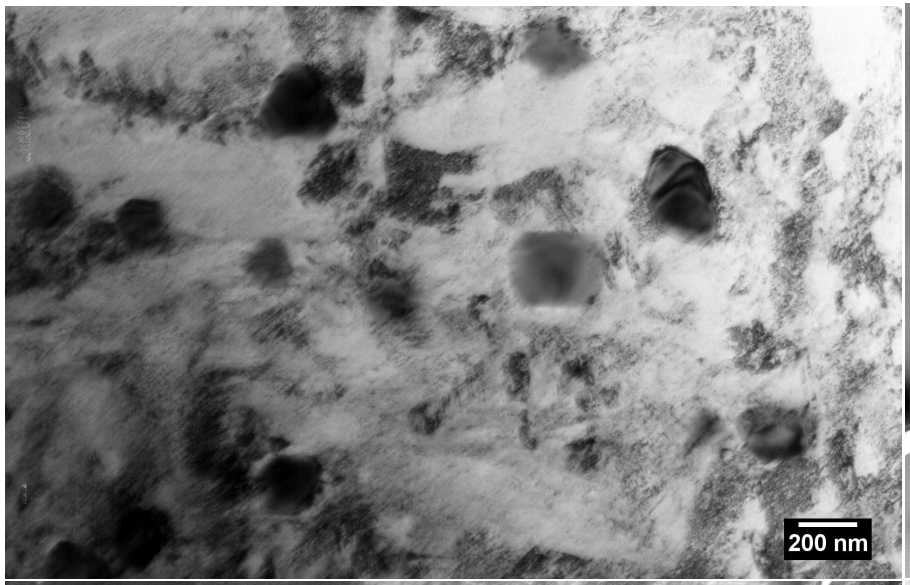


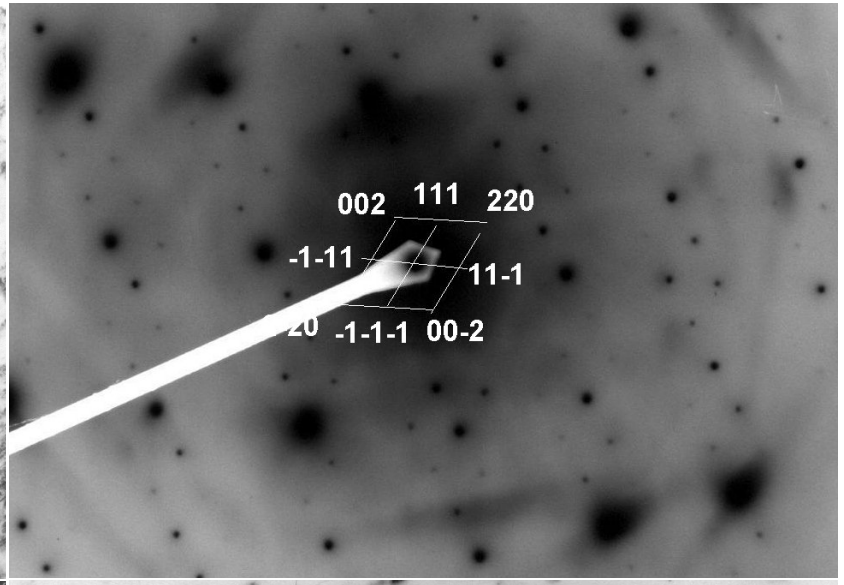
M2+0.6 vol.% W

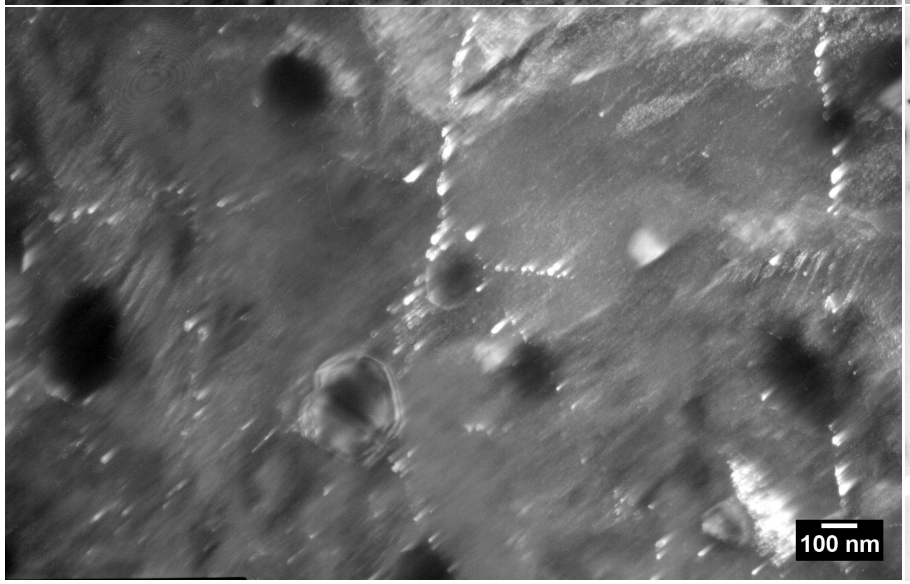


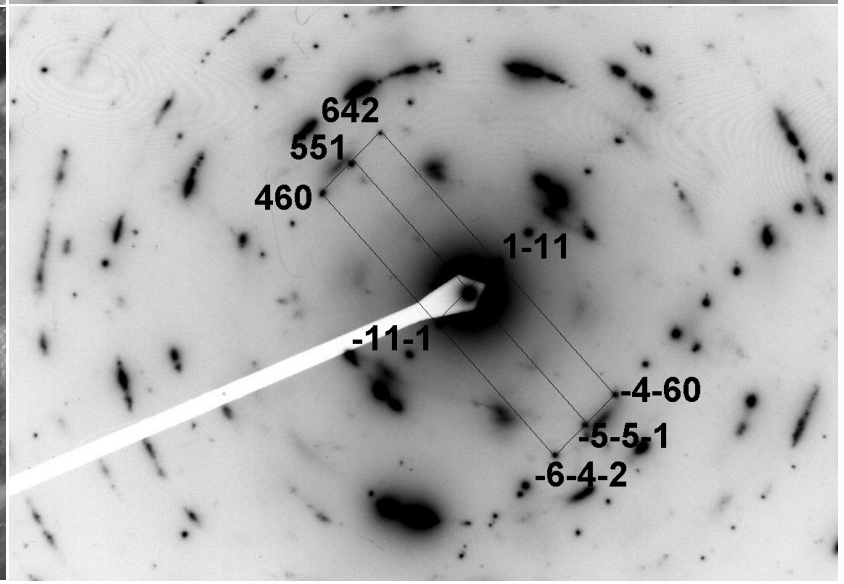
M2+0.1 vol.% WC

Secondary carbides in steel inoculated with 0.6 vol.% W

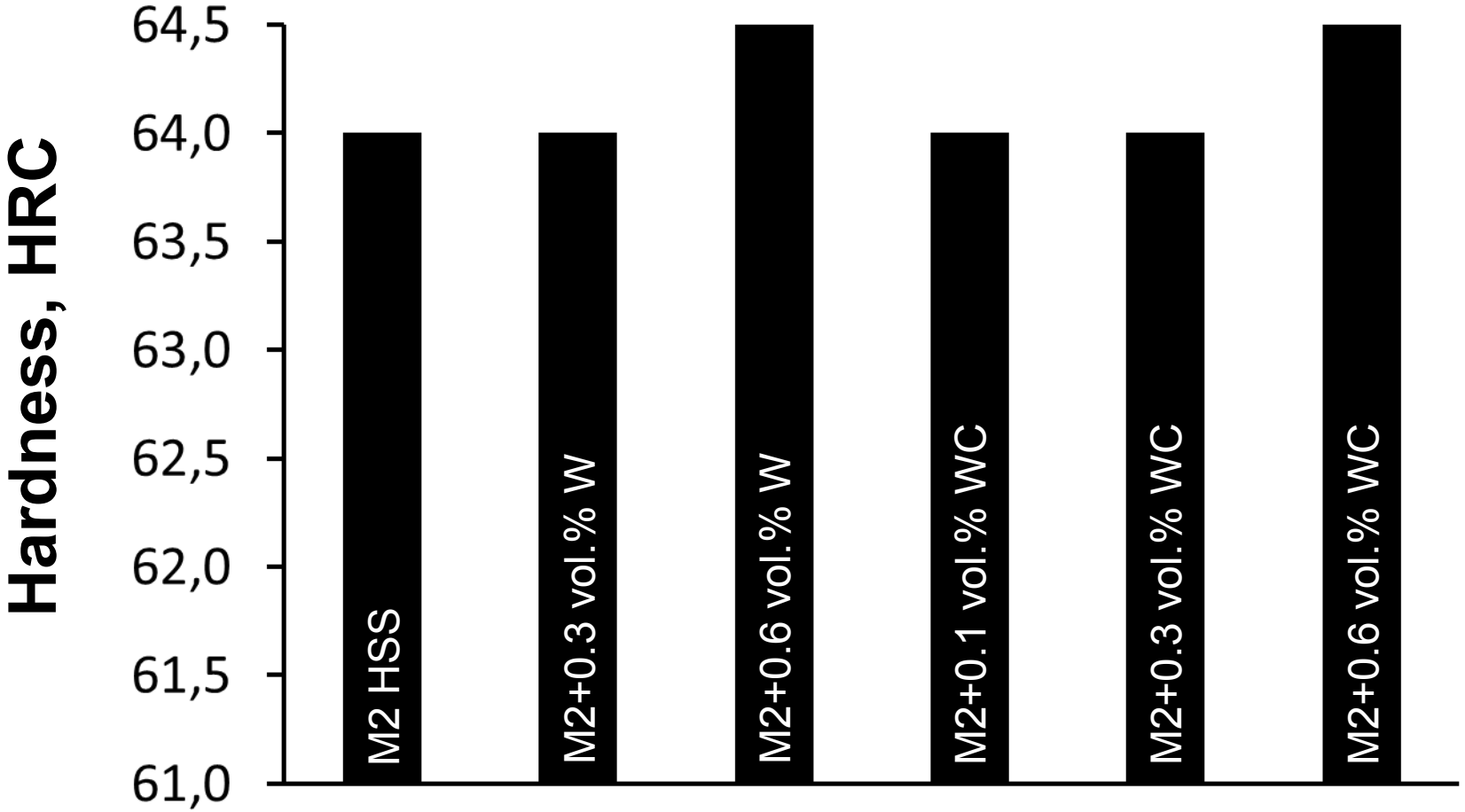






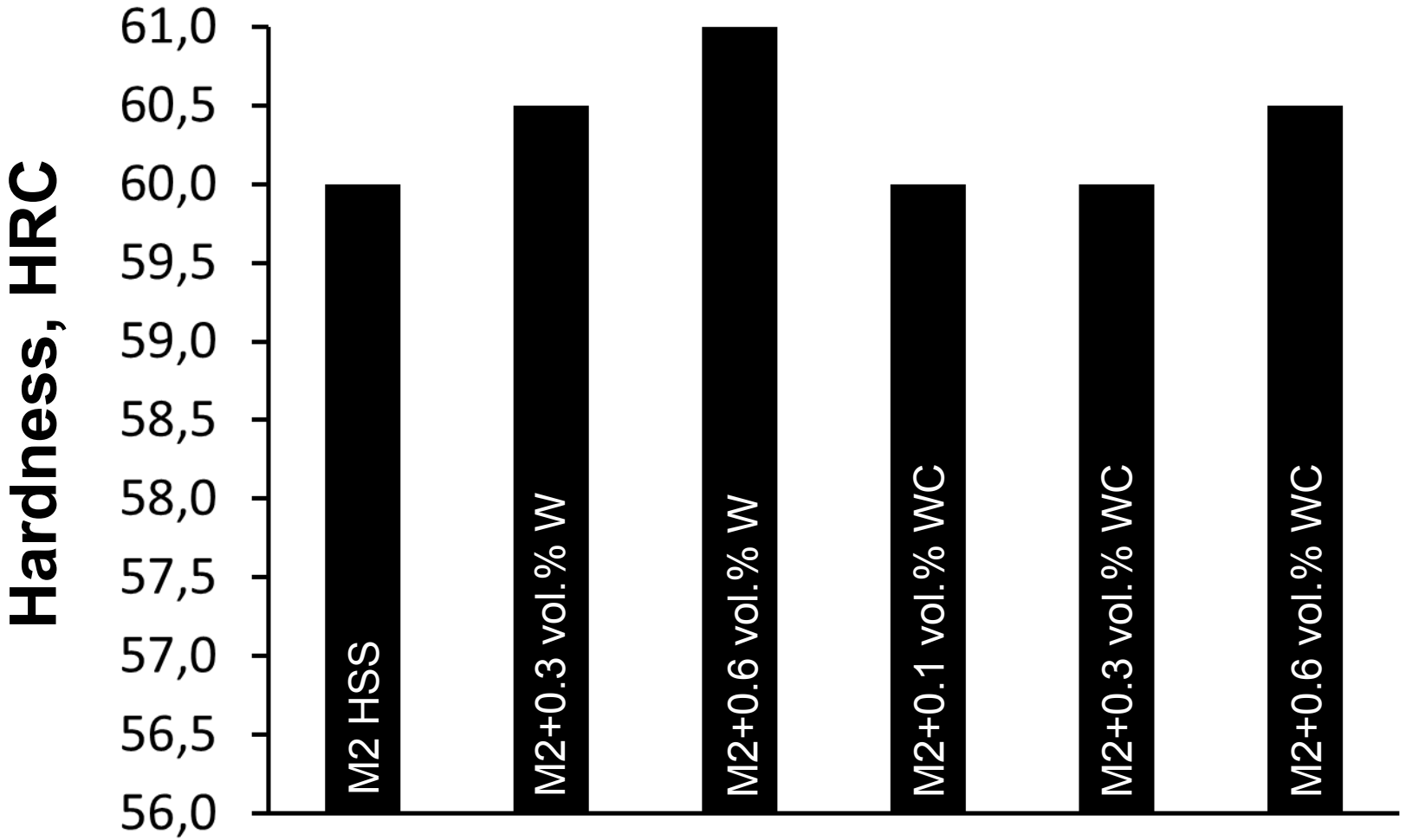


Effect of inoculating agents on hardness*



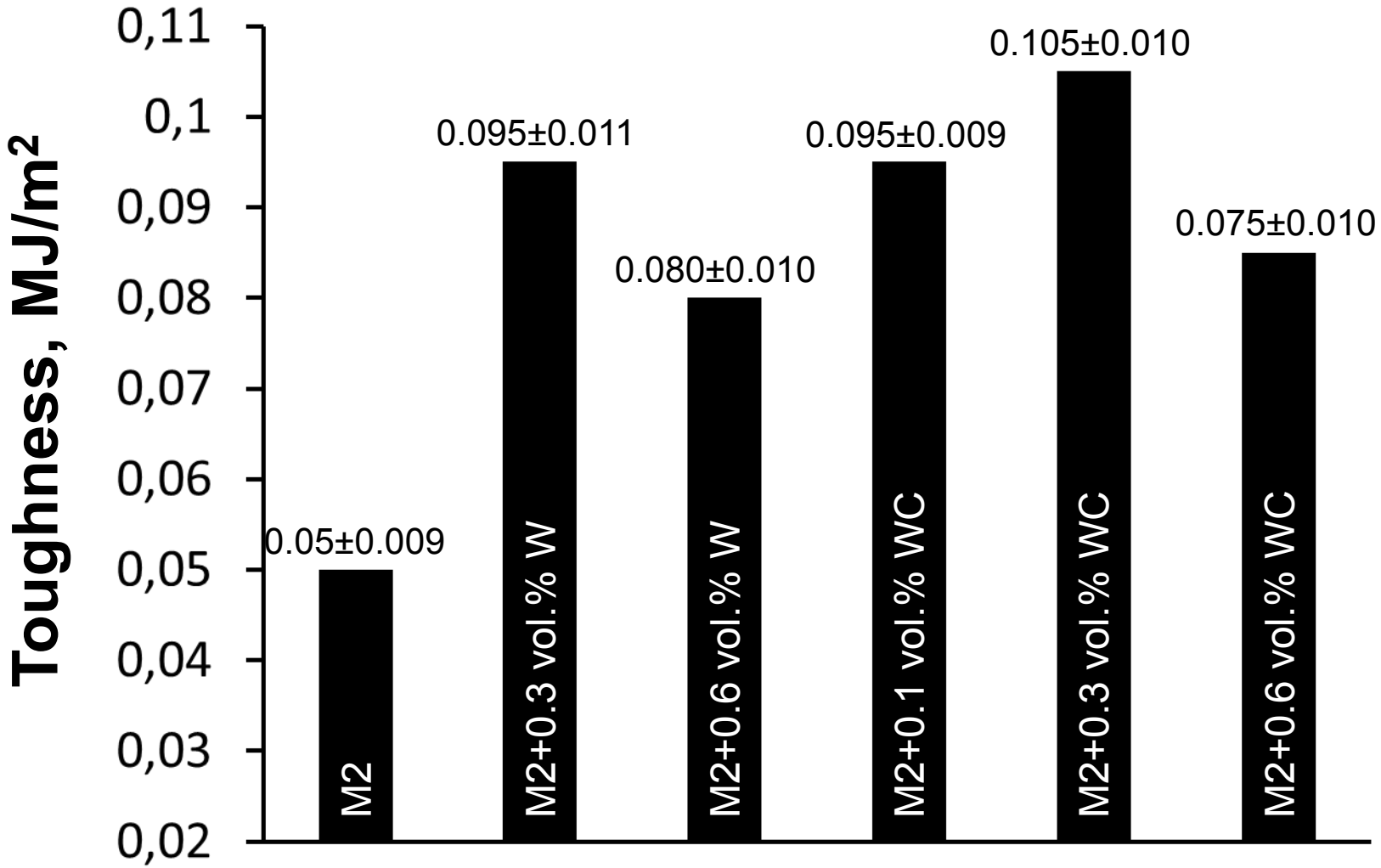
* Uncertainty in the measurements is in the range ±0.1-0.4

Effect of inoculating agents on red hardness*

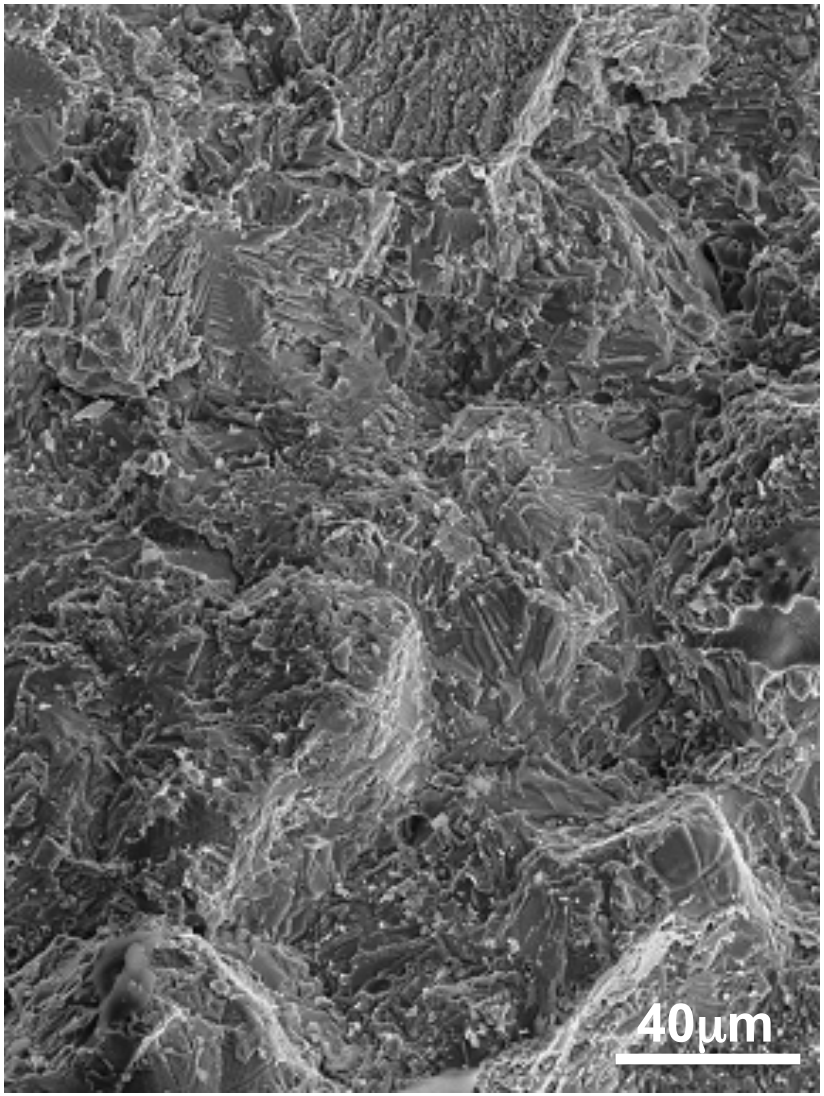


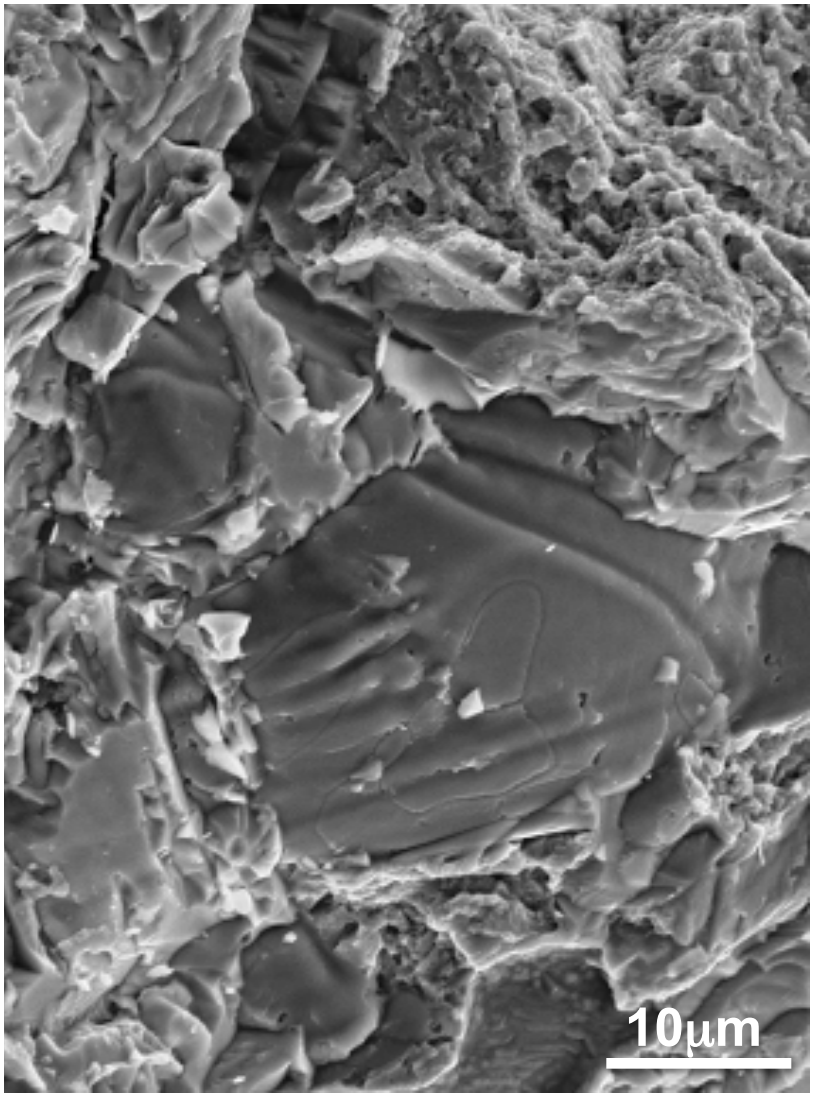
* Uncertainty in the measurements is in the range ±0.1-0.4

Effect of inoculating agents on toughness

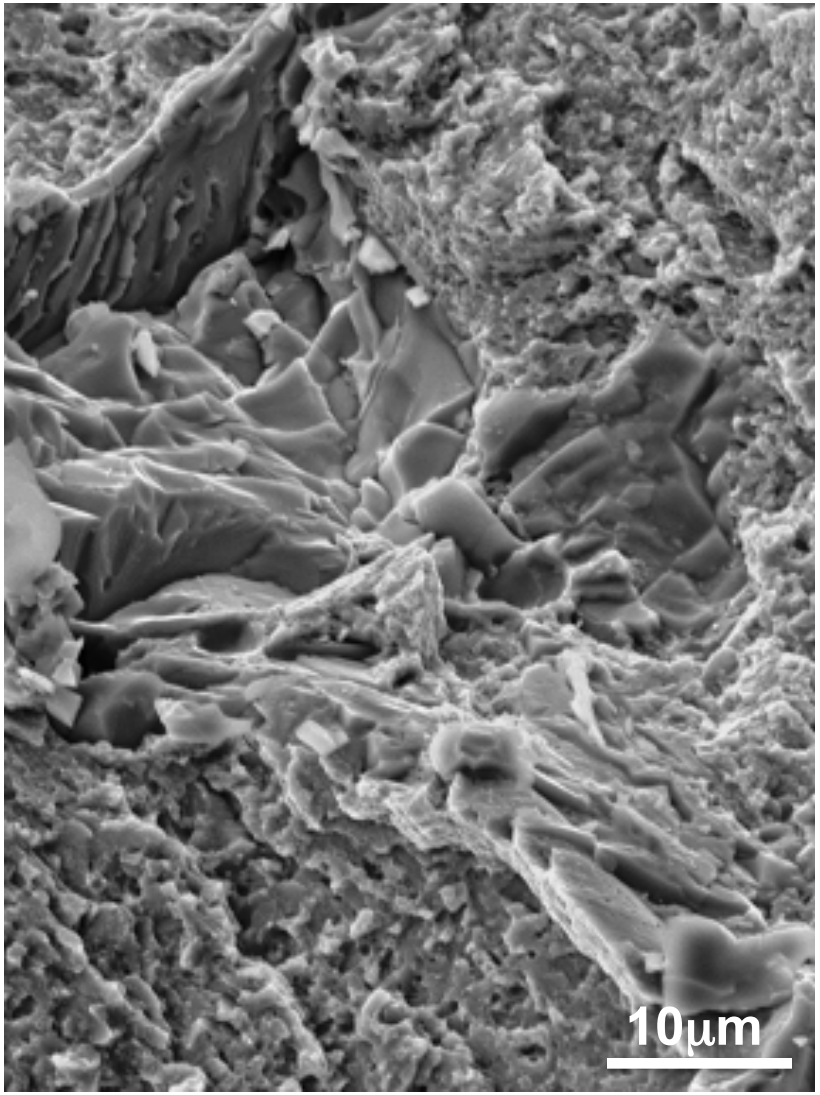


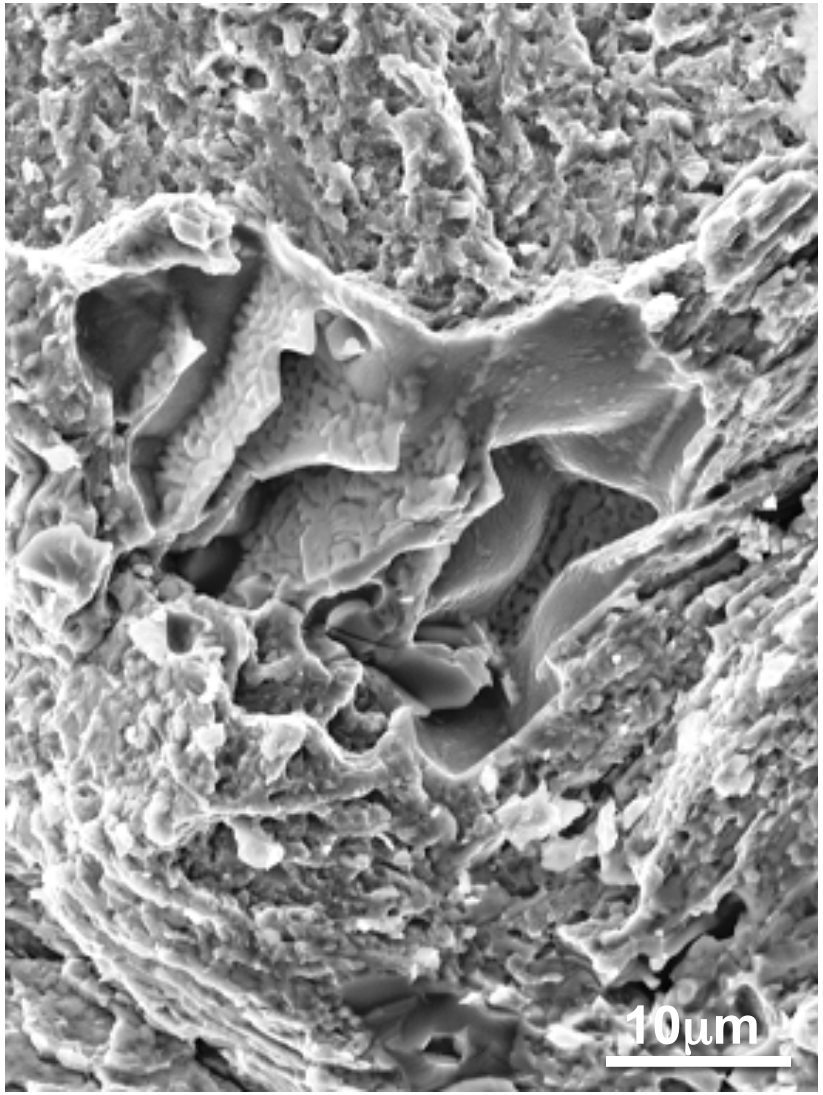
Fracture surfaces in steel inoculated with 0.3 vol.% W



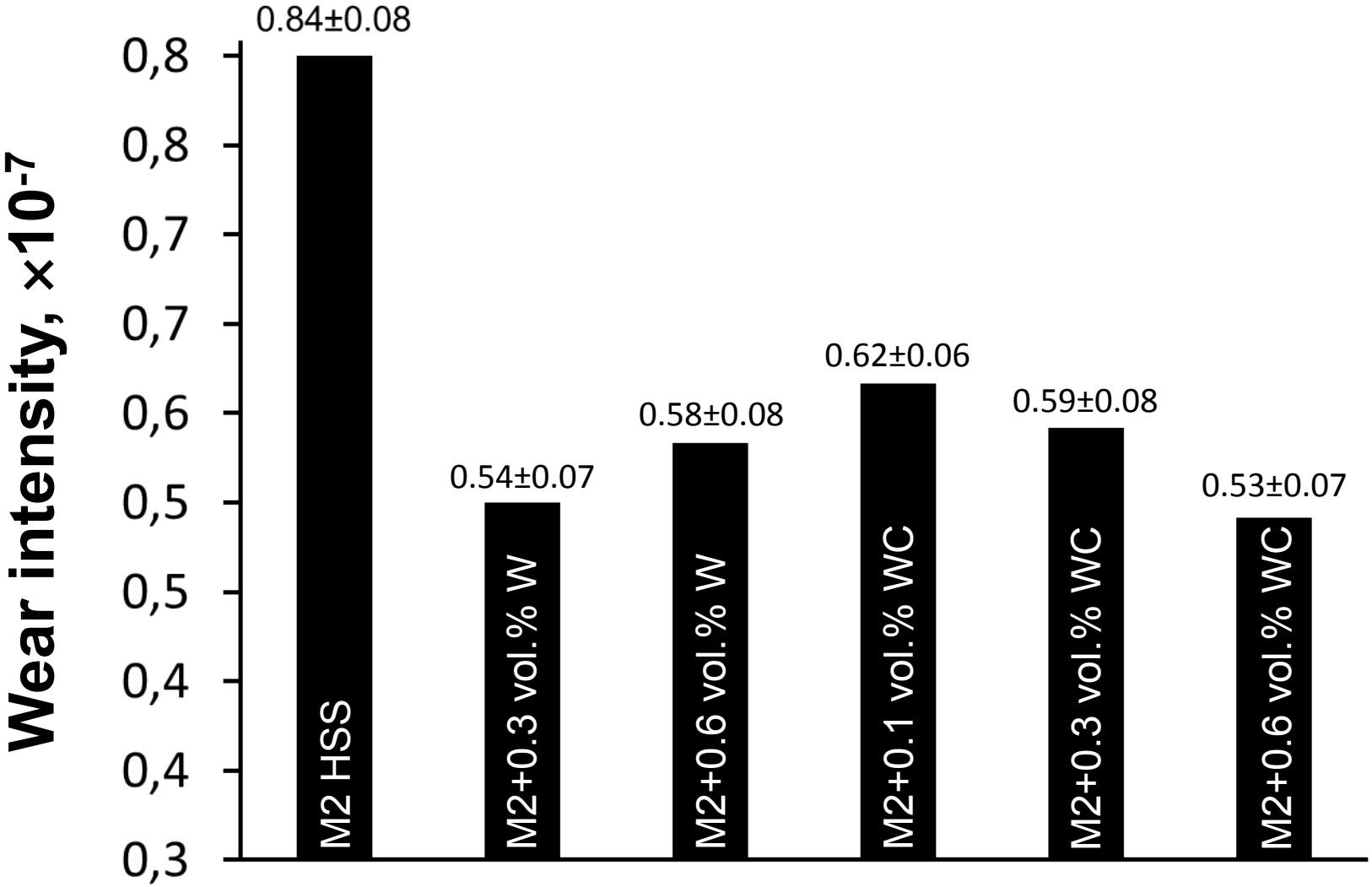


Fracture surfaces in steel inoculated with 0.3 vol.% W

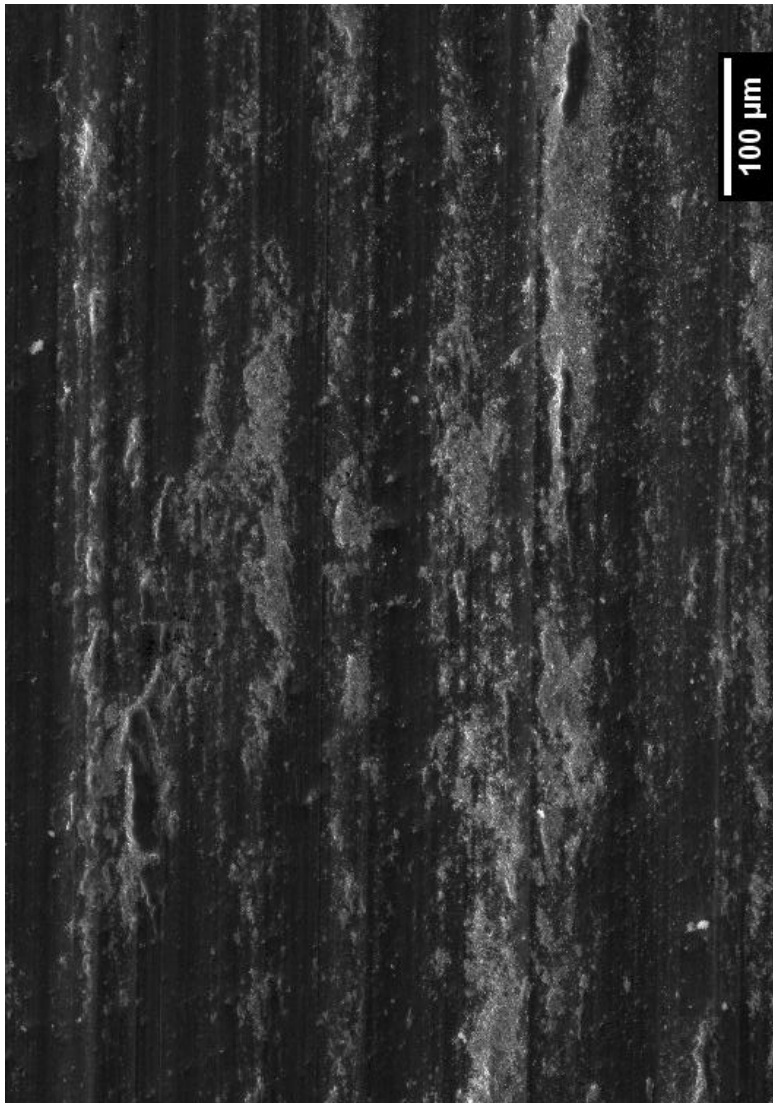




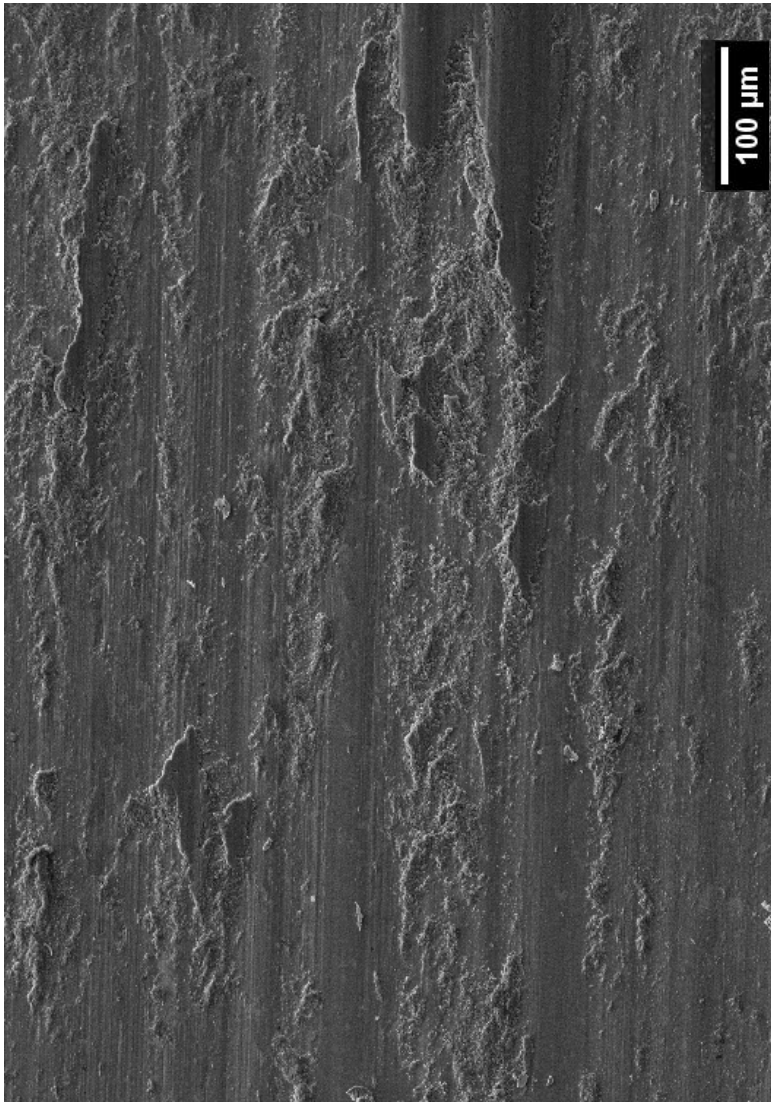
Effect of inoculating agents on wear intensity



Worn surfaces in parent and inoculated steel



M2 HSS



M2+0.6 vol.% WC

Conclusions

1. The inoculating of M2 HSS with W and WC promoted strong refinement of the matrix and transition from the slender dendrites to the equiaxed grains.

2. Compared to the parent steel, both agents favoured the formation of M_6C eutectic at the expense of M_2C eutectic and completely suppressed the formation of VC eutectic.

3. The refinement of the eutectic colonies was also observed that could be primarily related to the matrix grain refinement.

4. In the heat treated condition, the structural changes induced by the agents resulted in the enhanced toughness and wear resistance and minor changes in hardness and red hardness.