MICROSTRUCTURAL ANALYSIS OF Ti-Cu ALLOYS FOR DENTAL APPLICATIONS

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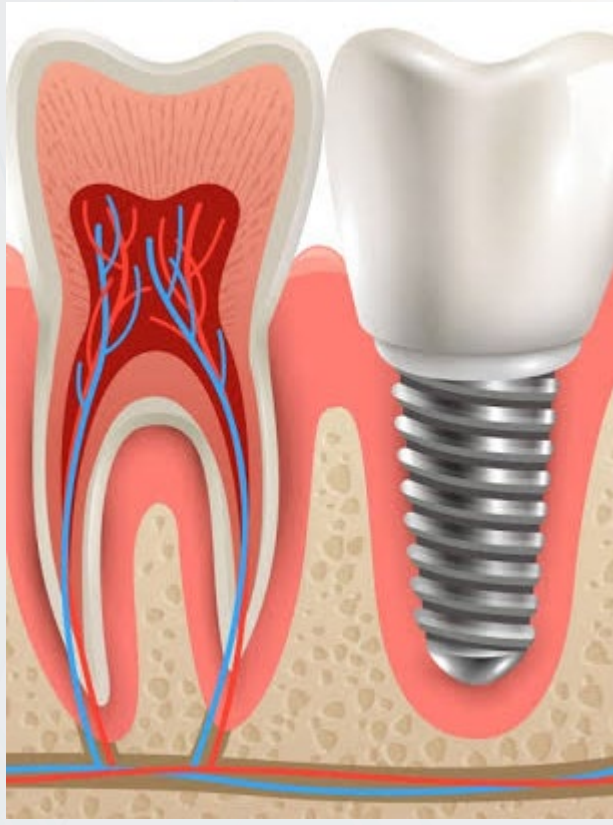
CHEMET SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

Background

- Titanium and titanium alloys have been widely used.
- An ideal bone implant material has:
  - Excellent corrosion resistance.
  - Acceptable strength.
  - High resistance to wear.
  - Modulus of elasticity similar to bone.
  - A biocompatible chemical composition.



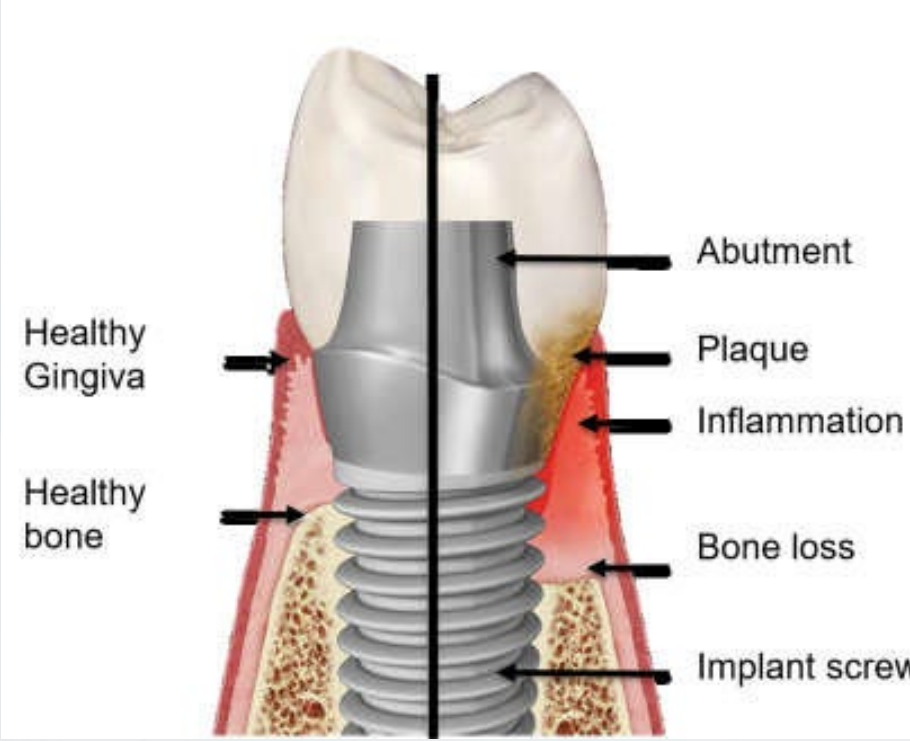
1. Ananth, H., Kundapur, V., Mohammed, H., Anand, M., Amarnath, G., & Mankar, S. (2015). A Review on Biomaterials in Dental Implantology. International Journal of Biomedical Science, 11(3), 113-120.
2. https://www.woodlanedentistry.com/services/cosmetic-dentistry/dental-implants.

Background

- The bacteria colonisation & subsequent accumulation of biofilms can cause localised gradients of:
  - Dissolved oxygen
  - pH ↓
  - Corrosive anions

Bacteria Influenced corrosion

- Corrosion trigger peri-implantitis.



1. Souza, j.C.M.,Ponthiaux ,P.,Henriques, M.,Oliveira, R.,Teughels,W.,Celis,J.P and Rocha,L.A. (2013). Corrosion behaviour of titanium in the presence of Streptococcus mutans, J. Dent. 41, 528 534.
2. Uhlmannab, et al., (2019). Application of laser surface nanotexturing for the reduction of peri-implantitis on biomedical grade 5 Ti-6Al-4V dental abutments. Research gate

Background

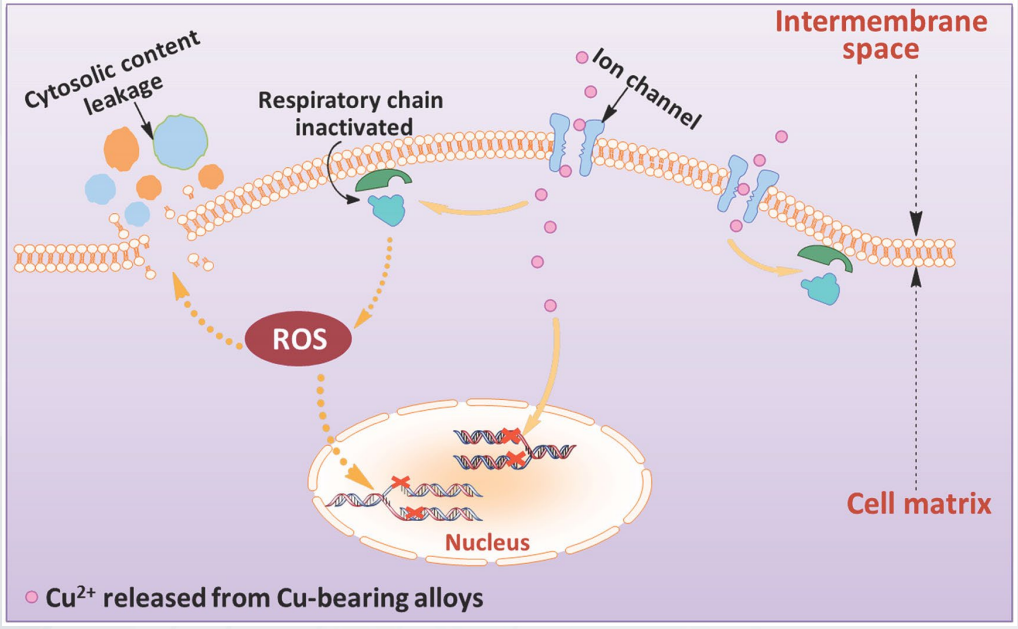
Cu ions kill at a distance from the surface.

- Produce reactive oxygen species (ROS).
  - ROS rupture the cell wall of bacteria.

    "Fenton chemistry reaction"

    $Cu^{+} + H_2O_2 \longrightarrow Cu^{2+} + OH^{-} + OH$

- The shape and size of Ti_2Cu phase.
- Heat treatment improves redistribution of copper and size of Ti_2Cu precipitates.



1. Mei Li, et al., (2016). Toward a Molecular Understanding of the Antibacterial Mechanism of Copper-Bearing Titanium Alloys against Staphylococcus aureus, Adv. Healthcare Mater.. 5, 557–566.
2. https://www.deardoctor.com/articles/peri-implantitis-can-cause-implant-failure.

Aim

Influence of copper on the corrosion and mechanical properties of Grade 4 titanium for biomedical applications.

- To assess the effect of the Ti_2Cu compound and its proportions on the corrosion resistance.
- To compare Ti-Cu alloys to the Grade 4 titanium.
- Microstructural analysis of Ti-Cu alloys for dental applications.

Experimental Procedure

Melting

- CP-Ti Grade 4 and SAE CA110 Copper
- Button arc melting of CP-Ti, Ti-15Cu, Ti-25Cu and Ti-47Cu alloys

Heat-treatment

Annealed @ 900°C water quenched

Materials Characterisation

- Chemical Analysis
  - JEOL 8230 Electron probe microanalyser microscope
- Phase Analysis
  - X-Ray diffraction (Bruker D8 Advance powder diffractometer)
- **Metallography**
  - DSX510 optical microscope

Prediction of Phases

- Thermo-Calc software

Corrosion Testing

- Electrochemical Testing

Experimental Procedure

Metallography

- Grinding
- Polishing
- Microstructures

Corrosion Testing

Electrochemical testing

- PDP

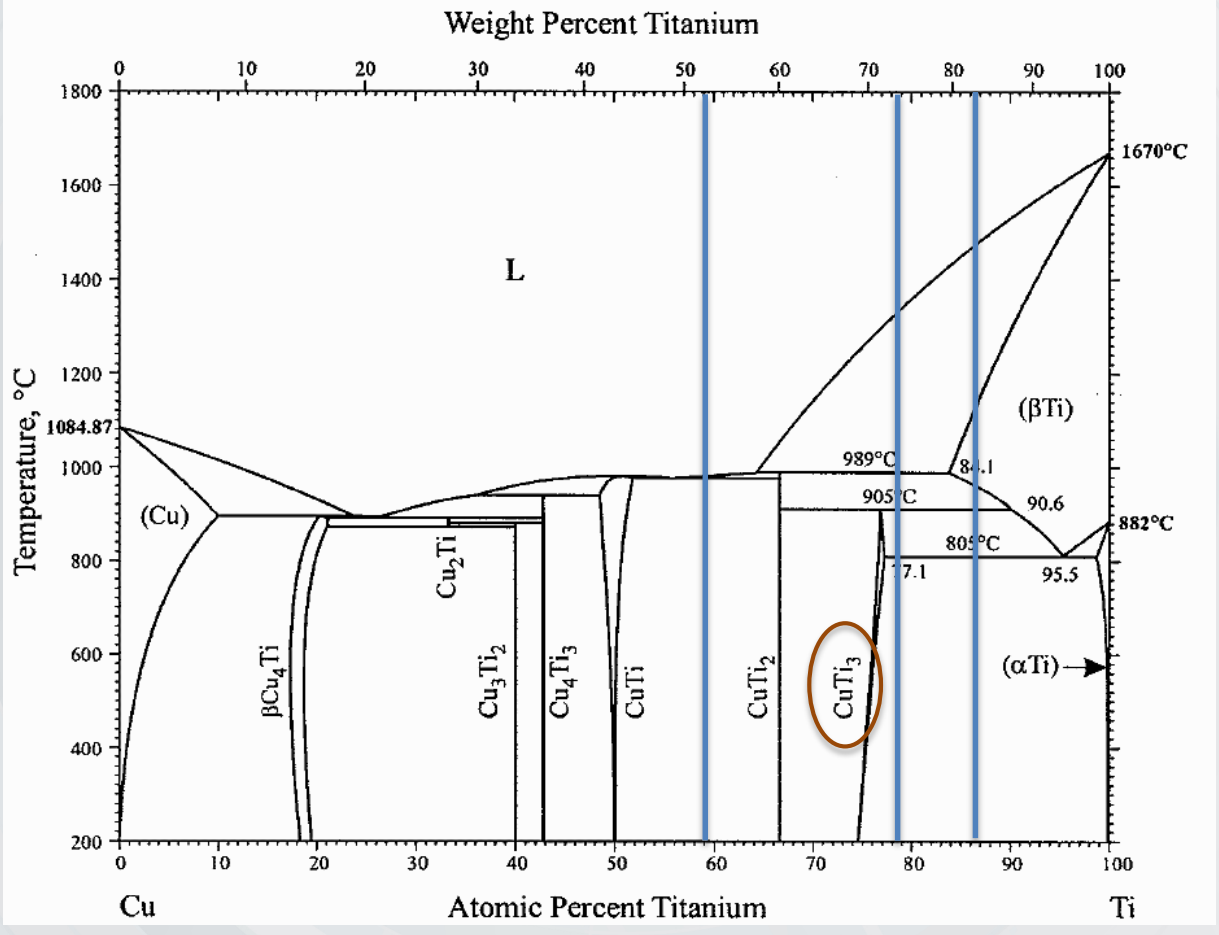
Solutions

- Simulating dental implant environment
  - 37°C (body temperature)
  - pH 7.4
  - Phosphate-buffered saline (PBS)
  - Nitrogen purging

Solution	Chemicals (g/L)			
PBS	NaCl	KCl	Na_2HPO_4	KH_2PO_4
	8.0	0.2	1.44	0.24

1. ASTM G5-2013 Standard Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements.

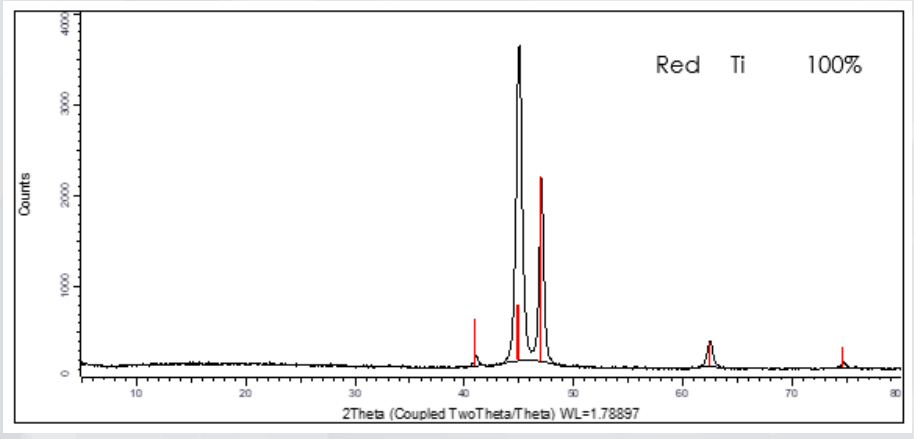
Thermo-Calc



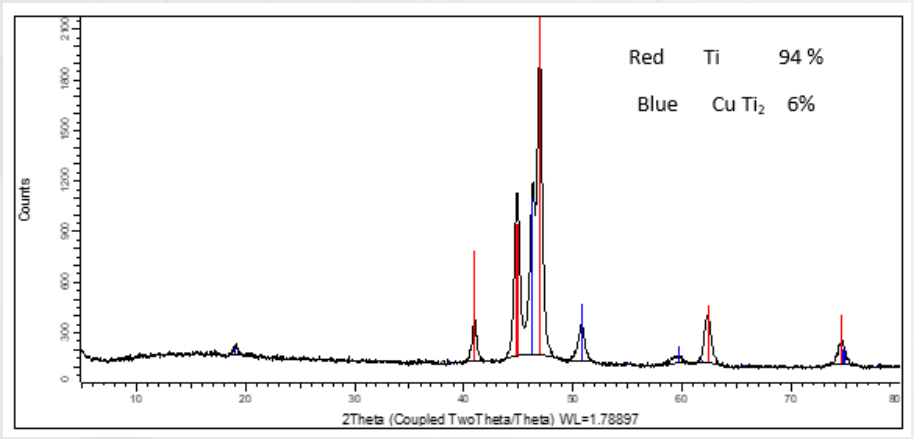
Alloys	Phases
CP Ti	α Ti and β Ti
Ti-15Cu	α Ti, β Ti and Ti_2Cu
Ti-25Cu	α Ti, β Ti and Ti_2Cu
Ti-47Cu	Ti_2Cu and TiCu

1. Okamoto, H. (2002). Cu-Ti (Copper-Titanium). *Journal of Phase Equilibra, 26*(3), 549-550.

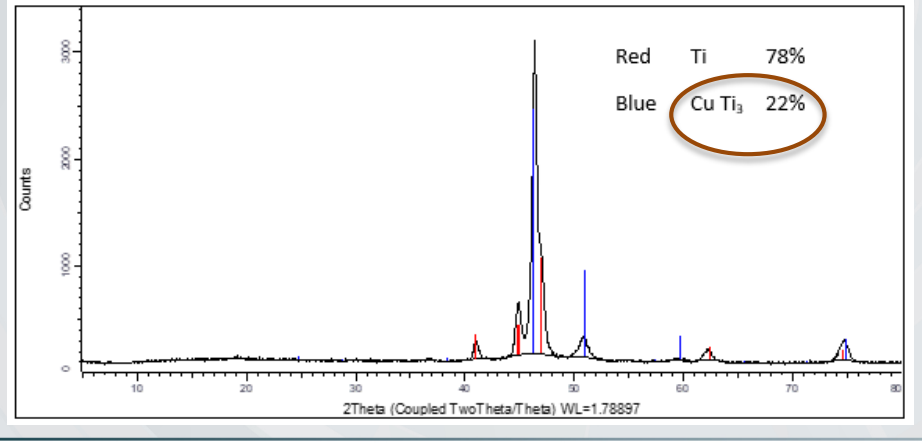
XRD_As-Cast



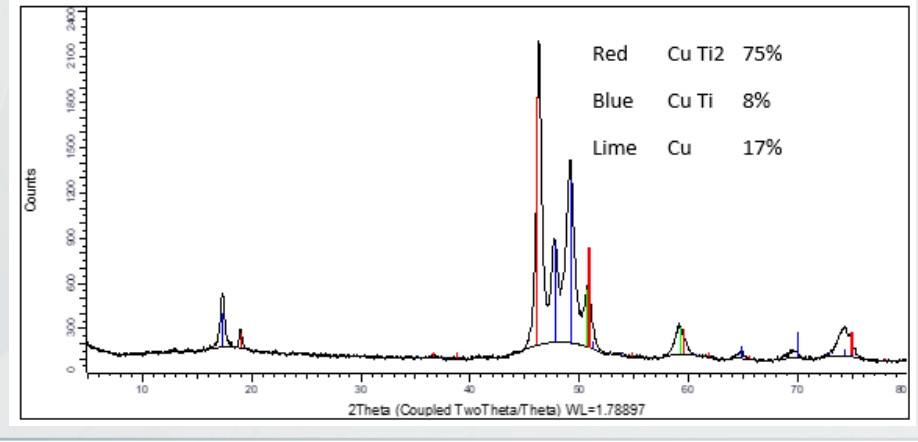
CP-Ti



Ti-15Cu

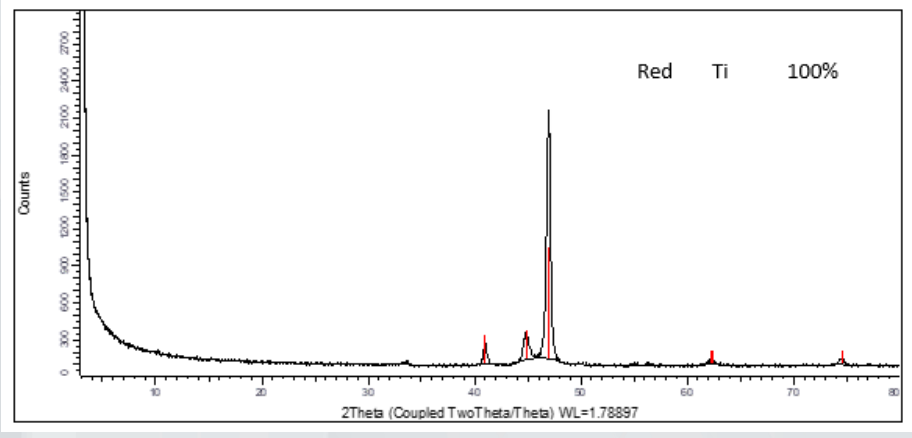


Ti-25Cu

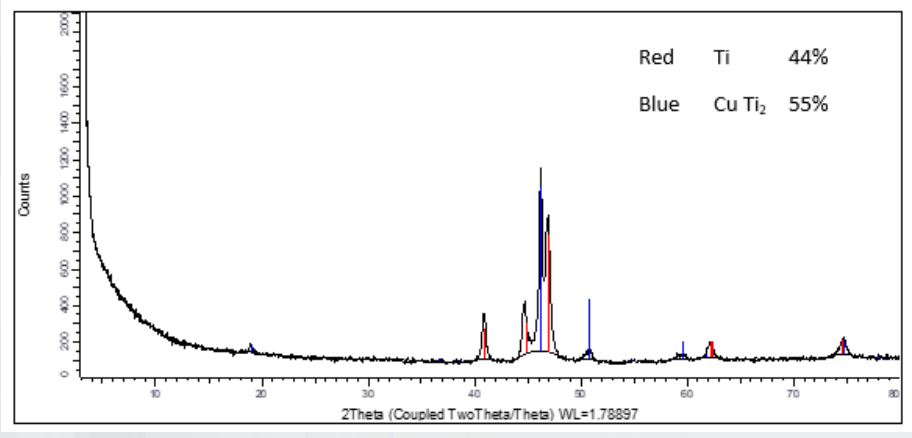


Ti-47Cu

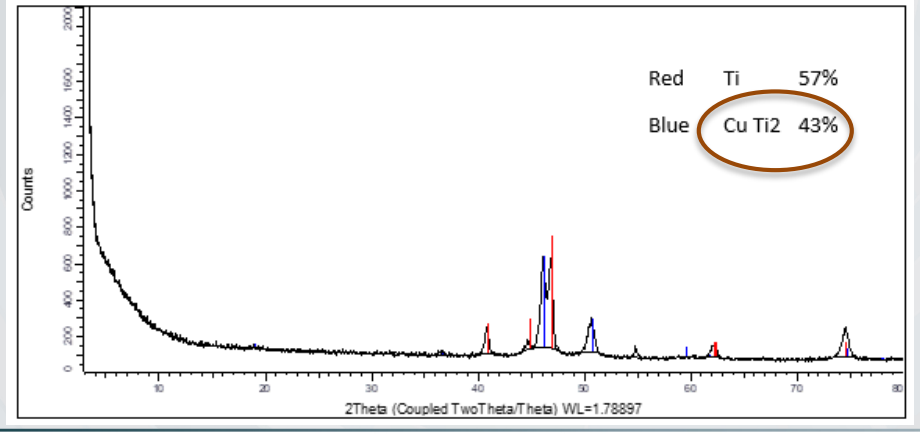
XRD_Annealed



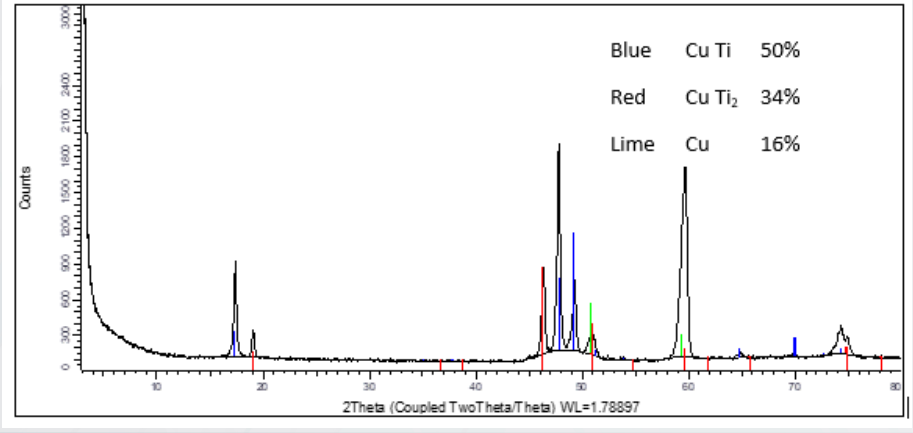
CP-Ti



Ti-15Cu

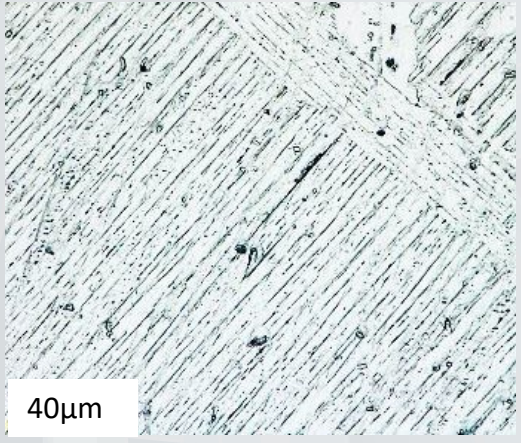


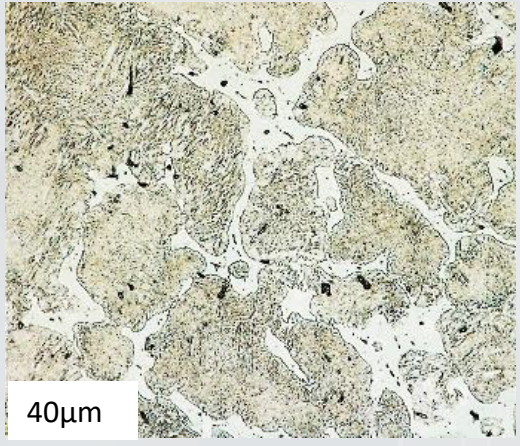
Ti-25Cu

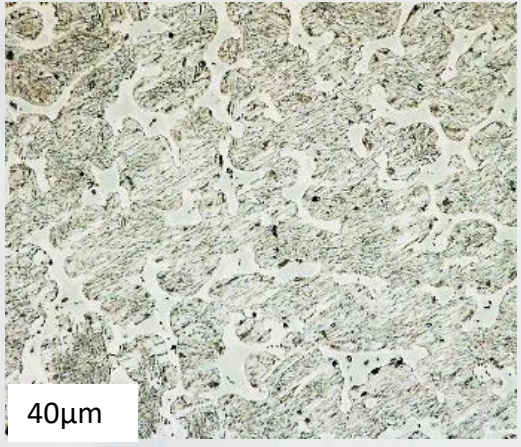


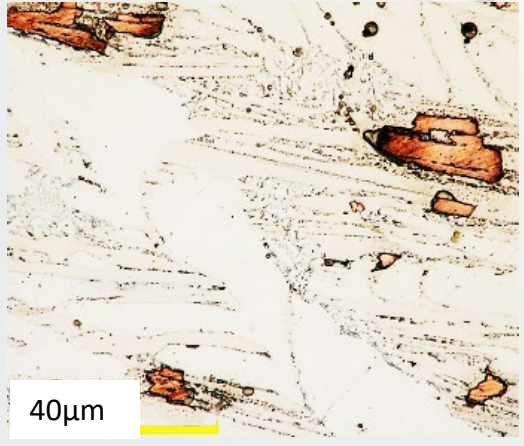
Ti-47Cu

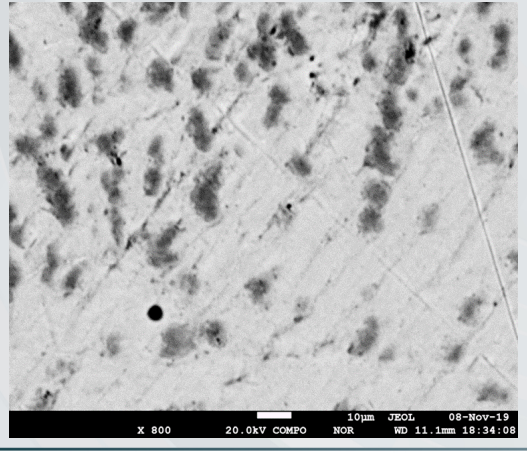
Micrographs_As-Cast

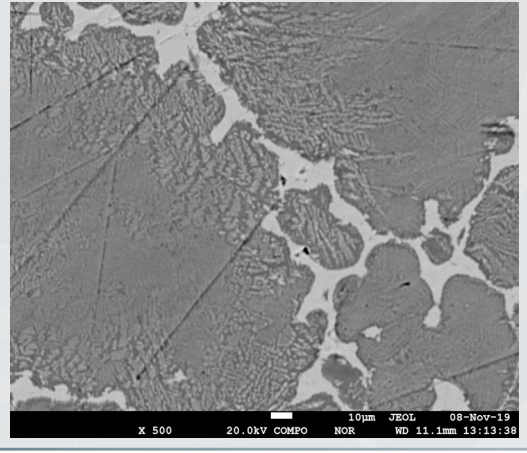


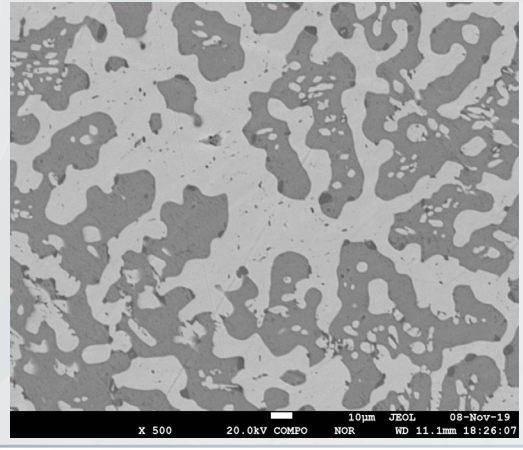


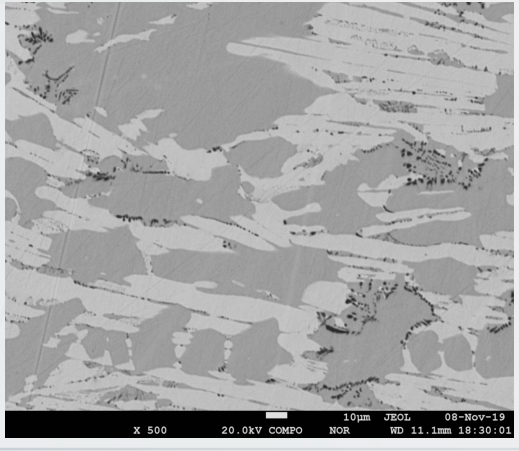






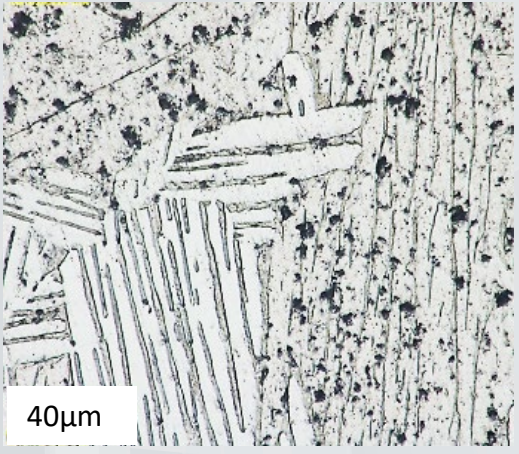


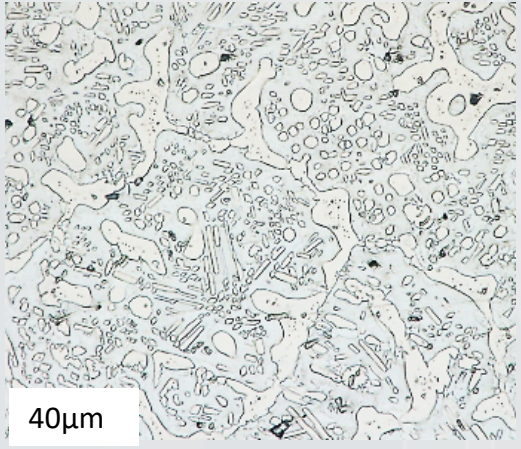


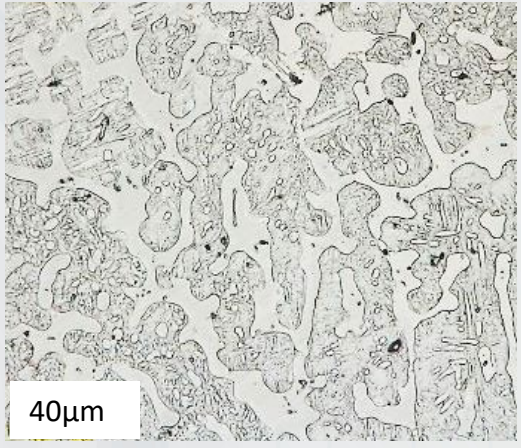


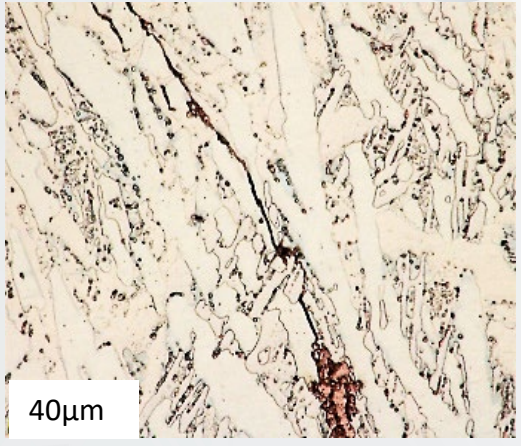
CP-Ti **Ti-15Cu** **Ti-25Cu** **Ti-47Cu**

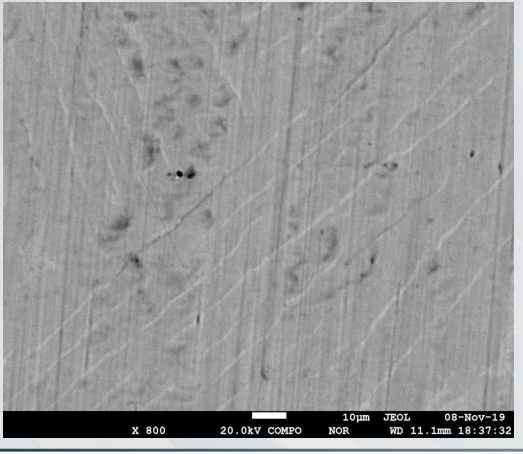
Micrographs_Annealed

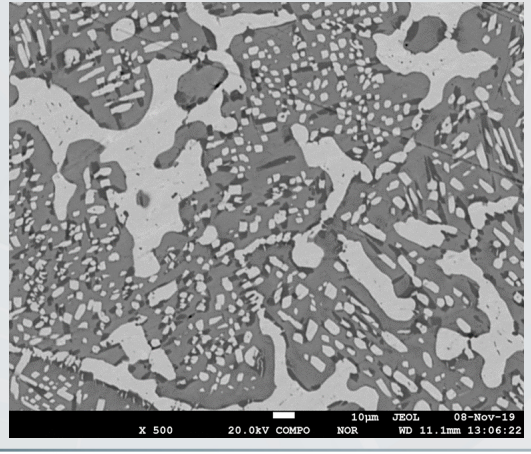


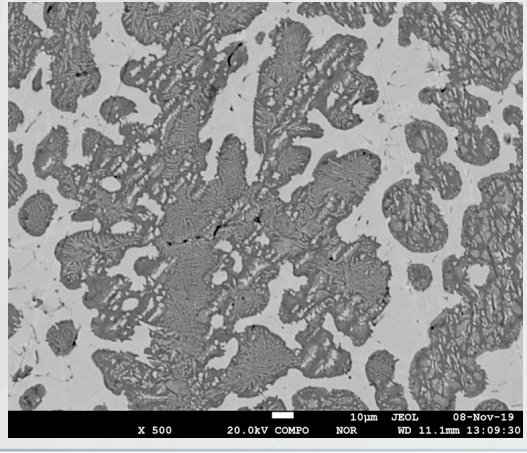


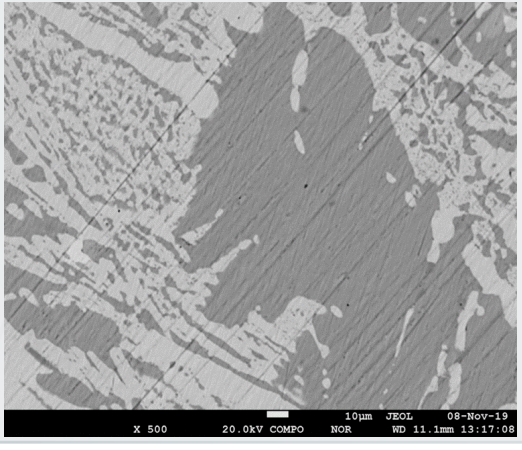






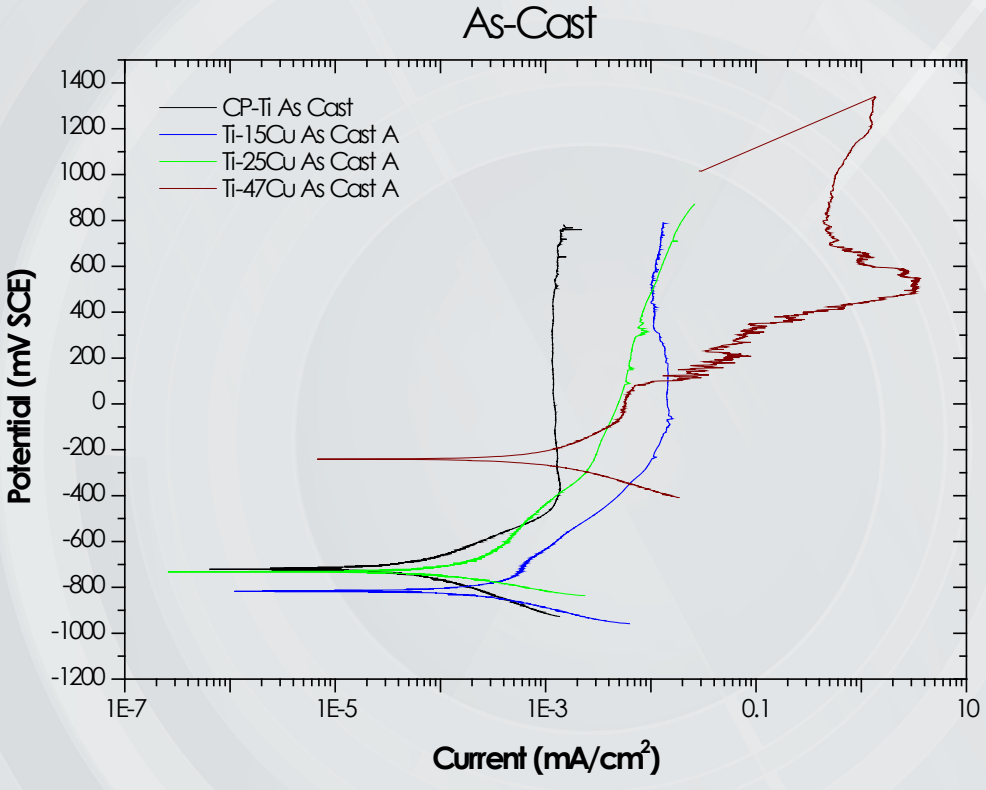


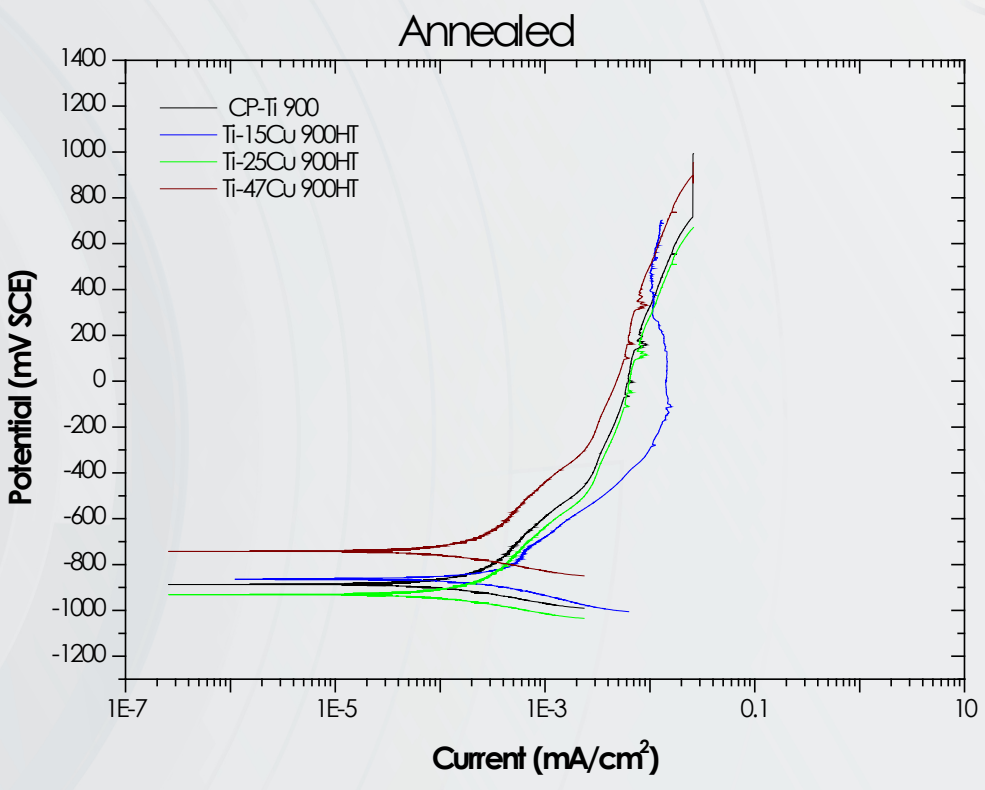




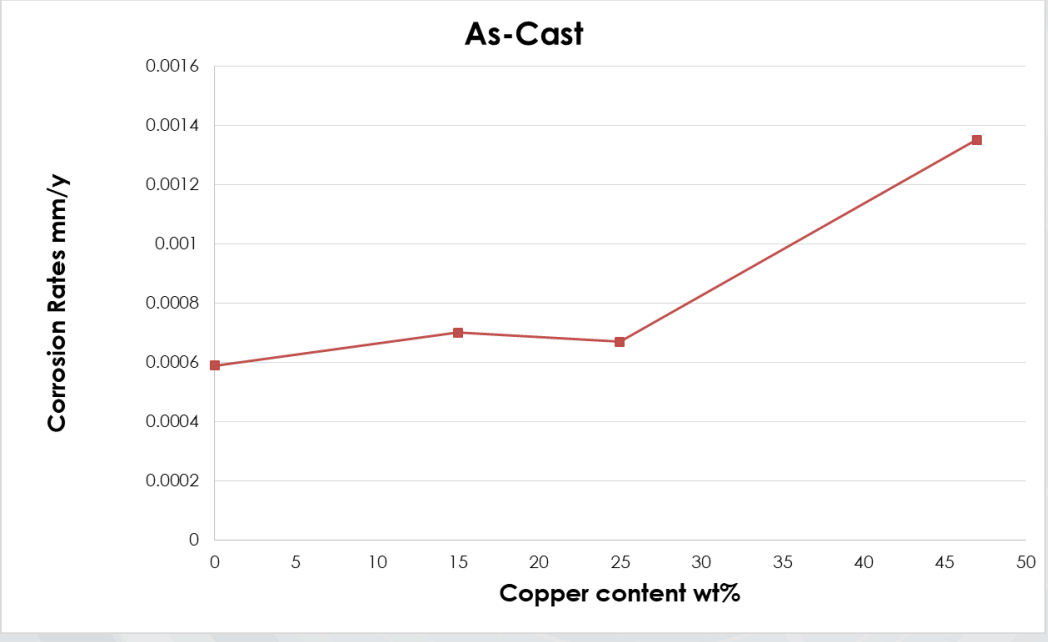
CP-Ti **Ti-15Cu** **Ti-25Cu** **Ti-47Cu**

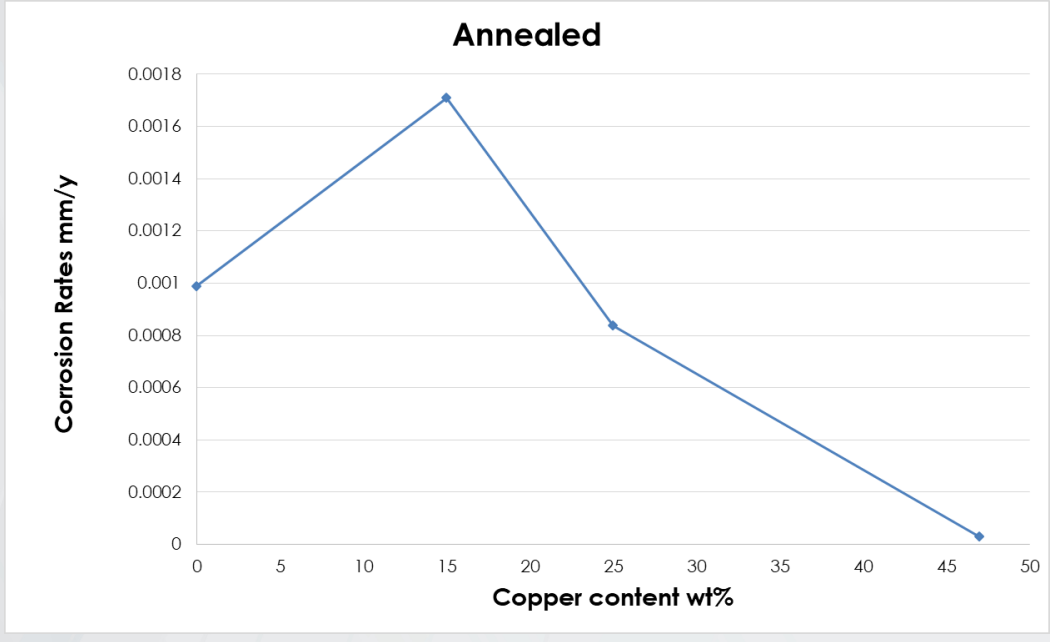
Potentiodynamic polirisation test





Potentiodynamic polirisation test





Conclusions

Thermo-Calc:

Predicted only equilibrium α, β & Ti_2Cu.

XRD:

Showed Ti_3Cu in Ti-25Cu instead of Ti_2Cu in the as-cast condition and not after annealing.

Microstructures:

- CP-Ti consisted of α lamellar Ti microstructure.
- Ti-15Cu and Ti-25Cu consisted of eutectoid α Ti and Ti_2Cu.
- Ti-47Cu consisted of a dual phase structure Ti_2Cu and TiCu with some metallic copper.

Conclusions

Potentiodynamic polirisation test:

- Copper decreased the corrosion resistance in the as-cast condition.
- Copper increased the corrosion resistance in the annealed condition.
- The corrosion rates are still within the acceptable range for biocompatibility of metallic implants < 0.02mm/y.

Acknowledgements

Thank You

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