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In vitro analysis of antibacterial FeMnSi-Cu biodegradable alloy in Simulated Body Fluid

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INTRODUCTION & AIM

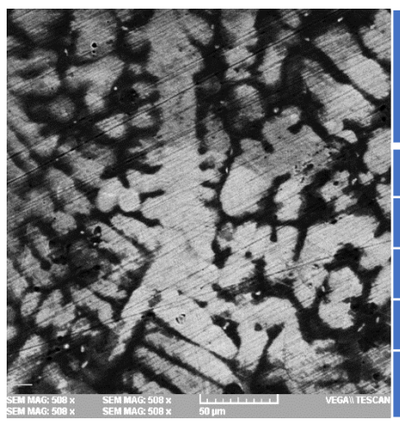
Biodegradable Fe-based alloys such as Fe-Mn-Si are currently being studied for temporary medical implant applications and are designed to perform temporary structural functions in the human body while undergoing gradual degradation.

The aim of this study was to develop a novel biodegradable FeMnSi alloy with antimicrobial properties and an enhanced degradation rate suitable for long-term medical implant applications. Therefore, the FeMnSi-1Cu alloy was developed and investigated in both cast and hot-rolled states, focusing on its physical, chemical, thermal and corrosion resistance properties.

METHOD

Scanning electron microscopy (SEM), X-ray diffraction (XRD), and energy-dispersive X-ray spectroscopy (EDX) were used for microstructural and chemical evaluation. The thermal properties were characterized by means of dynamic mechanical analysis (DMA), and the resulting microstructural changes were observed using atomic force microscopy (AFM). Simulated body fluid (SBF) immersion tests and linear and cyclic potentiometry were used to investigate degradation. To correlate the metal–liquid chemical reactions with the degradation progress, the pH of the solution during immersion was recorded over minutes. ASTM G31-72(2004) was used to determine the degradation rates (DRs).

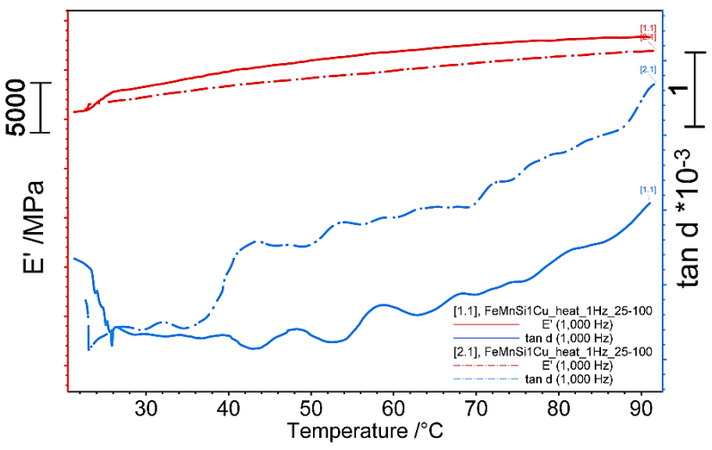
RESULTS & DISCUSSION



FeMnSi-1Cu-Element/area	Fe		Mn		Si		Cu	
	wt%	at%	wt%	at%	wt%	at%	wt%	at%
Point 1	65.27	62.45	29.70	28.88	4.18	7.95	0.85	0.72
Point 2	64.93	62.07	30.04	29.20	4.25	8.07	0.79	0.66
Point 3	65.87	62.98	28.87	28.06	4.28	8.14	0.98	0.82
Average	65.36	62.5	29.54	28.71	4.24	8.05	0.87	0.73
St. Dev. %	0.068		0.022		0.009		0.001	

Figure 1. SEM and EDX of the FeMnSi-1Cu alloy.

Figure 2. DMA diagrams (heat 25-100°C, 1Hz) for the wrought plates before (straight line) and after (dashed line) the immersion.



CORROSION RESISTANCE RESULTS

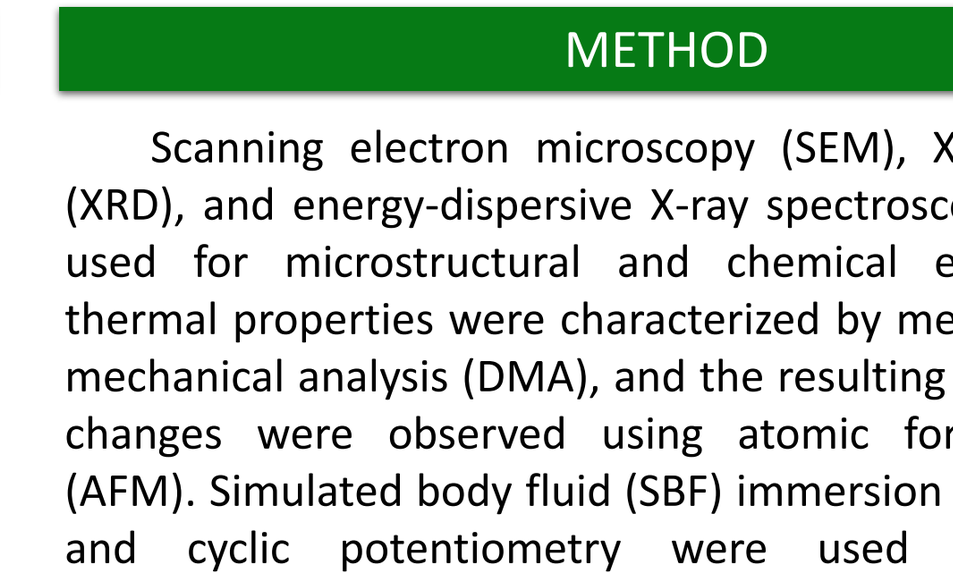


Figure 4. SEM and EDX images after 1 (a,d), 7 (b,e) and 14 days (c,f) of immersion in SBF.

Table 1. DRs determined by each mass loss.

FeMnSi-1Cu	1 day		7 days		14 days	
	C	W	C	W	C	W
Initial mass (mg)	6181.6	593.7	5751	1083.7	5948.5	1190.3
Mass after immersion (mg)	6186.3 (+4.7)	594 (+0.3)	5742 (-9)	1083.5 (-0.2)	5917.6 (-30.9)	1186.9 (-3.4)
Mass after ultrasound (mg)	6181.1 (-0.5)	592.7 (-1)	5736.6 (-14.4)	1078.7 (-5)	5915.5 (-33)	1182.5 (-7.8)
DR (µm/y)	36	223	148	100	170	65

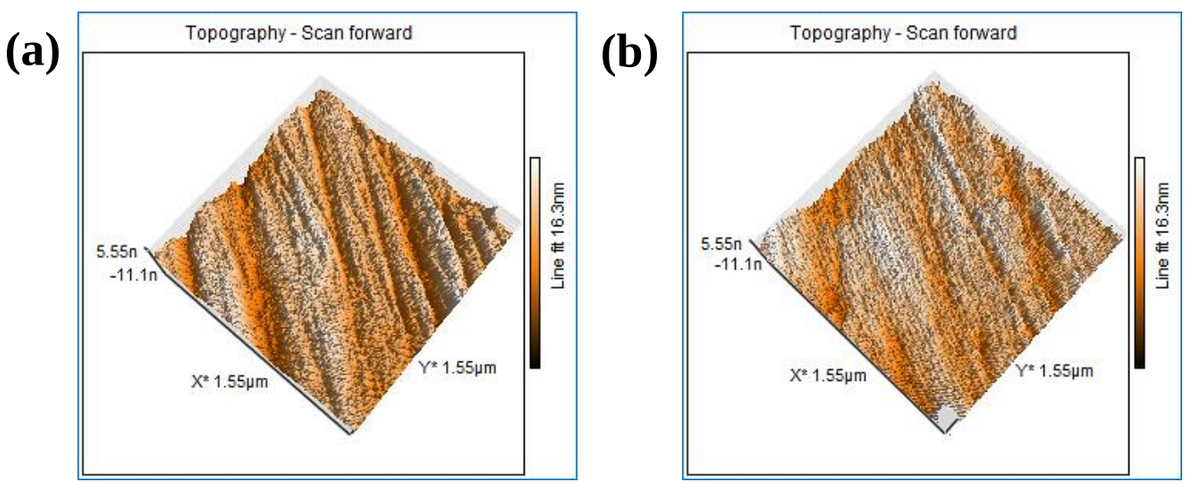


Figure 3. AFM images (3D topography) of the wrought plates (a) before and (b) after DMA testing.

CONCLUSION AND FUTURE WORK

Cu addition to the FeMnSi alloy is favorable for its antimicrobial effect, as well as for improving workability and corrosion resistance. Future research is aimed in developing a complex mathematical model of the whole degradation process based on experimental results.

References

[1] Roman, A.M. et al.; J. Funct.Biomater. 2023, 14, 377.

[2] Roman, A.-M. et al.; Nanomaterials 2024, 14, 330.

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