Effect of different copper additions to Ti-10.1Ta-1.7Nb-1.6Zr

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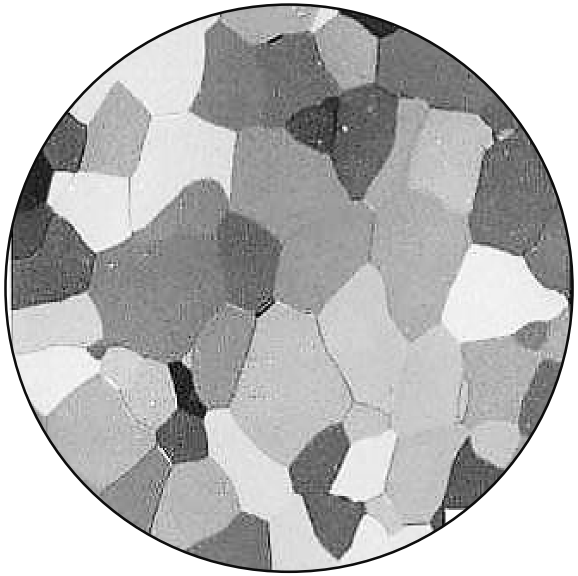
[4]Advanced Materials Division, Mintek, Randburg,

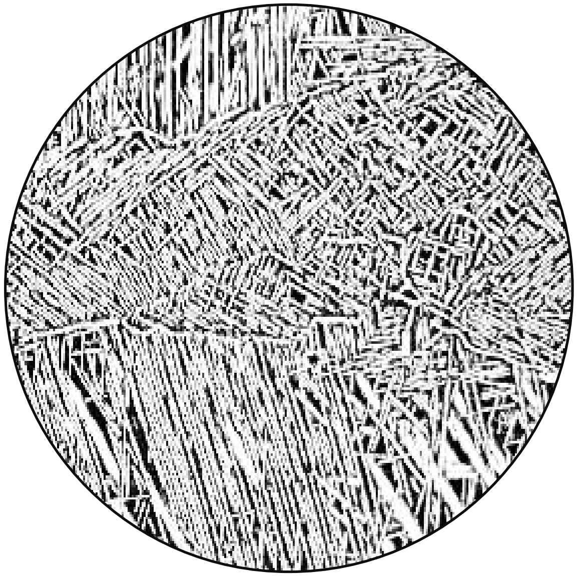
[5]Sandvik Coromant R&D, Stockholm, Sweden

Classes of Titanium alloys

hcp (α Ti)

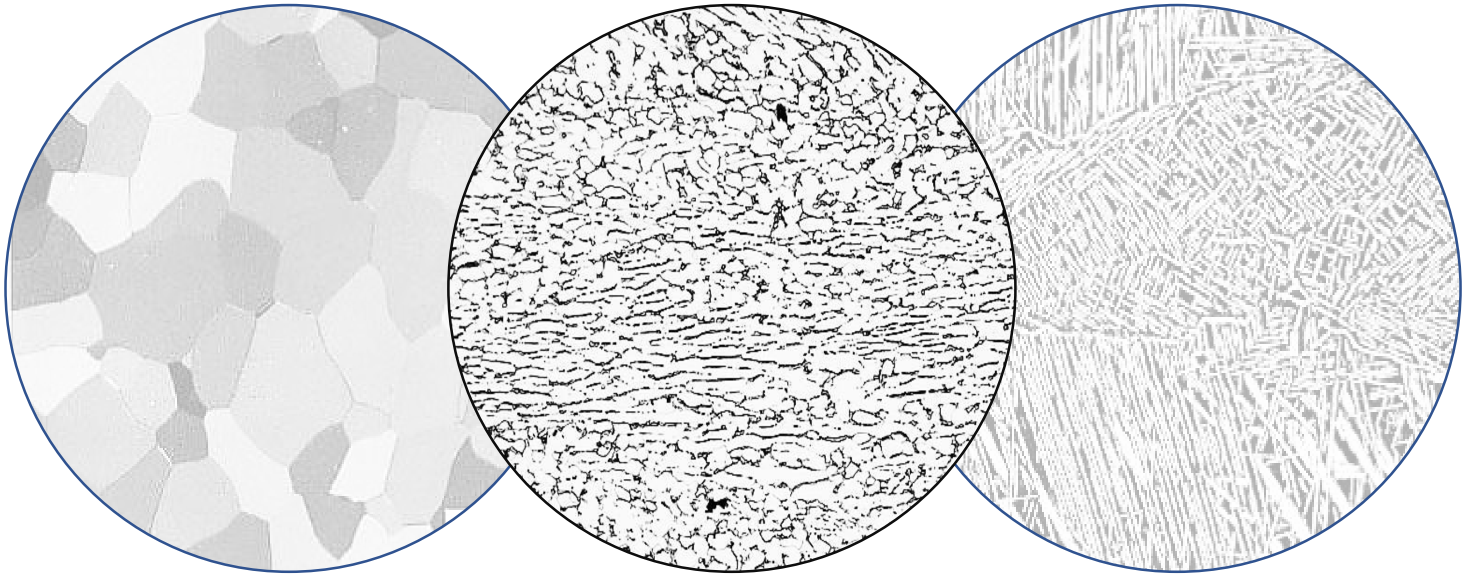


bcc (β Ti)



Classes of Titanium alloys

hcp (α Ti) | (α + β) | bcc (β Ti)



Biocompatible titanium alloys

CP titanium

hcp αTi (and << β Ti)

Bone-anchored dental devices – 'implants'

Biocompatible

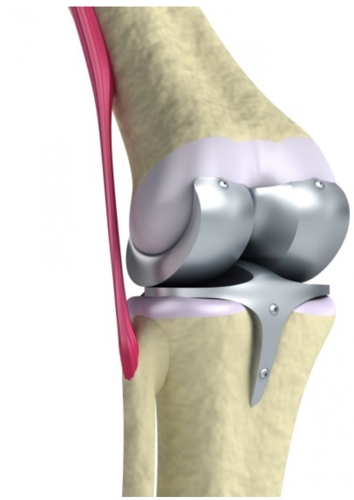
Good osseo-integration

https://dentalcarebaskingridge.com/dental-services/implants/

Ti-6Al-4V

(α + β) Ti

Higher load applications



Toxic aluminium and vanadium??

alex-mit/Getty Images/iStockphoto

‘New’ (α+β) alloys

Replace **Al** with other α stabilising elements (O, N, C, Ga)

Replace **V** with other β stabilising elements

β isomorphous
V, Mo, W, Ta, Nb

β eutectoid
Fe, Mn, Co, Ni, Cu,
Si, H, W, Cr

Similar proportions of (αTi) and (βTi) to Ti-6Al-4V

“TTNZ” [i]

Ti-10.1Ta- 1.7Nb-1.6Zr

i Stenlund, P. *et al.* (2015) Acta Biomat. 20, 165.

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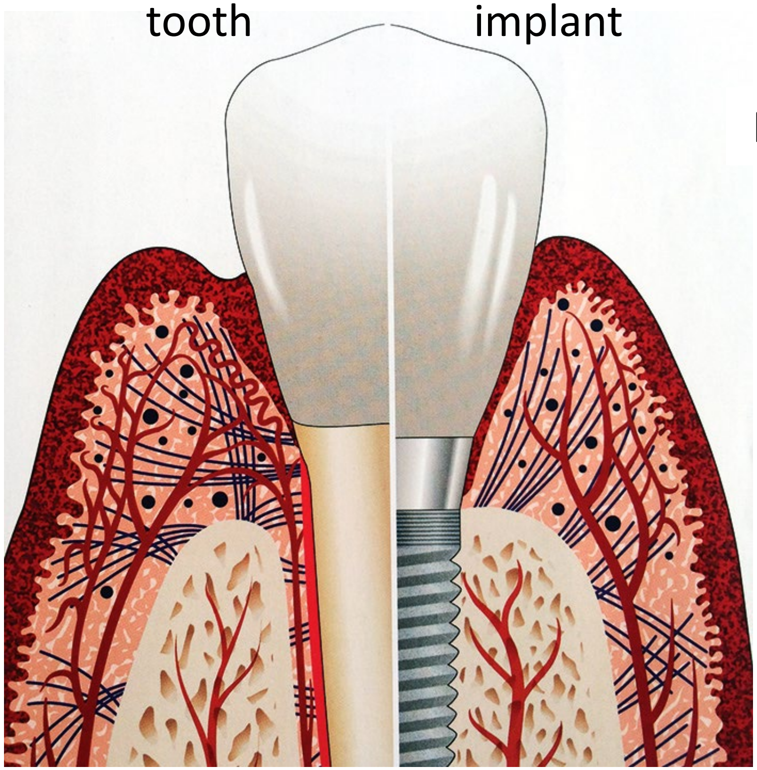
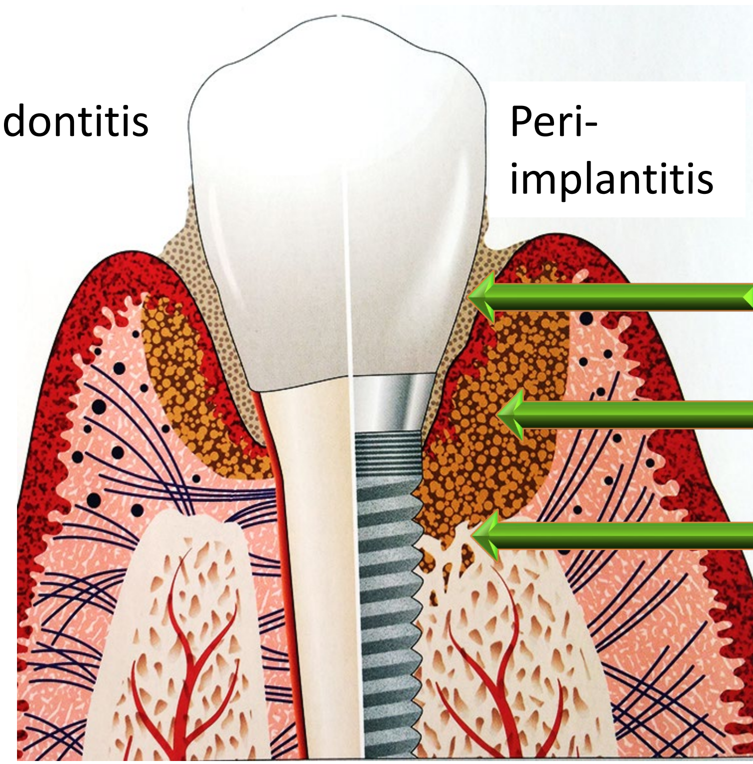
Dental issues and implants

Healthy



Diseased



https://www.dentistryiq.com/dental-hygiene/clinical-hygiene/article/16359651/ guidelines-for-periimplantitis-and-antibiotic-premedication

Prevention / Cure

~7% of patients suffer from peri-implantitis within 10 years

Cure:

- Instruments: manual, ultrasonic
- Antibiotics
- Laser

Preventative measures:

- Pre-antibiotics
- Antibacterial coatings
- Add antibacterial elements??

Copper…

Copper and its alloys (e.g. brass, bronze and Cu-Ni) are inherently antimicrobial. [i]

Used as coatings, or alloys

Titanium alloys: Ti – x Cu (x = 2, 5, 10, 25 wt%) [ii]

Antibacterial activity $\rightarrow$ due to Ti_3Cu or Ti_2Cu?

i) www.copper.org/applications/marine/cuni/properties/antimicrobial/

ii) Liu *et al*. (2014) Mat. Sci. & Eng. C35, 392.

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Experimental Alloys

TTNZ: Ti-10.1Ta- 1.7Nb-1.6Zr

+ 0, 1, 3, 5 10 wt% Cu

Ti and Zr sponge, Ta and Nb wire

Mixed and compressed
Melted in vacuum in an electron beam furnace

Vickers hardness, SEM-EDX, XRD

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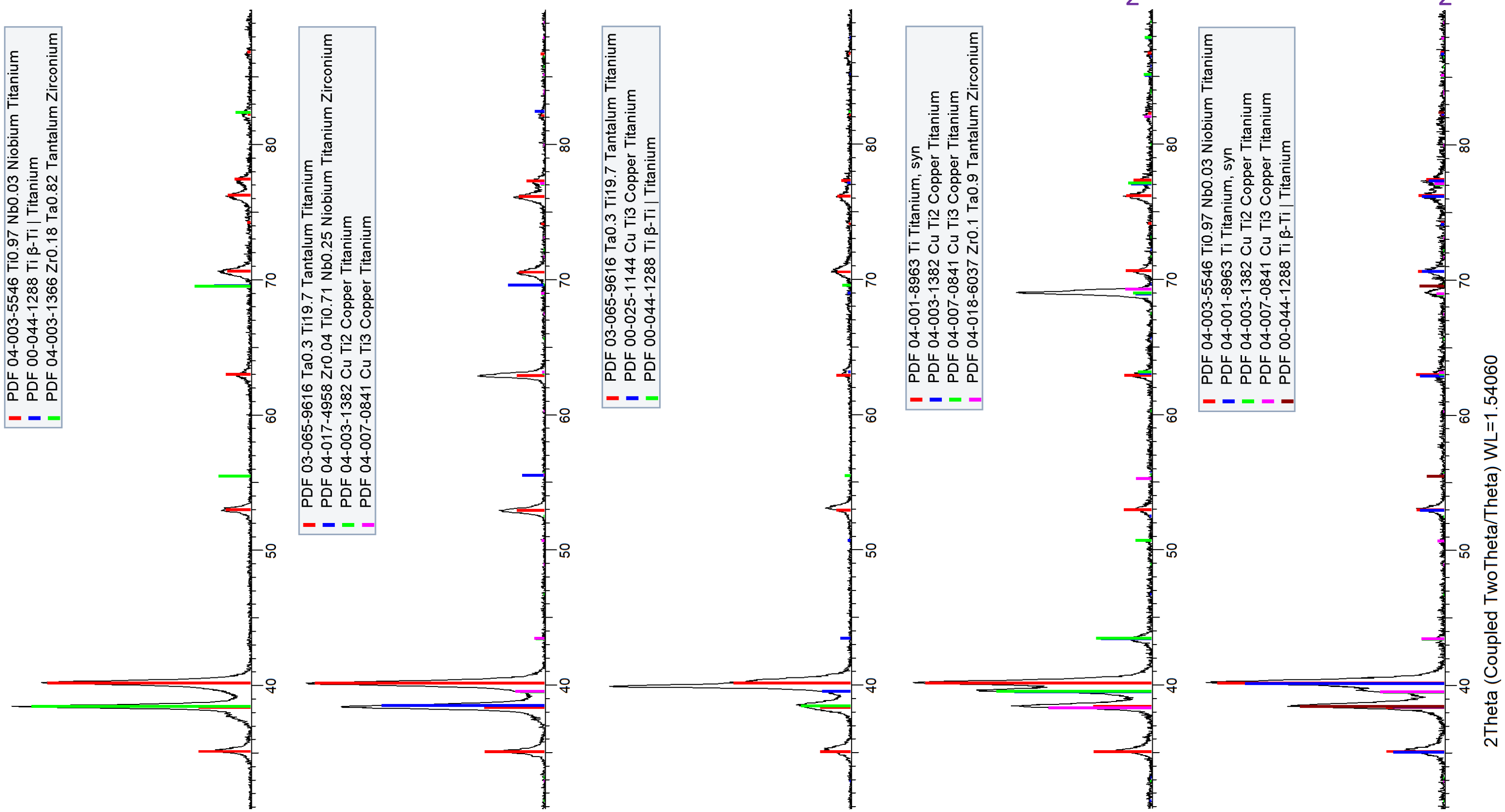
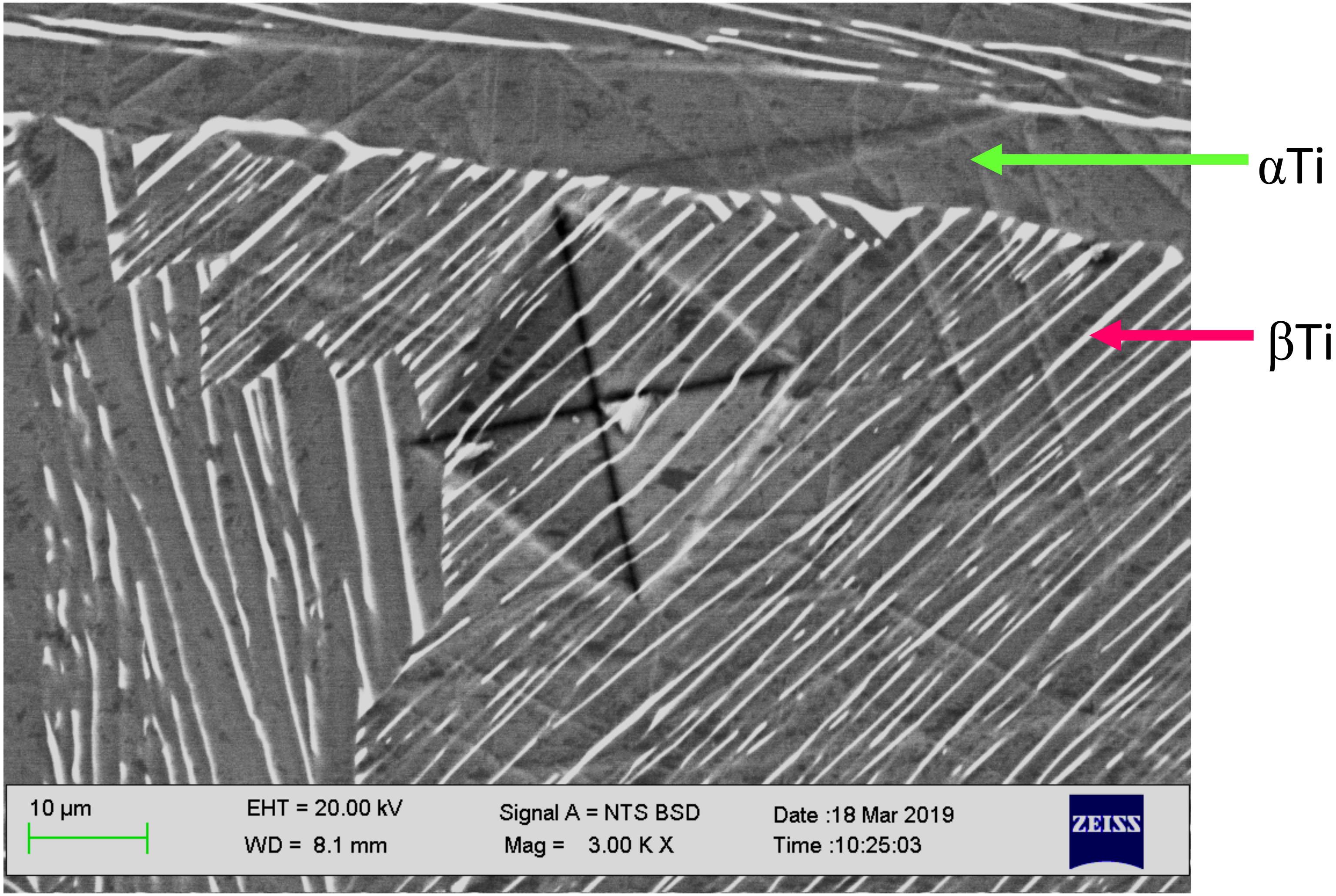
XRD

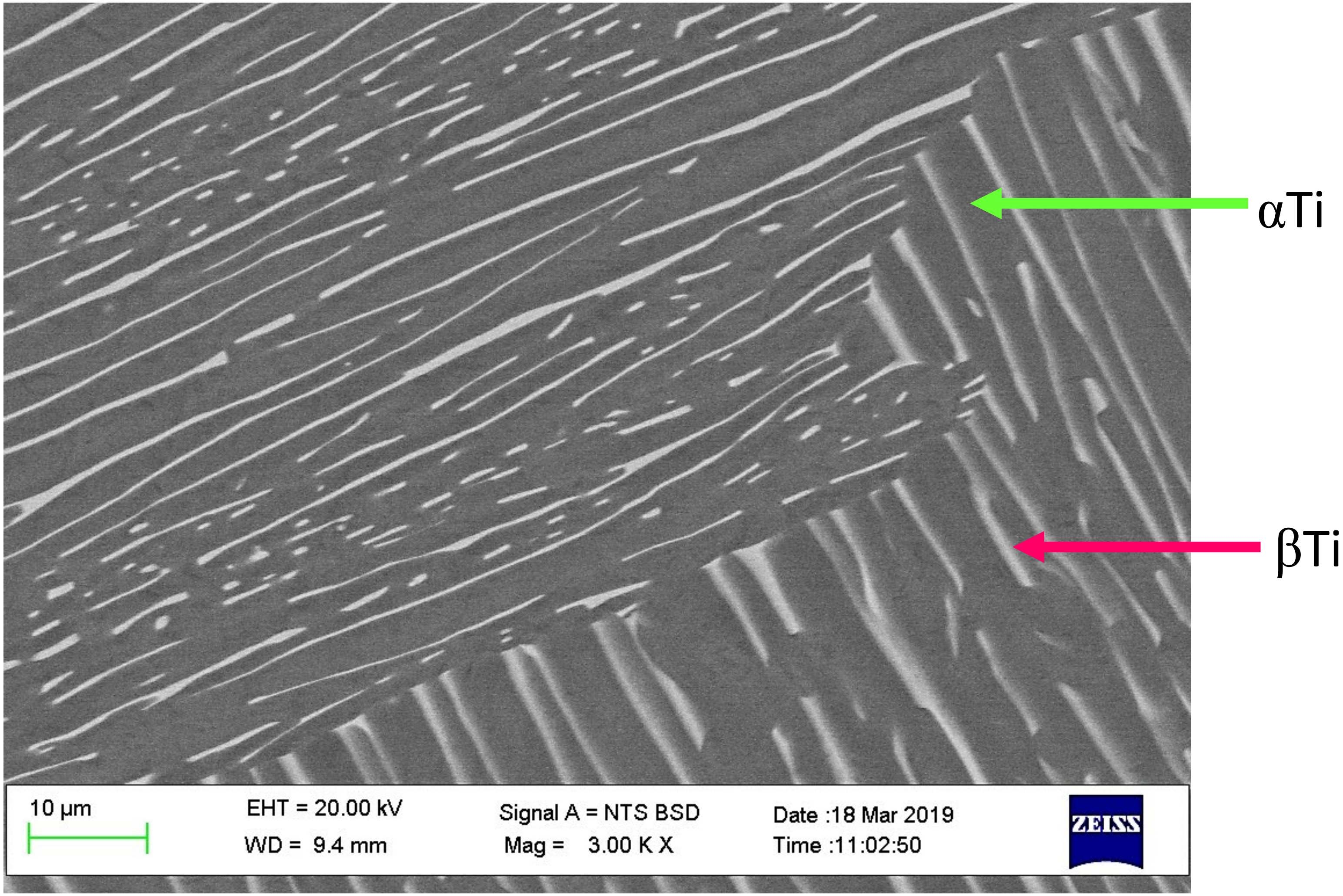
0 wt% Cu	1 wt% Cu	3 wt% Cu	5 wt% Cu	10 wt% Cu
βTi, αTi	βTi, αTi and $CuTi_3$	βTi, αTi and $CuTi_3$	βTi, αTi, $CuTi_3$ and $CuTi_2$	βTi, αTi, $CuTi_3$ and $CuTi_2$



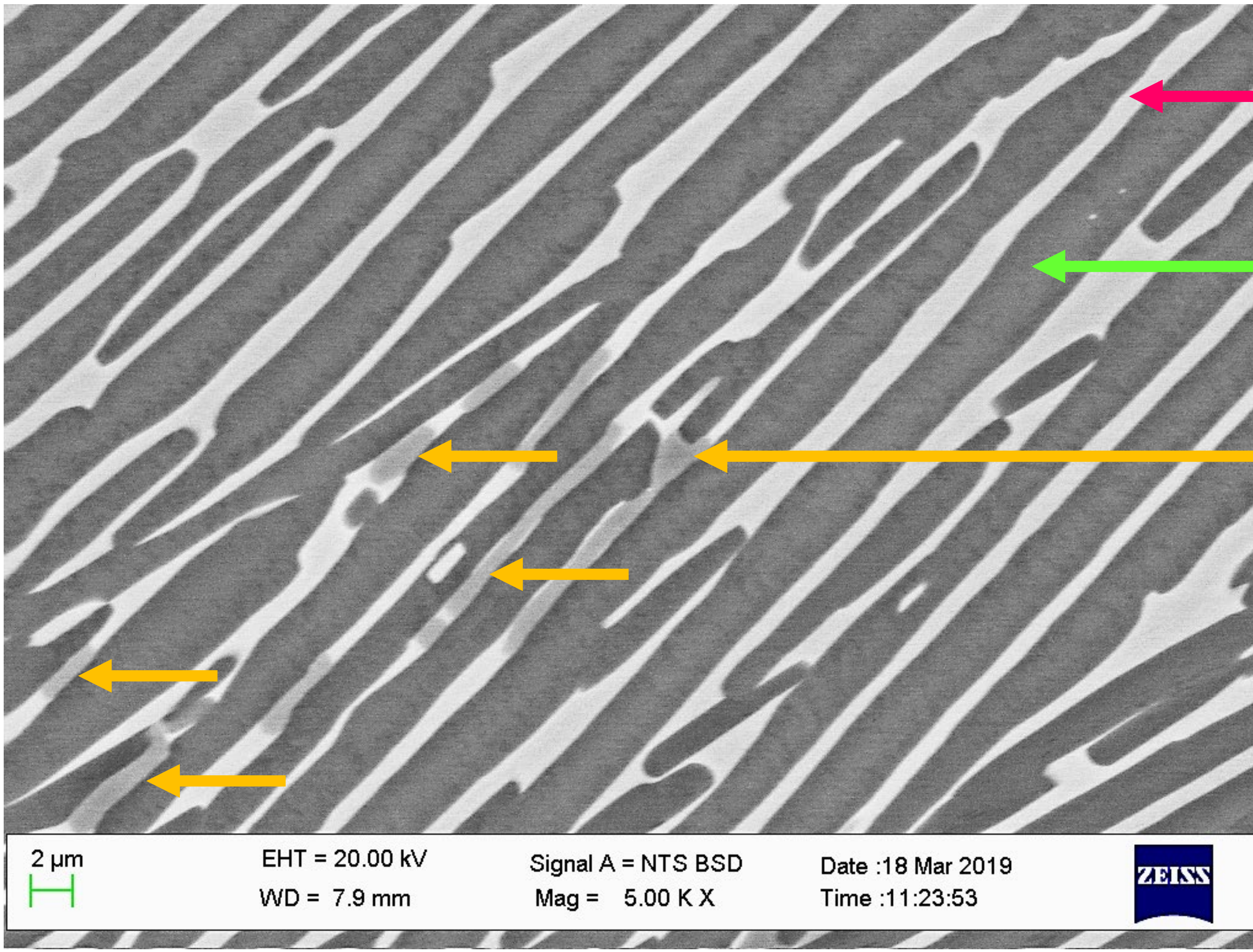
TNTZ


αTi
βTi
10 µm
EHT = 20.00 kV
WD = 8.1 mm
Signal A = NTS BSD
Mag = 3.00 K X
Date :18 Mar 2019
Time :10:25:03
ZEISS

1% Cu


αTi
βTi
10 µm
EHT = 20.00 kV
WD = 9.4 mm
Signal A = NTS BSD
Mag = 3.00 K X
Date :18 Mar 2019
Time :11:02:50
ZEISS

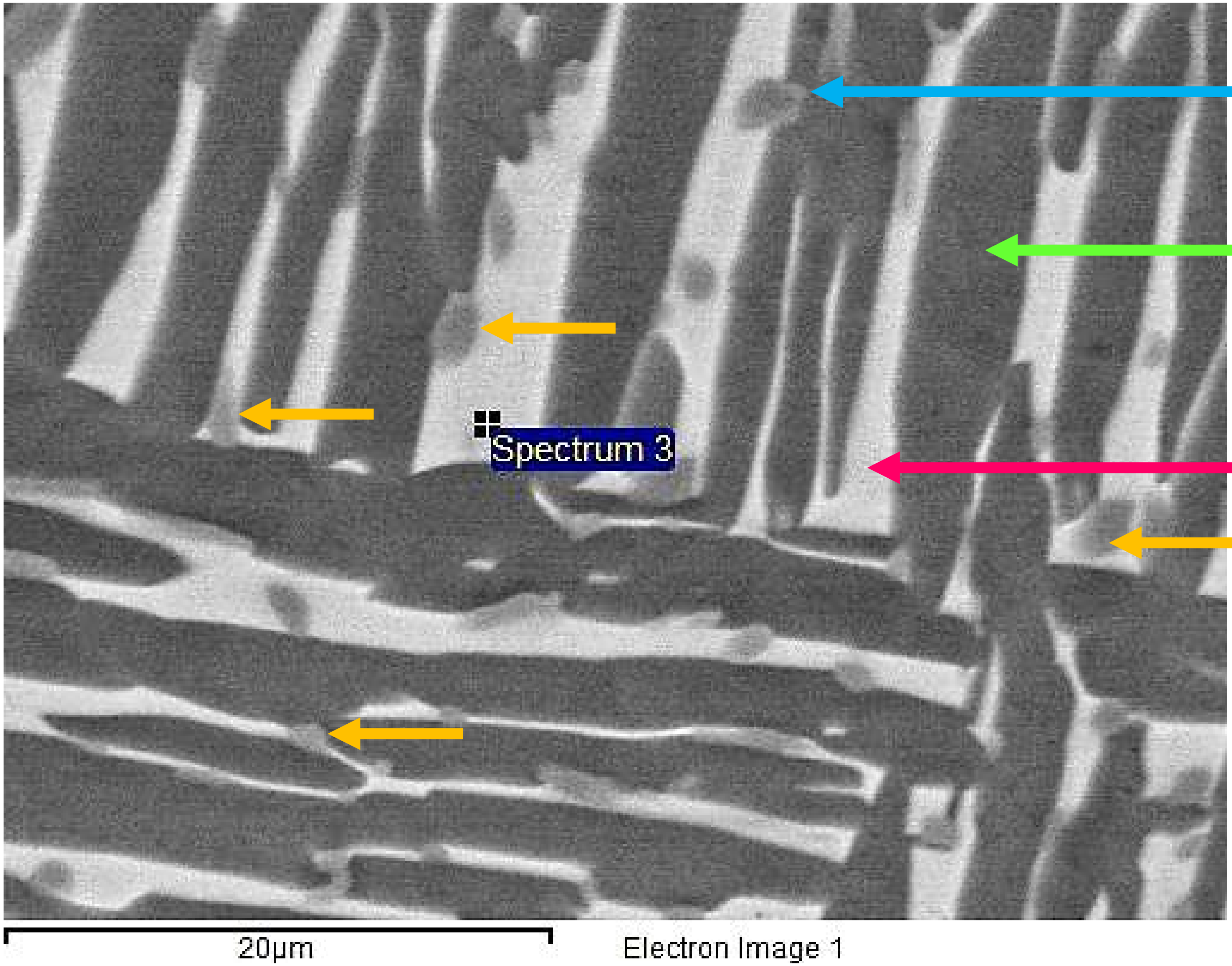
3% Cu



	at.%
Ti	70.0
Zr	1.0
Nb	0.1
Ta	0.8
Cu	**28.1**

i) Canale, Servant (2002) Z. Metallk. 93, 273

5% Cu



Light edges: $CuTi_2$ around $CuTi_3$?

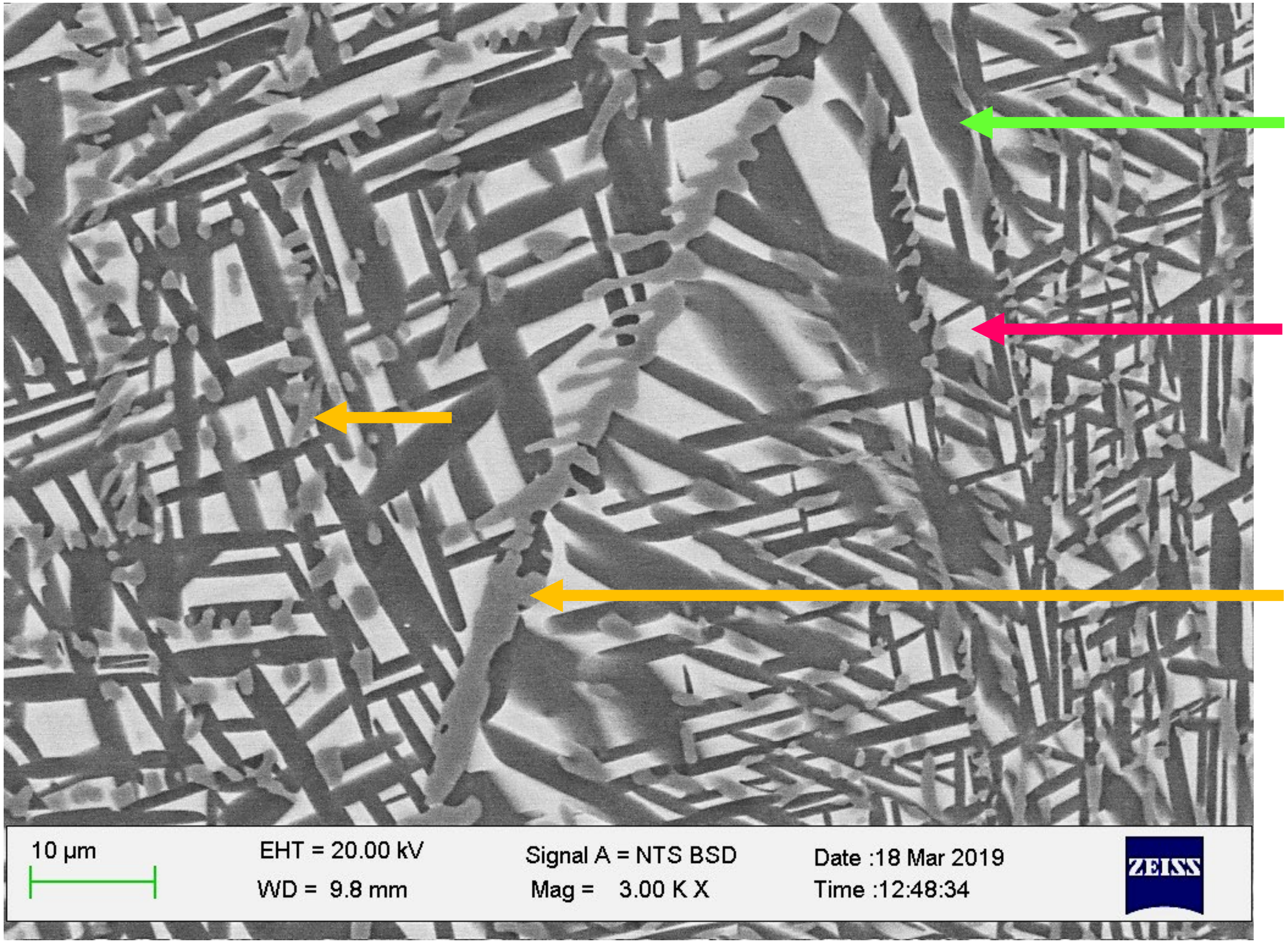
αTi

βTi

$CuTi_3$

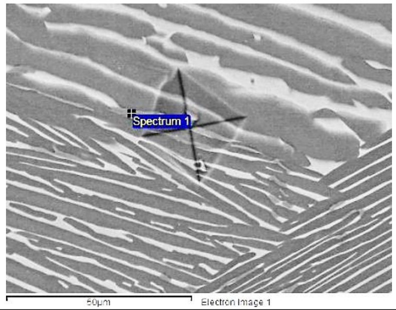
	at.%
Ti	76.0
Zr	1.0
Nb	0.1
Ta	1.6
Cu	**21.0**

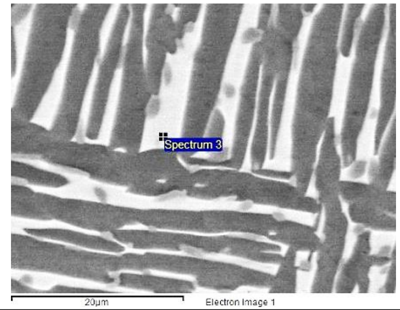
10% Cu



	at.%
Ti	**68.7**
Zr	0.8
Nb	0.1
Ta	0.6
Cu	**29.7**

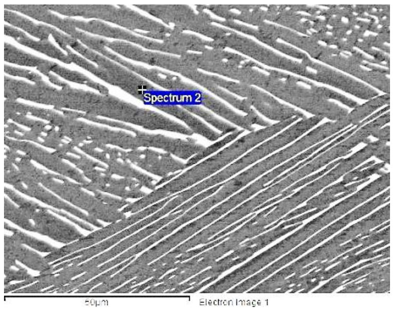
Hardness

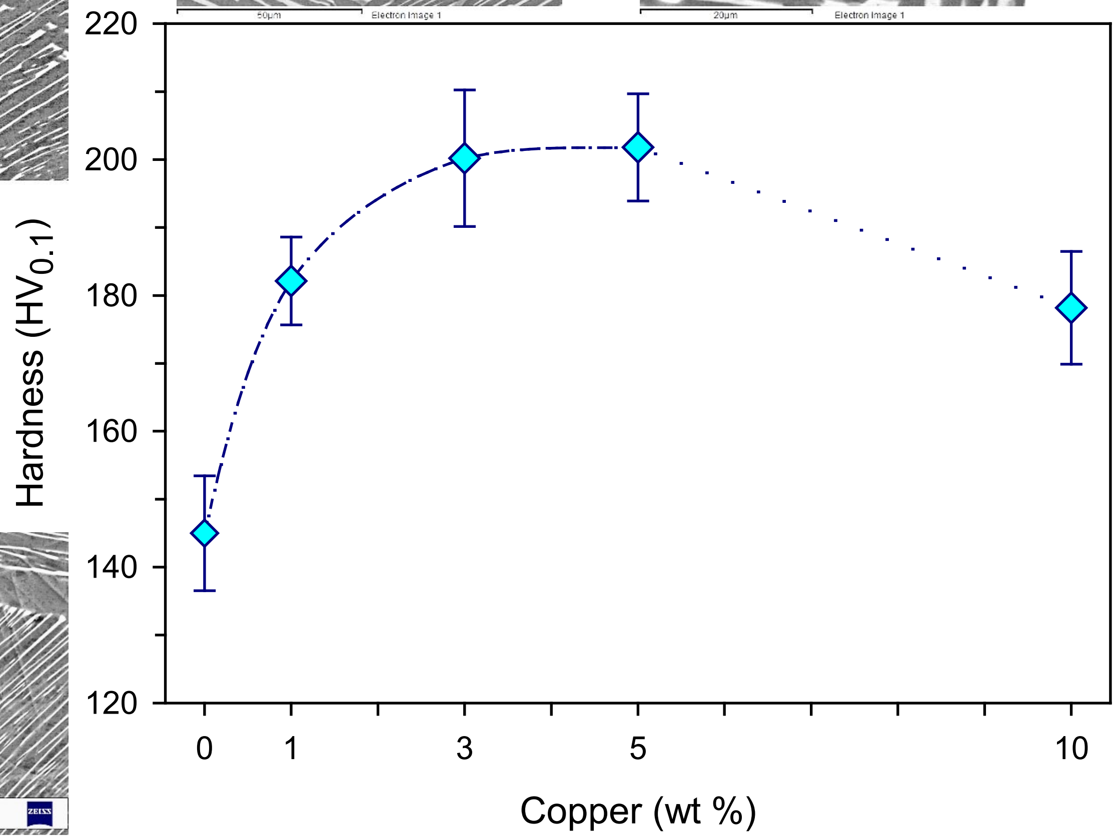




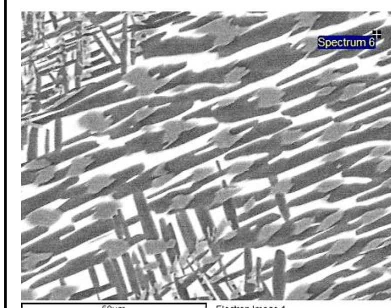
$CuTi_3 + CuTi_2$

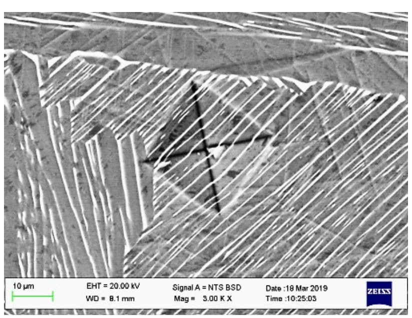
$CuTi_3 + CuTi_2$



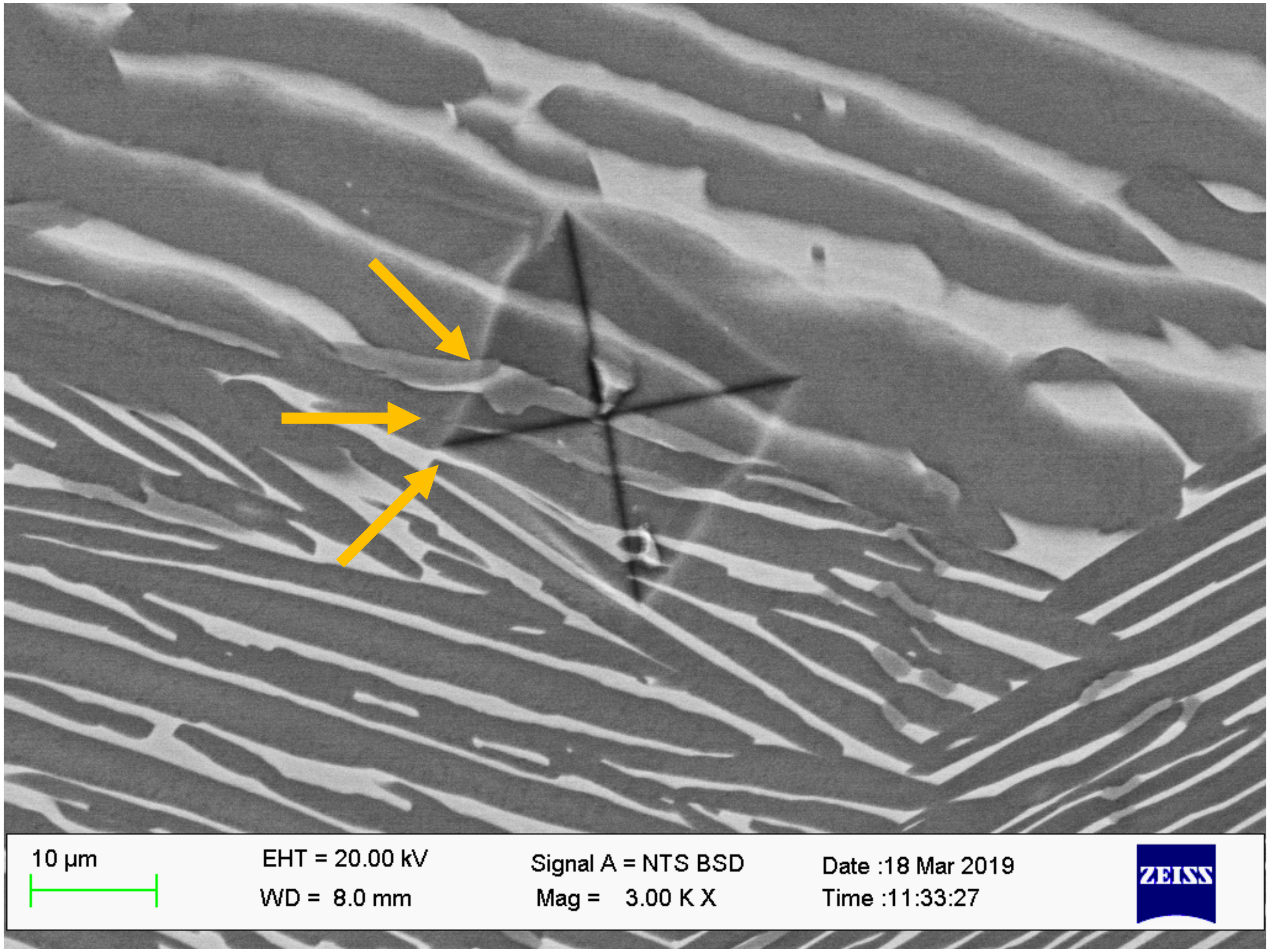


$CuTi_3$? $CuTi_2$





3 wt% Cu: harder phase



Conclusions

1. As-cast alloys of TNTZ + 0 – 3% Cu: Lamellar structure

2. TNTZ + 3% Cu: hard Ti_3Cu in βTi phase.

3. TNTZ + 5% Cu: 'Broken' lamellar αTi.
   More visible Ti_3Cu / Ti_2Cu precipitates, mostly in βTi phase.

4. TNTZ + 10% Cu: Lenticular αTi, βTi with globular Ti_2Cu or Ti_3Cu

5. Hardness increases with 1-3% Cu, then decreases slightly with 10% Cu.

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