國立中山大學

National Sun Yat-Sen University, Taiwan

Simulated body fluid electrochemical response of amorphous and nanocrystalline TiZr-based metallic glasses without reactive copper

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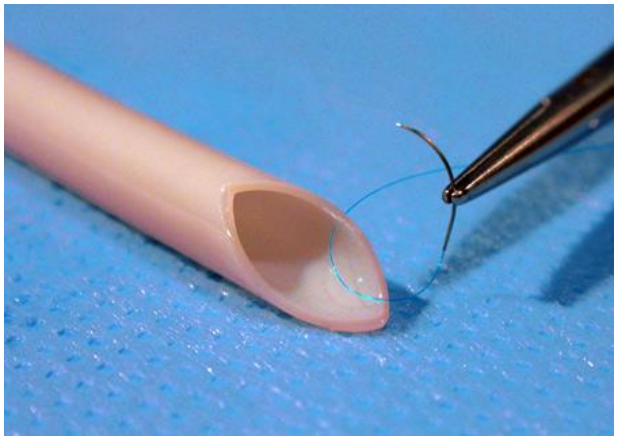
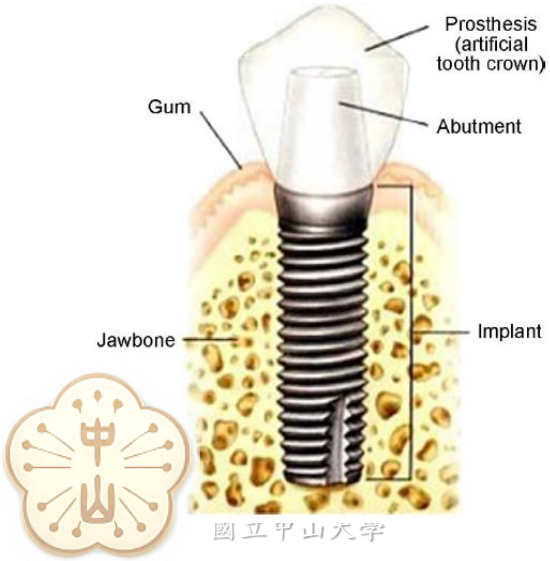
Outline

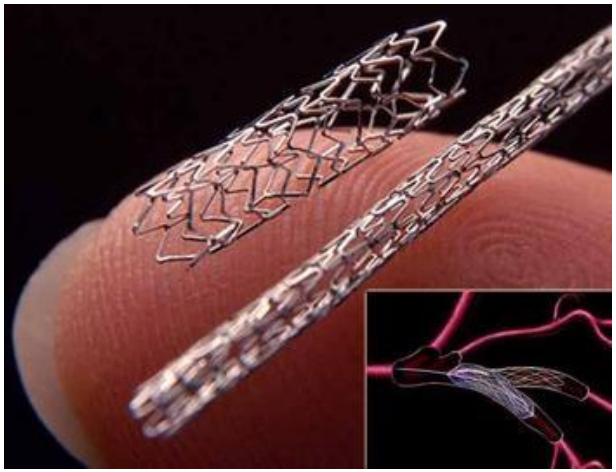
- **Introduction (Application, Motivation)**
- **Experimental procedure**
- **Results**
- **Conclusions**

Introduction

- **Four well-known major types of biomaterials:**
  1. **Metals**
  2. **Ceramics**
  3. **Polymers**
  4. **Biopolymers**







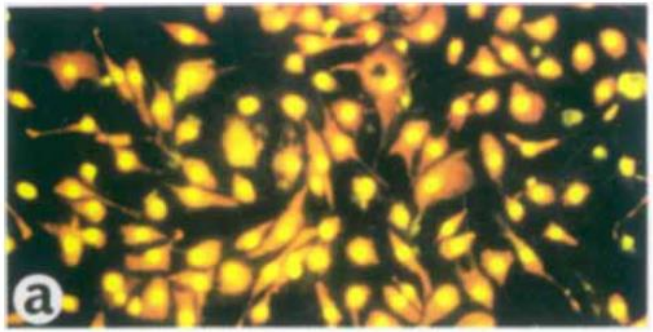
The disadvantages of general biomaterials for load-bearing applications

- **Polymers and ceramics are widely used in many biomedical applications, but they are not favorable for load-bearing applications due to their poor strength or fatigue endurance limit.**
- **Notwithstanding Ti-based and Co-based alloys are popular for metallic implants in early stages, their unsatisfactory wear resistance gives rise to the toxic debris after long-term uses.**

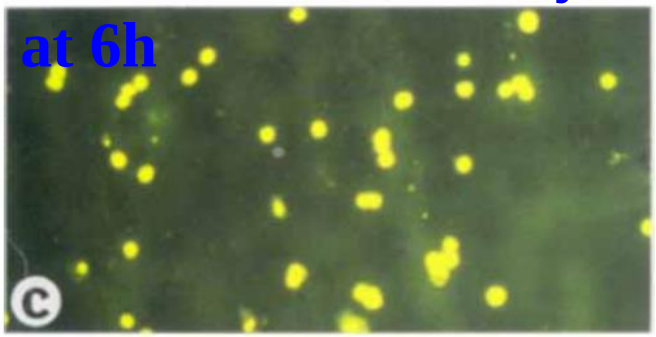
Superior properties of metallic glasses for biomedical applications

Characterization:

Outstanding corrosion resistance, high hardness and wear resistance, good biocompatibility and low Young's modulus

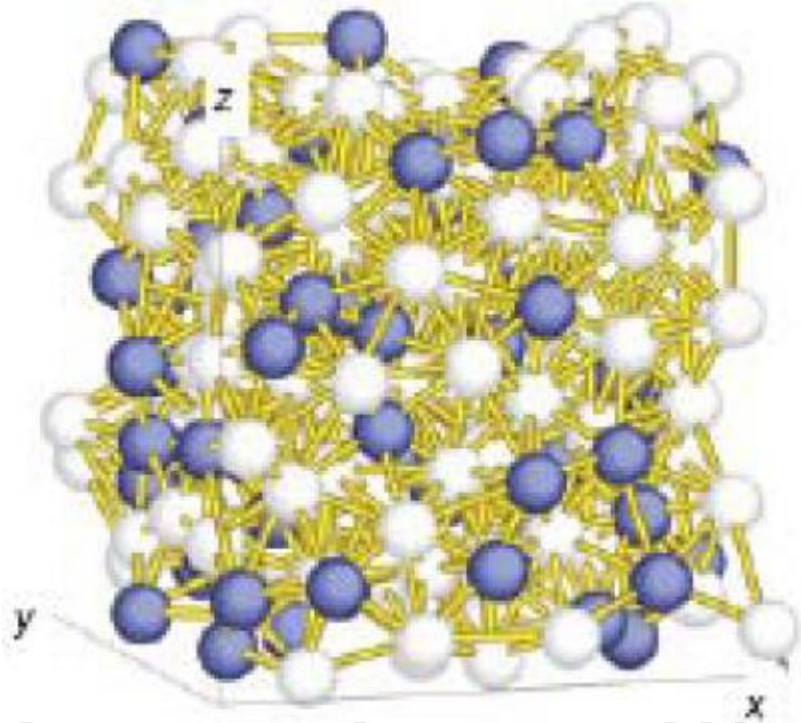


BAE + FCS on shiny side, at 6h



BAE on shiny side, at 6h

McAuslan et.al, J. Biomed. Mater. Res., 22 (1988) 905



Short range clusters would lead to presence of excess free volume.

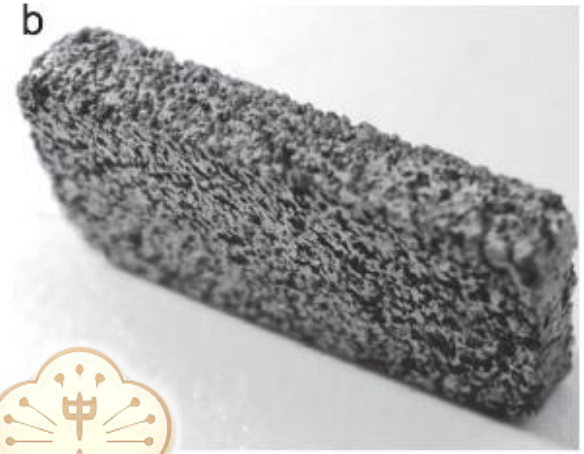
Hirata et.al, Nat. lett., 10 (2011) 28

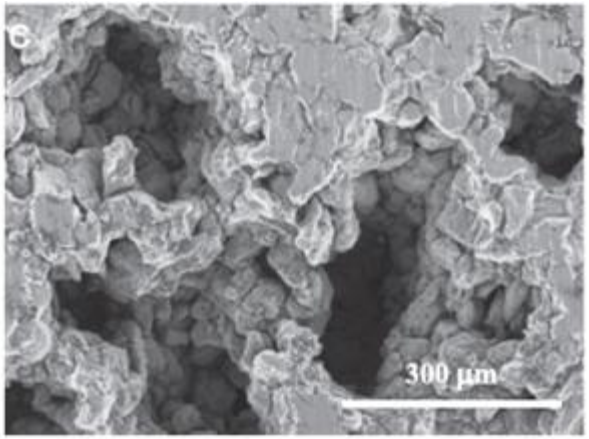
Various types of metallic glasses for biomedical applications

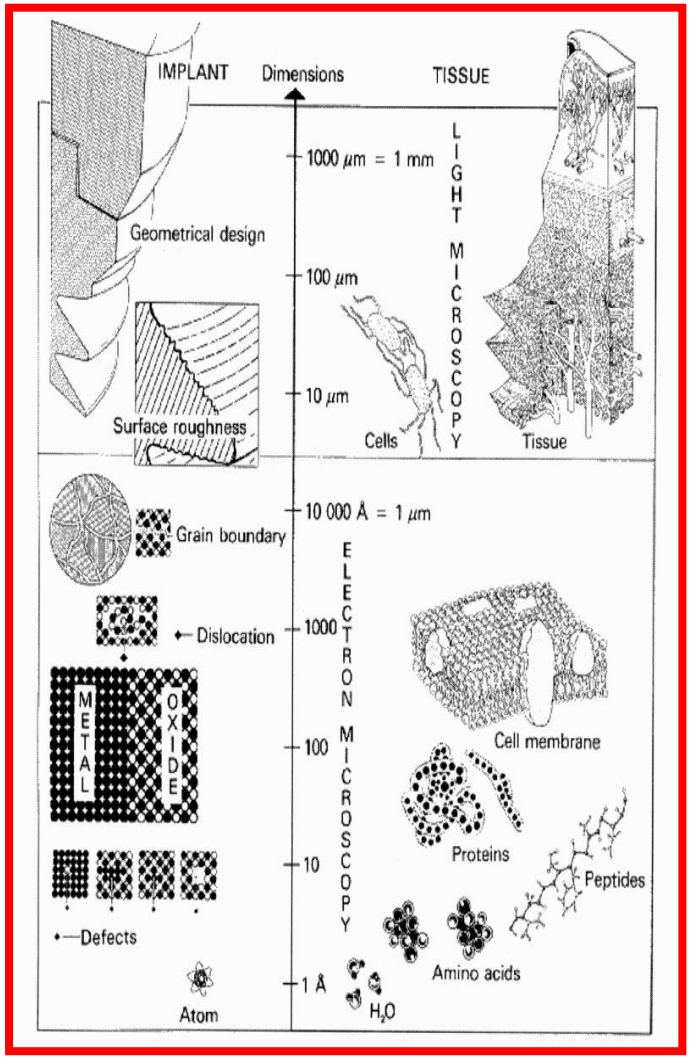
- **Thin film metallic glasses (TFMGs)**
- **Bulk metallic glasses (ribbons and rods)**

↓ **Powder sintering**

- **Porous metallic glasses foams (PMGFs)**

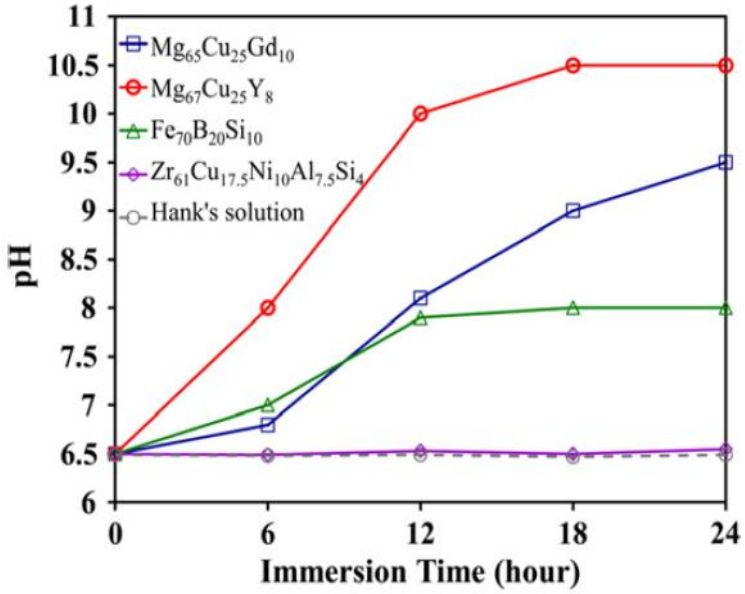


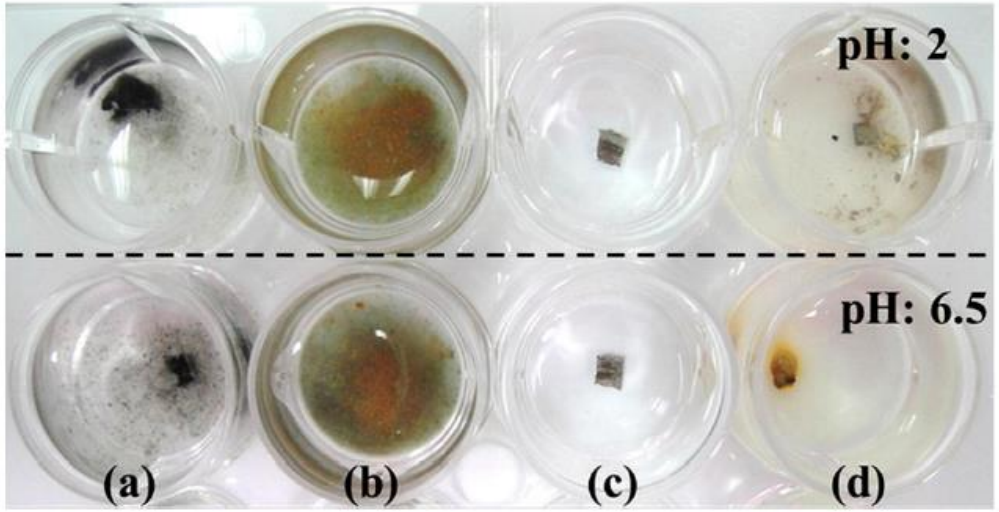




Li et al., Mater. Lett., 140 (2013) 7226

Immersion test of the Fe-based, Mg-based, and Zr-based metallic glasses under SBF





$Mg_{67}Cu_{25}Y_8$ $Fe_{70}B_{20}Si_{10}$

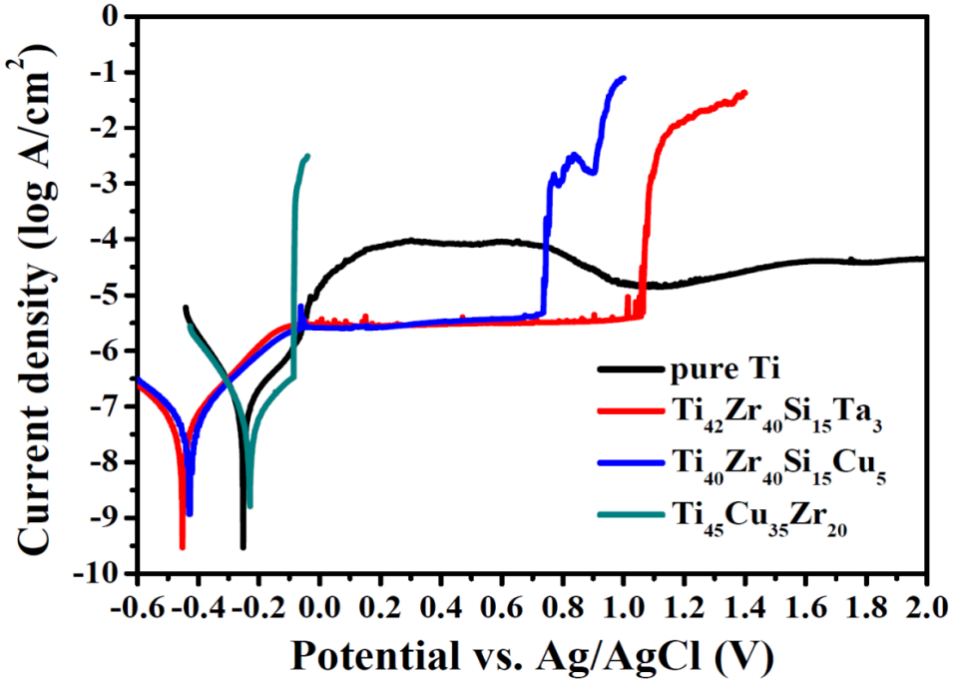
$Mg_{65}Cu_{25}Gd_{10}$ $Zr_{61}Cu_{17.5}Ni_{10}Al_{7.5}Si_4$

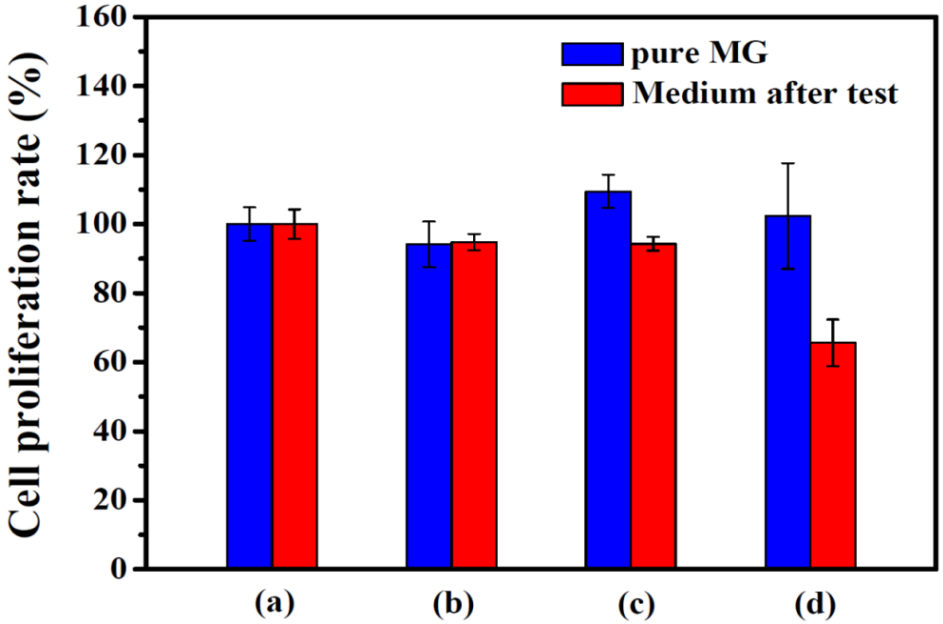
Zr-, Mg-, and Fe-based metallic glasses under SBF (NaCl, $NaHCO_3$, Na_2CO_3, KCl, $K_2HPO_4 \cdot 3H_2O$, $MgCl_2 \cdot H_2O$, $CaCl_2$ and Na_2SO_4)

Zr-based metallic glasses are potential materials for biomedical applications

Lin et al., Mater. Sci. Eng. C, 32 (2013) 2578

Electrochemical responses and biocompatibility of the TiZr-based metallic glasses

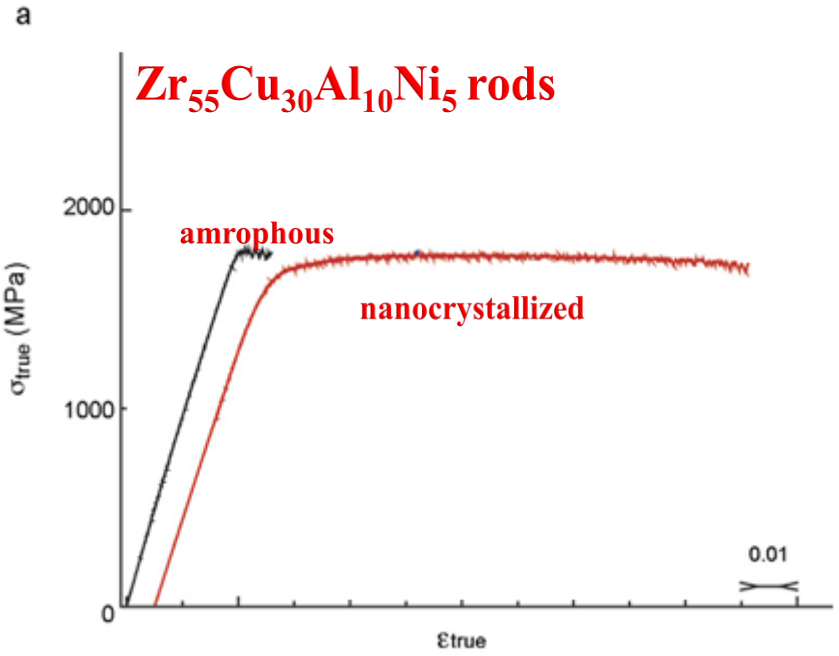




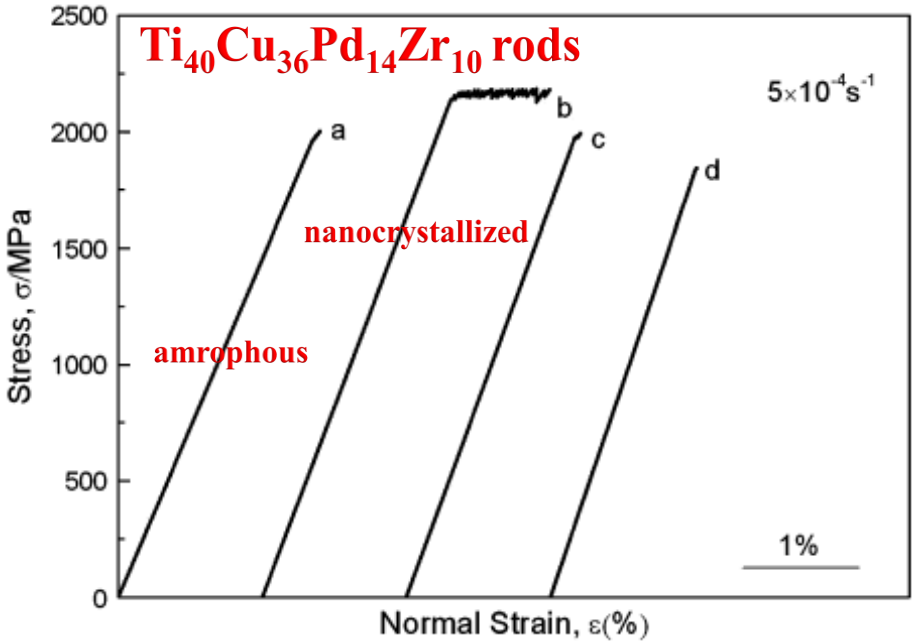
The lower Cu-containing and Cu-free TiZr-based metallic glasses show promising potentials for long-term immersion under the SBF.

Huang et al., Mater. Sci. Eng. C, (2014) submitted

High ductility of nanocrystallized metallic glasses



Van Steenberge et al., Mater. Sci. Eng. A, 491 (2008) 124



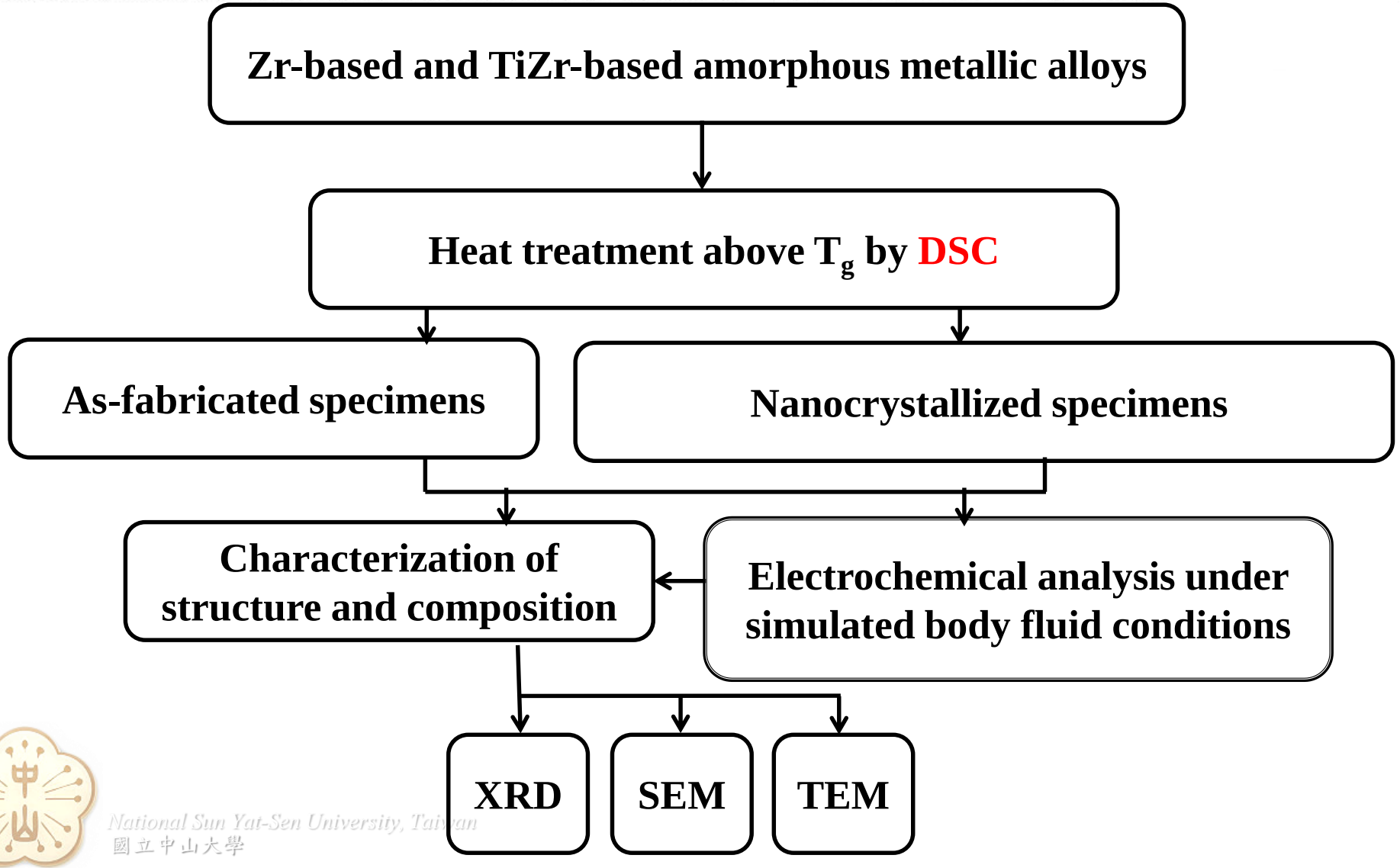
Qin et al., Intermetallics, 15 (2007) 1337

The nanocrystallized Zr-based and Ti-based metallic glasses possesses higher ductility than amorphous ones.

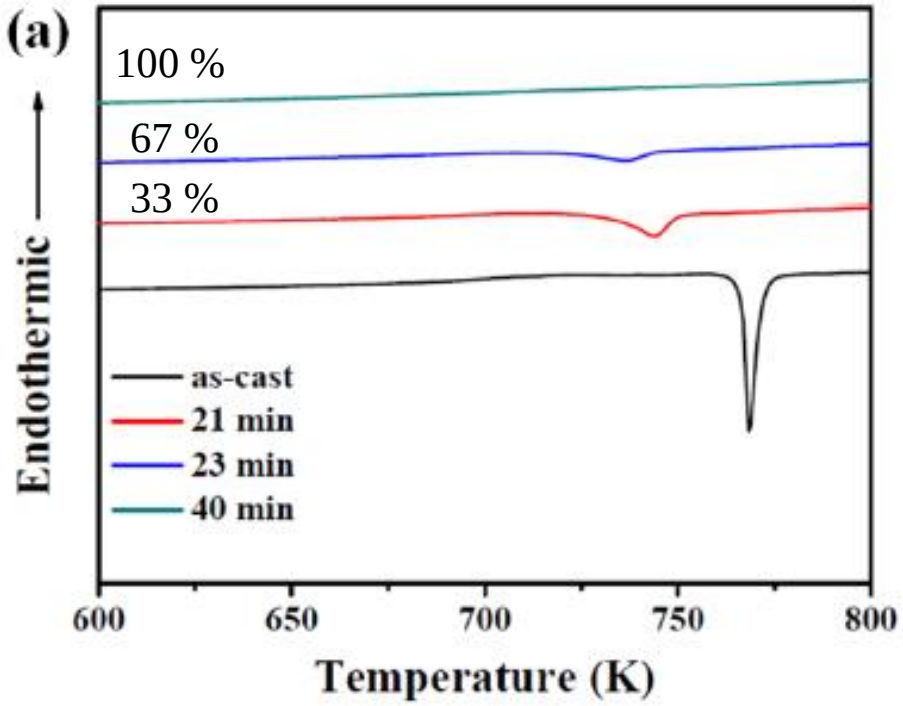
Motivation

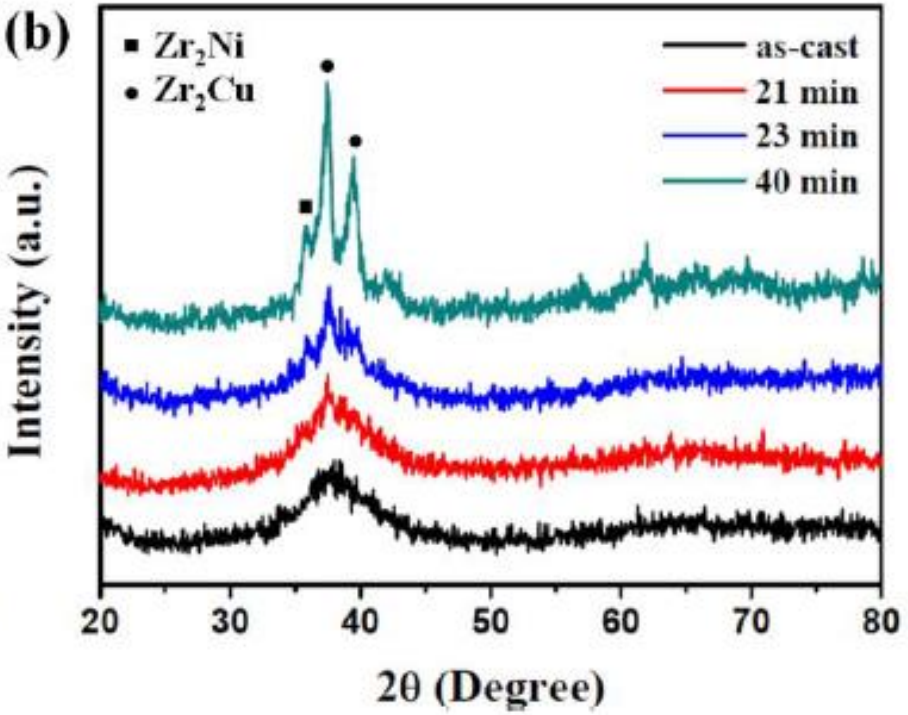
- The nanocrystallized metallic glasses own superior mechanical properties compared to amorphous one. But it is still not certain whether the metallic glass alloys in fully amorphous or partially nanocrystalline state would exhibit better bio-corrosion behavior.

Experimental procedure



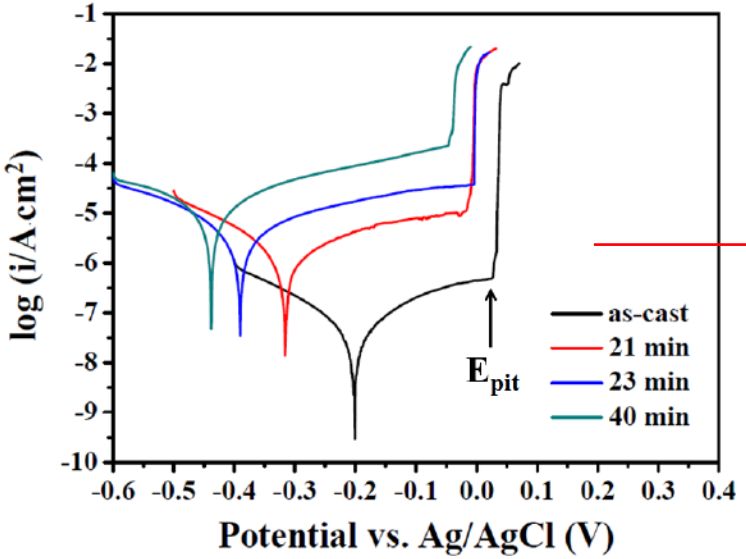
Heat treatment of $Zr_{53}Cu_{30}Ni_9Al_8$ metallic glasses

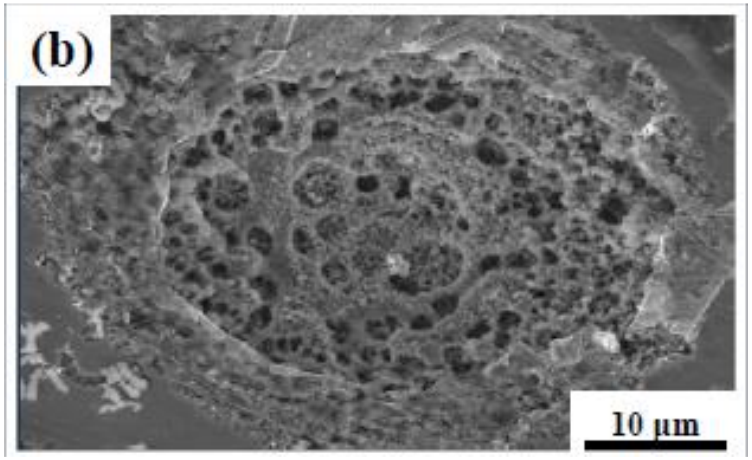




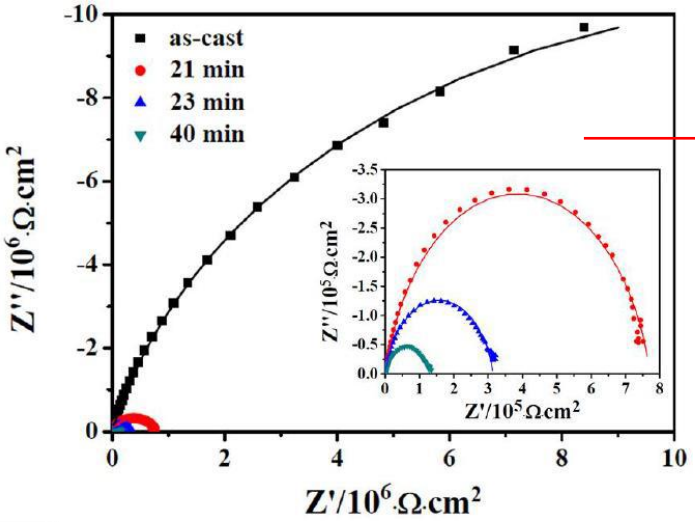
Huang et al., Mater. Sci. Eng. C, 33 (2013) 4183

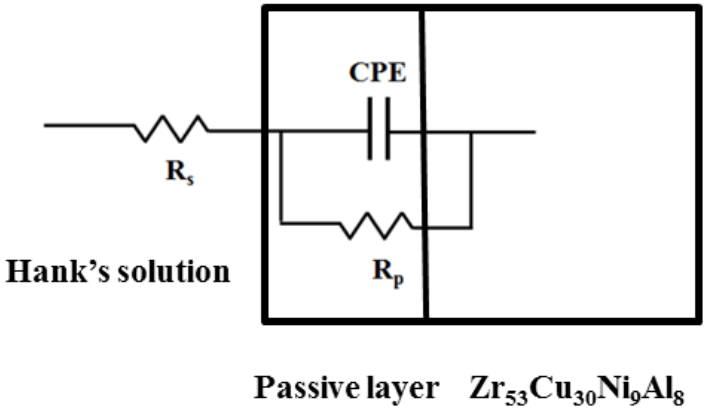
Electrochemical behaviors of as-cast and nanocrystallized $Zr_{53}Cu_{30}Ni_9Al_8$ metallic glasses under SBF





The formation of reactive Zr_2Cu nanocrystalline phases in the amorphous matrix would reduce the bio-corrosion resistance.

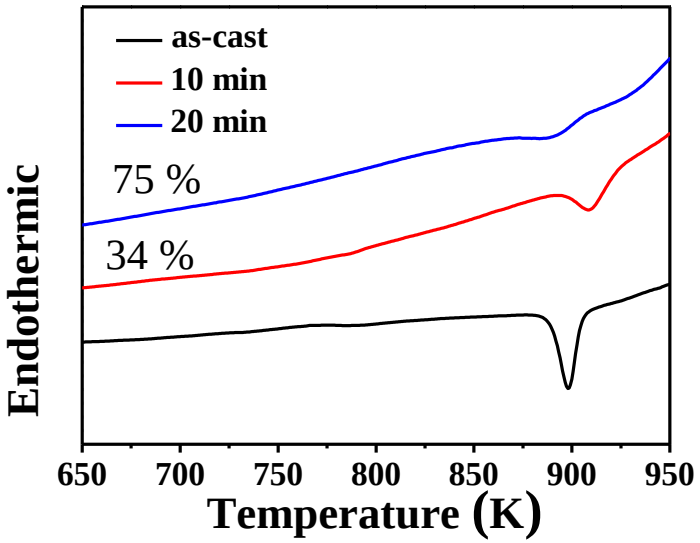


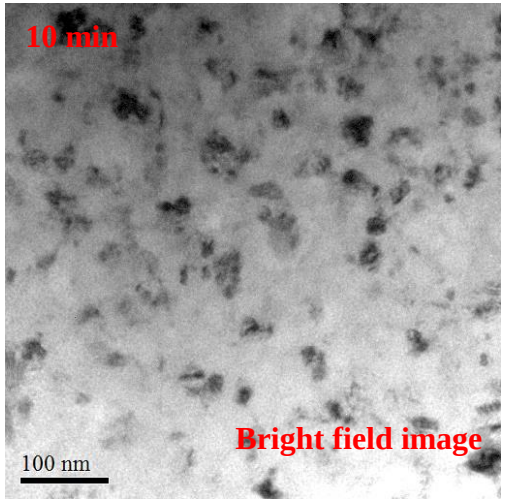


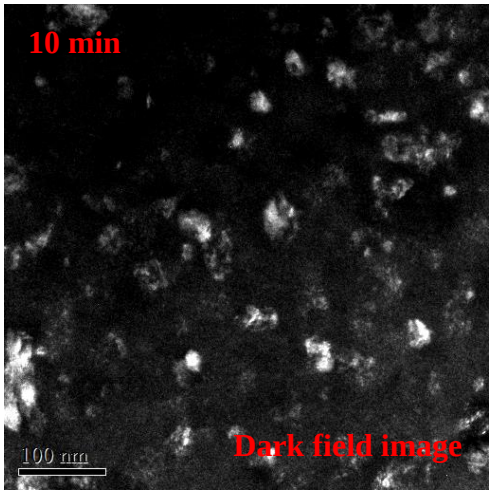
Passive layer $Zr_{53}Cu_{30}Ni_9Al_8$

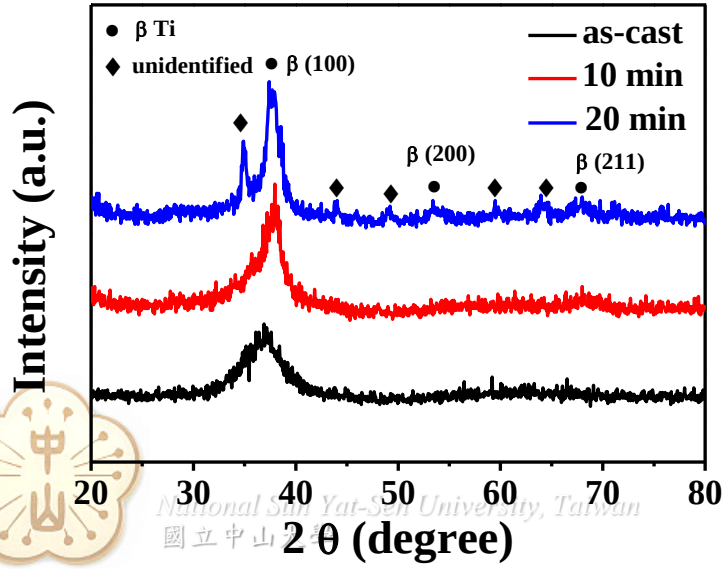
Huang et al., Mater. Sci. Eng. C, 33 (2013) 4183

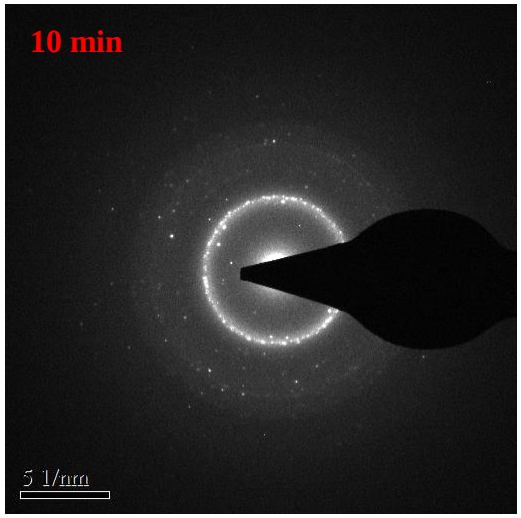
Heat treatment of $Ti_{42}Zr_{40}Si_{15}Ta_3$ metallic glasses

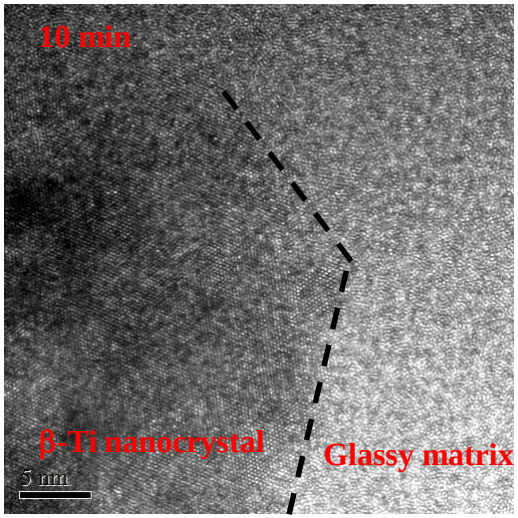




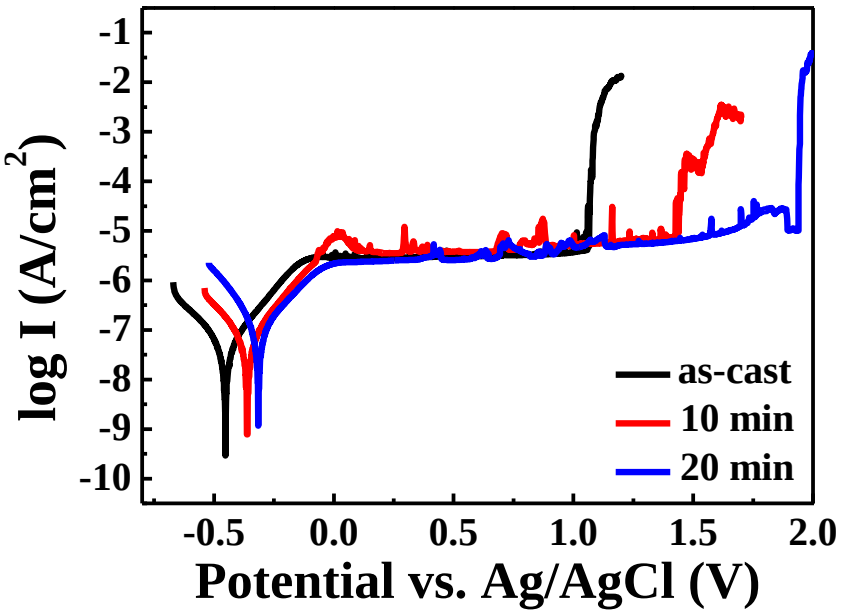


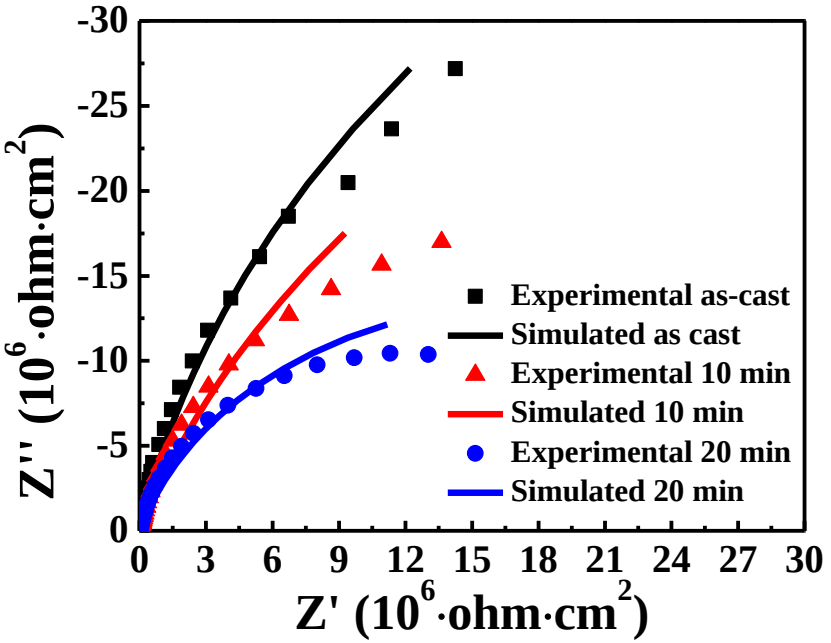






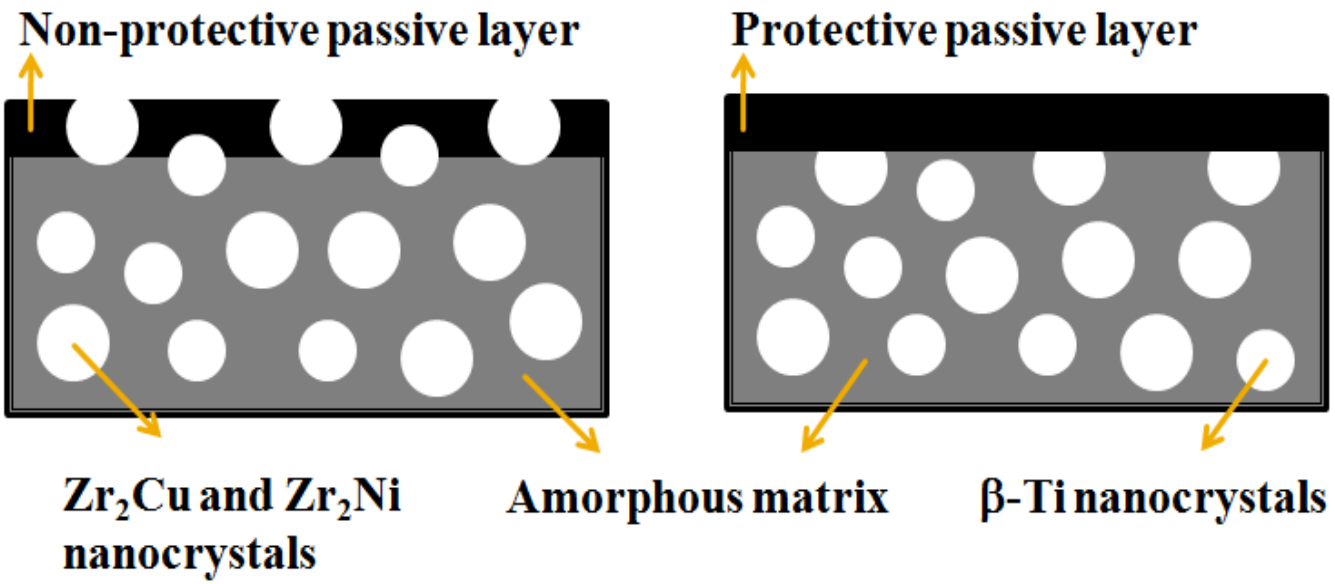
Electrochemical behaviors of as-cast and nanocrystallized $Ti_{42}Zr_{40}Si_{15}Ta_3$ metallic glasses under SBF





The pitting resistance enhancement can be explained by the oxide bridge model.

Summary



	E_{corr}	I_{corr}	R_p	E_{pit}
Zr_2Cu in Zr-based metallic glasses	--	++	--	-
β-Ti in TiZr-based metallic glasses	++	+	-	++

Conclusions

- Based on the bio-corrosion voltage and current, as well as the polarization resistance, it is concluded that the fully amorphous $Zr_{53}Cu_{30}Ni_9Al_8$ exhibits the highest bio-electrochemical resistance.

- The formation of reactive nanocrystalline Zr_2Cu and Zr_2Ni phases, which themselves would induce serious galvanic corrosion, in the amorphous matrix would reduce the bio-corrosion resistance.

- For the $Ti_{42}Zr_{40}Si_{15}Ta_3$, the corrosion resistance is improved with increasing degree of crystallization.

- The formation of pitting-resistant nanocrystalline Ti phases, which is lack of galvanic corrosion and less prone to pitting reaction, in the amorphous matrix would enhance the bio-corrosion resistance.

Acknowledgement

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Thank you for your attention.