Supplementary Information (SI) for Journal of Materials Chemistry B.

Supporting Information for

Wire Arc Additively Manufactured Nitinol with Excellent Superelasticity for Biomedical Applications

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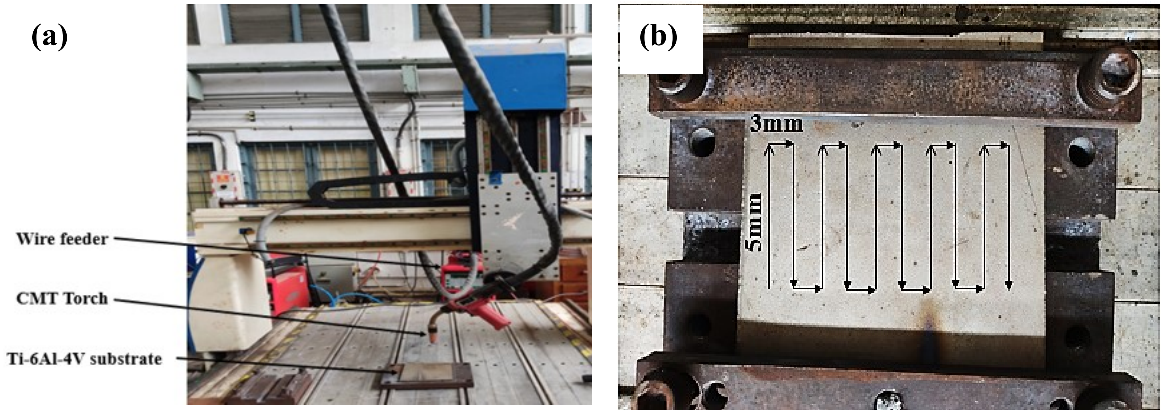


Figure S1. Photographs of (a) Experimental setup of the WAAM process and (b) Weaving pattern scan strategy used to print the nitinol samples over the substrate of Ti-6Al-4V.

Figure S2. Layer-by-layer buildup of the nitinol for 3-D printing in (a) 2^{nd} trial, (b) 1^{st} trial

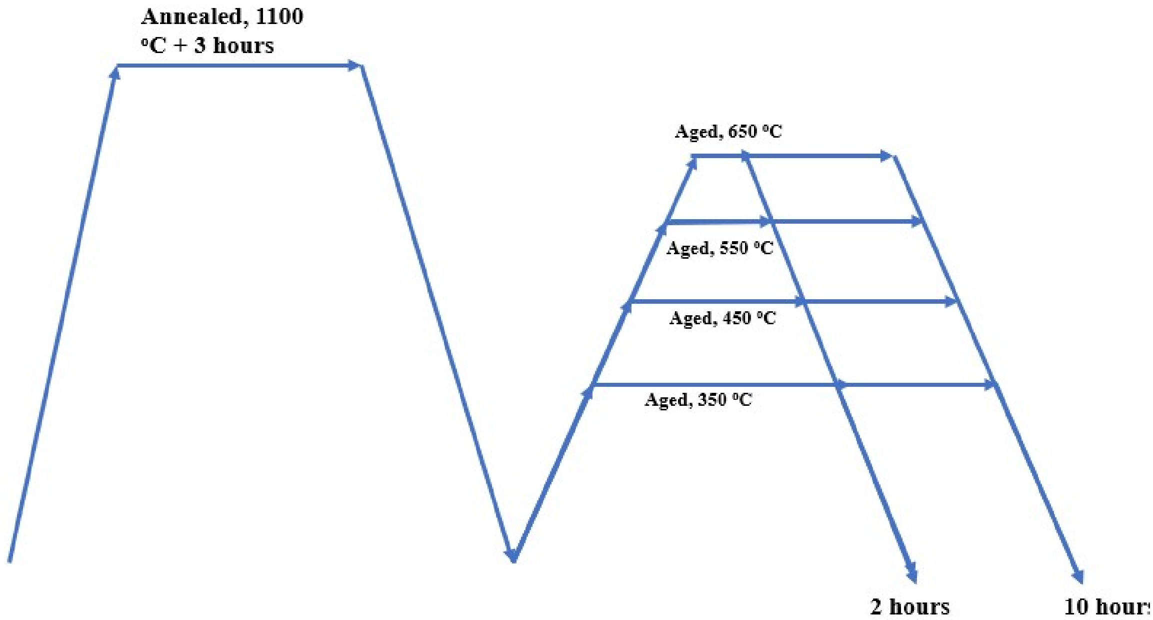


Figure S3. Heat treatment cycles used for aging.

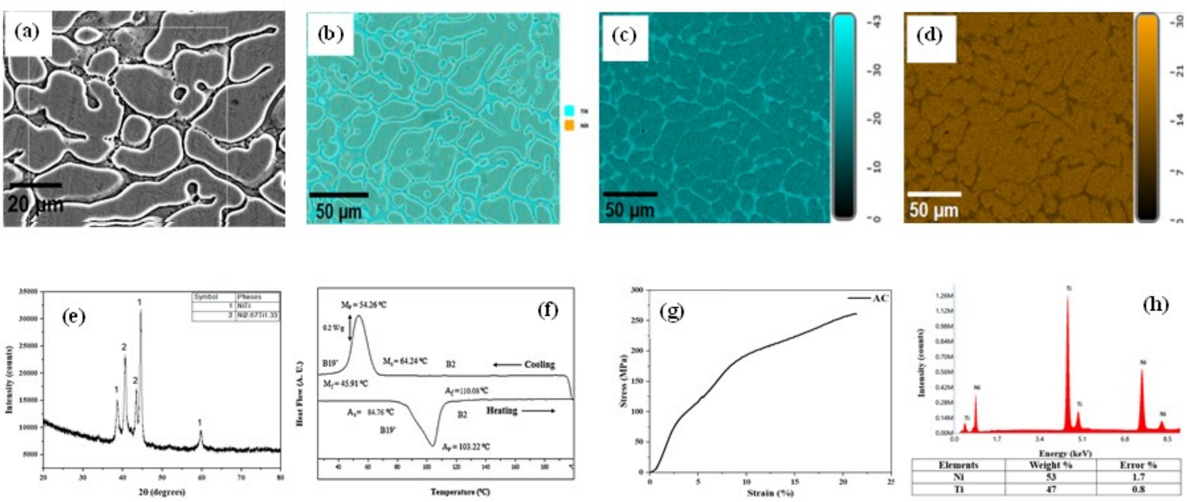
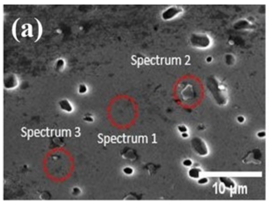
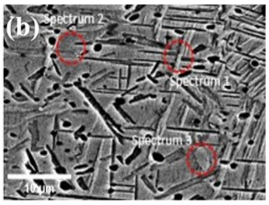


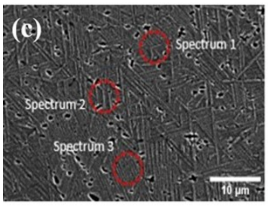
Figure S4. (a) SEM micrographs (b) area channel mapping (c) matrix mapping (d) grain boundary mapping (e) XRD results (f) DSC studies for the AC sample.



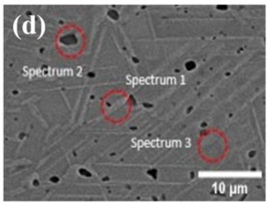
Spectrum	Elements (wt.%)	
	Ni	Ti
1	54.5	45.5
2	33.3	66.7
3	73.2	26.8



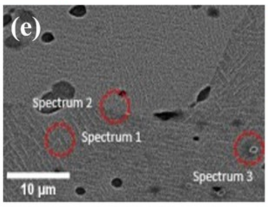
Spectrum	Elements (wt.%)	
	Ni	Ti
1	58.1	41.9
2	54.9	45.1
3	74.2	25.8



Spectrum	Elements (wt.%)	
	Ni	Ti
1	75.3	24.7
2	58.1	41.9
3	55.7	44.3

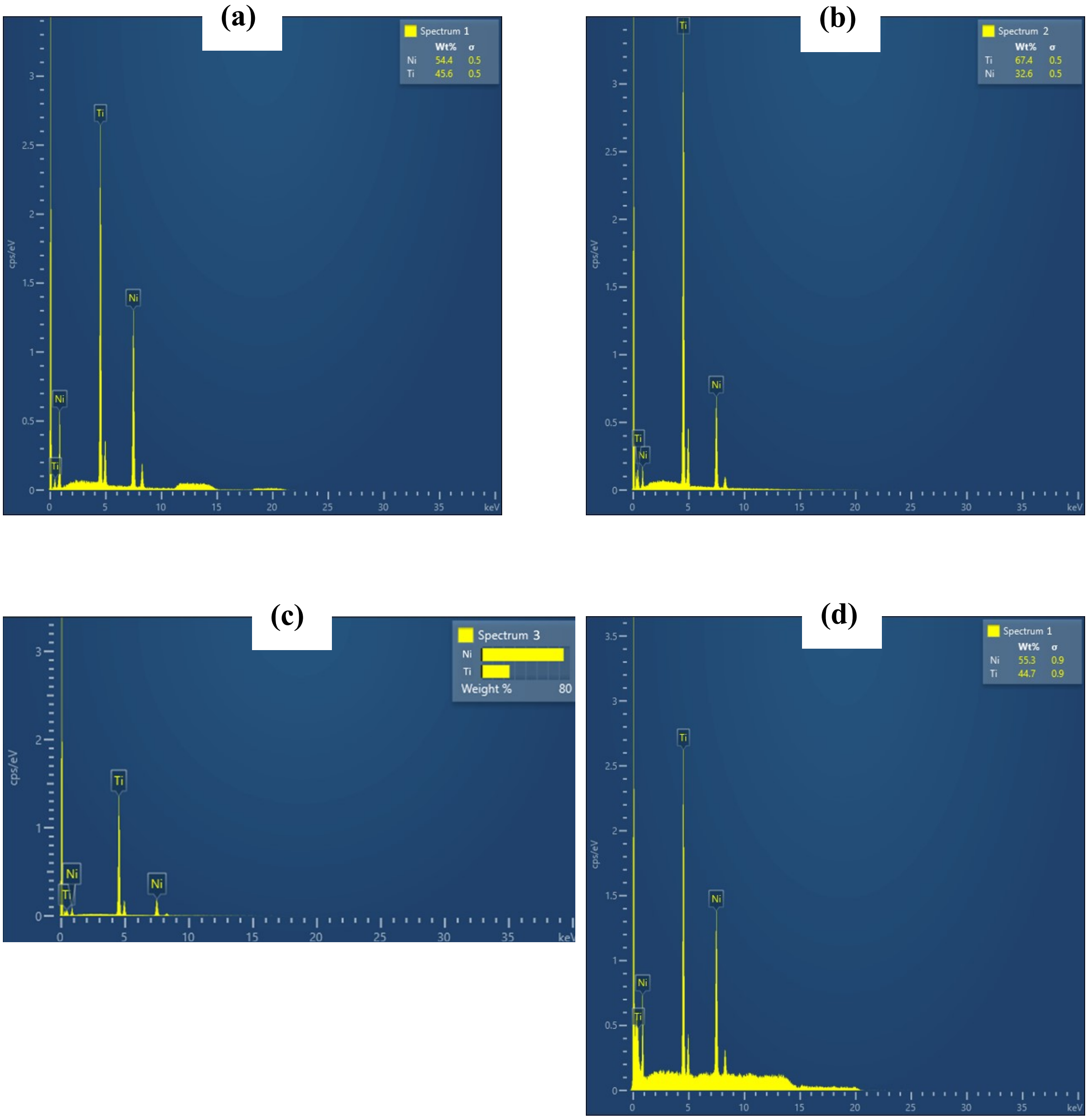


Spectrum	Elements (wt.%)	
	Ni	Ti
1	68.3	31.7
2	33.3	66.7
3	54.2	46.8

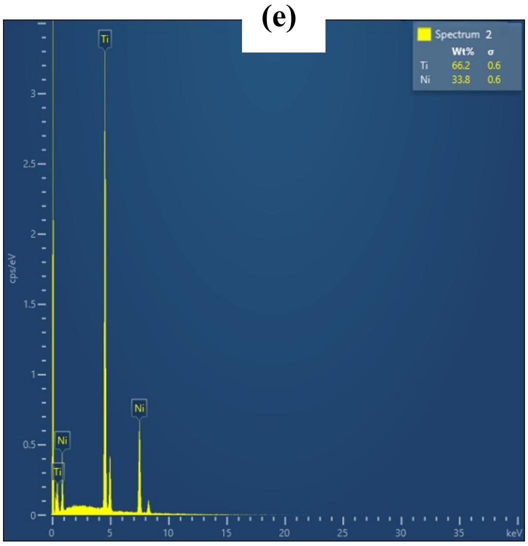


Spectrum	Elements (wt.%)	
	Ni	Ti
1	54.9	45.1
2	72.1	27.9
3	33.8	66.2

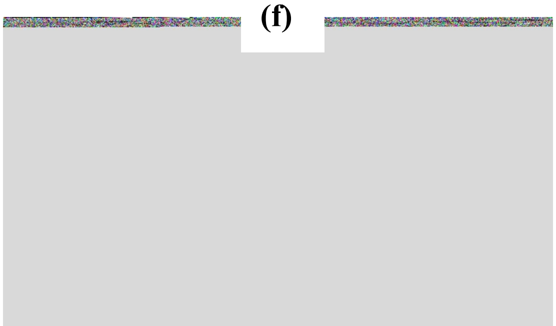
Figure S5. SEM images and corresponding EDS studies of HT-3, HT-5, HT-6, HT-8, and HT-9.


(a)
Spectrum 1
Wt% σ
Ni 54.4 0.5
Ti 45.6 0.5
(b)
Spectrum 2
Wt% σ
Ti 67.4 0.5
Ni 32.6 0.5
(c)
Spectrum 3
Ni
Ti
Weight % 80
(d)
Spectrum 1
Wt% σ
Ni 55.3 0.9
Ti 44.7 0.9
cps/eV
keV

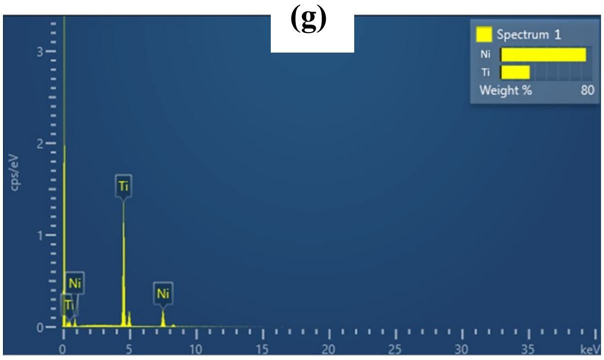
(e)


Spectrum 2
Wt% σ
Ti 66.2 0.6
Ni 33.8 0.6
cps/eV
keV

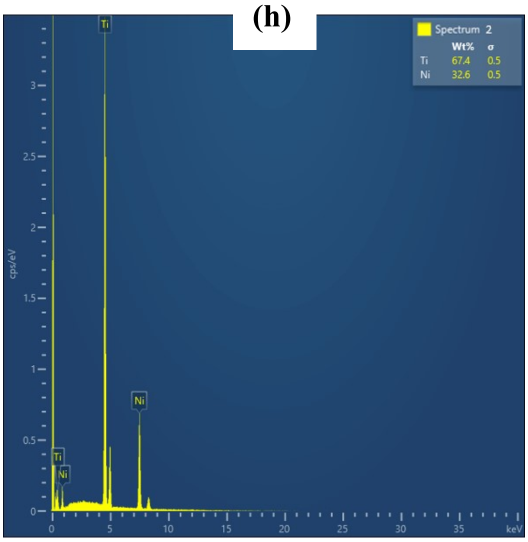
(f)



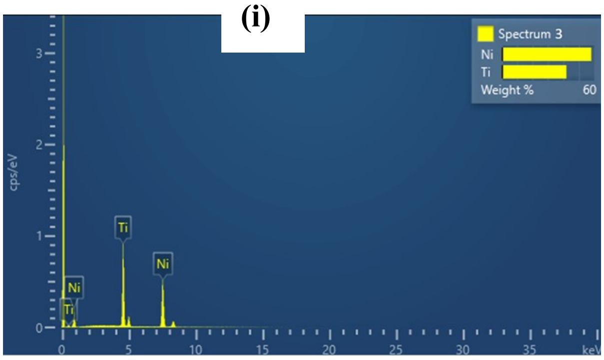
(g)


Spectrum 1
Ni
Ti
Weight % 80
cps/eV
keV

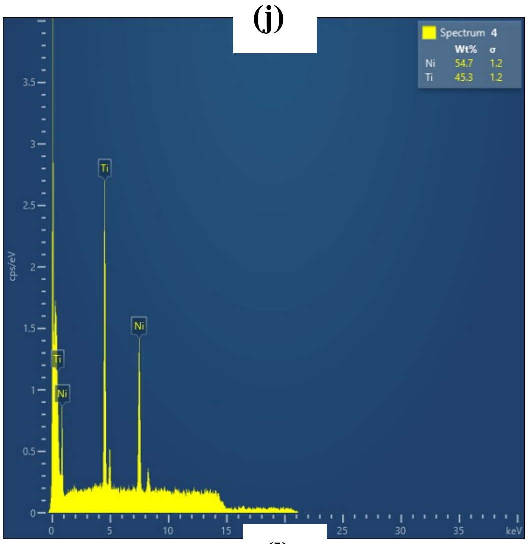
(h)


Spectrum 2
Wt% σ
Ti 67.4 0.5
Ni 32.6 0.5
cps/eV
keV

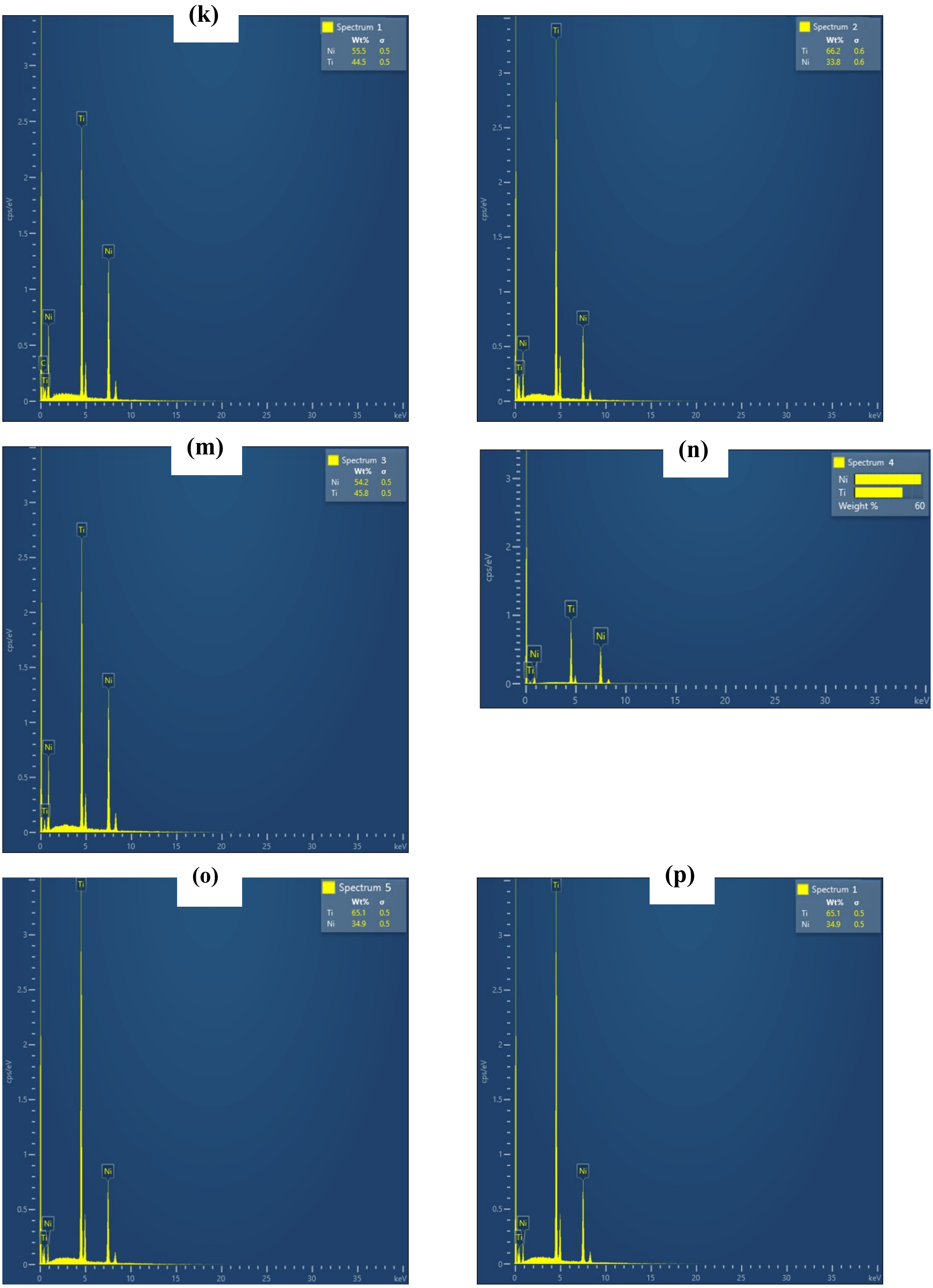
(i)


Spectrum 3
Ni
Ti
Weight % 60
cps/eV
keV

(j)

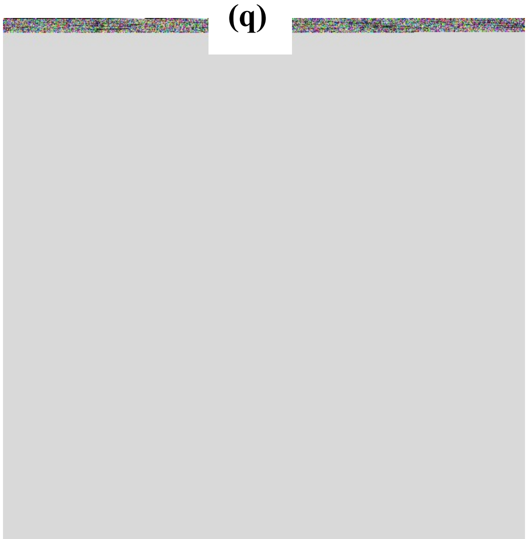

Spectrum 4
Wt% σ
Ni 54.7 1.2
Ti 45.3 1.2
cps/eV
keV

(l)

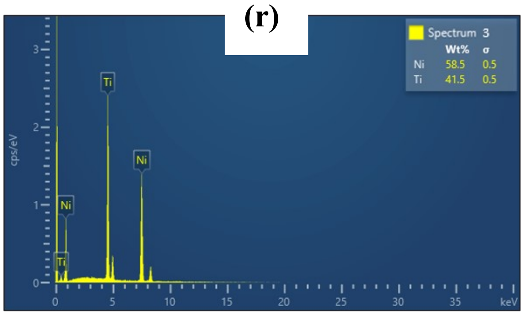


(k)
Spectrum 1
Wt% σ
Ni 55.5 0.5
Ti 44.5 0.5
Spectrum 2
Wt% σ
Ti 66.2 0.6
Ni 33.8 0.6
(m)
Spectrum 3
Wt% σ
Ni 54.2 0.5
Ti 45.8 0.5
(n)
Spectrum 4
Ni
Ti
Weight % 60
(o)
Spectrum 5
Wt% σ
Ti 65.1 0.5
Ni 34.9 0.5
(p)
Spectrum 1
Wt% σ
Ti 65.1 0.5
Ni 34.9 0.5
cps/eV
keV

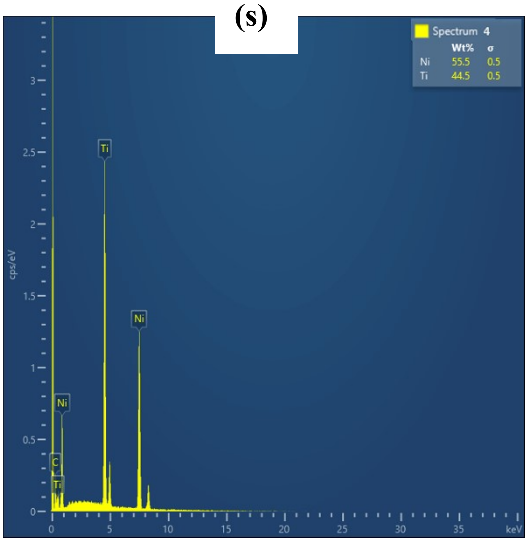
(q)



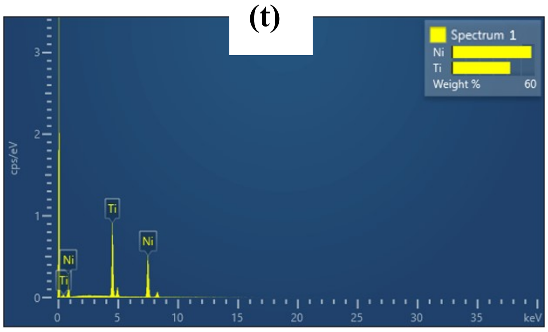
(r)


Spectrum 3
Wt% σ
Ni 58.5 0.5
Ti 41.5 0.5
cps/eV
keV

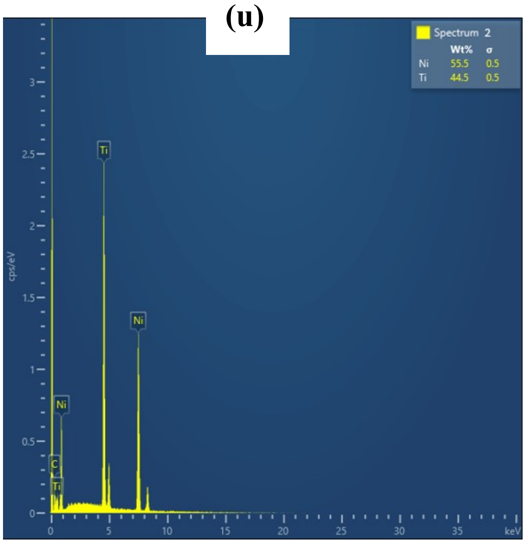
(s)


Spectrum 4
Wt% σ
Ni 55.5 0.5
Ti 44.5 0.5
cps/eV
keV

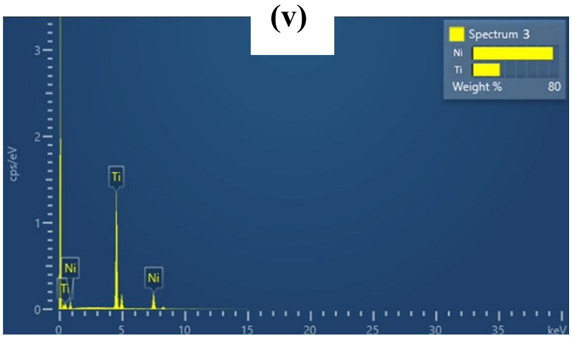
(t)


Spectrum 1
Ni
Ti
Weight % 60
cps/eV
keV

(u)


Spectrum 2
Wt% σ
Ni 55.5 0.5
Ti 44.5 0.5
cps/eV
keV

(v)


Spectrum 3
Ni
Ti
Weight % 80
cps/eV
keV

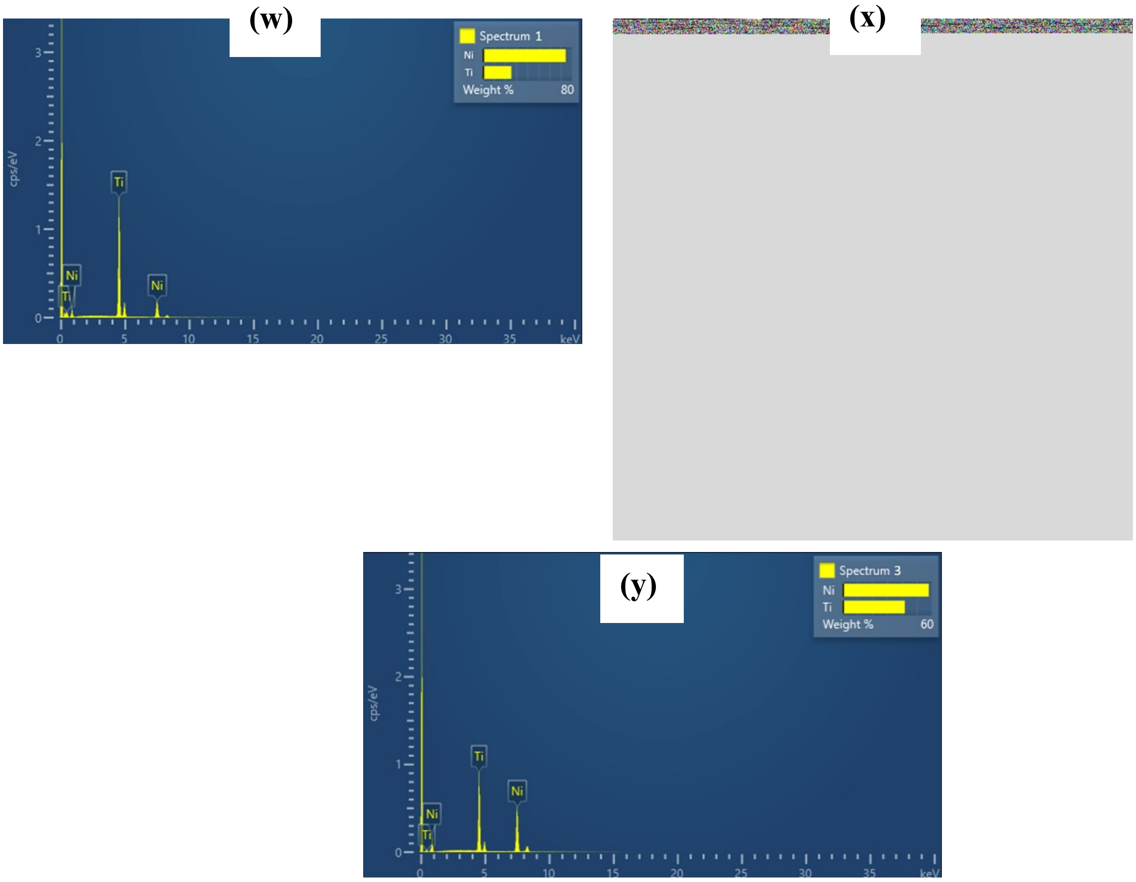


Figure S6. EDS study spectrum results for AP-L1 (a-c) AP-L3 (d-f) AP-L5 (g-j) HT-1 (k-o) HT-2 (p-s) HT-4 (t-v) HT-7 (w-y).

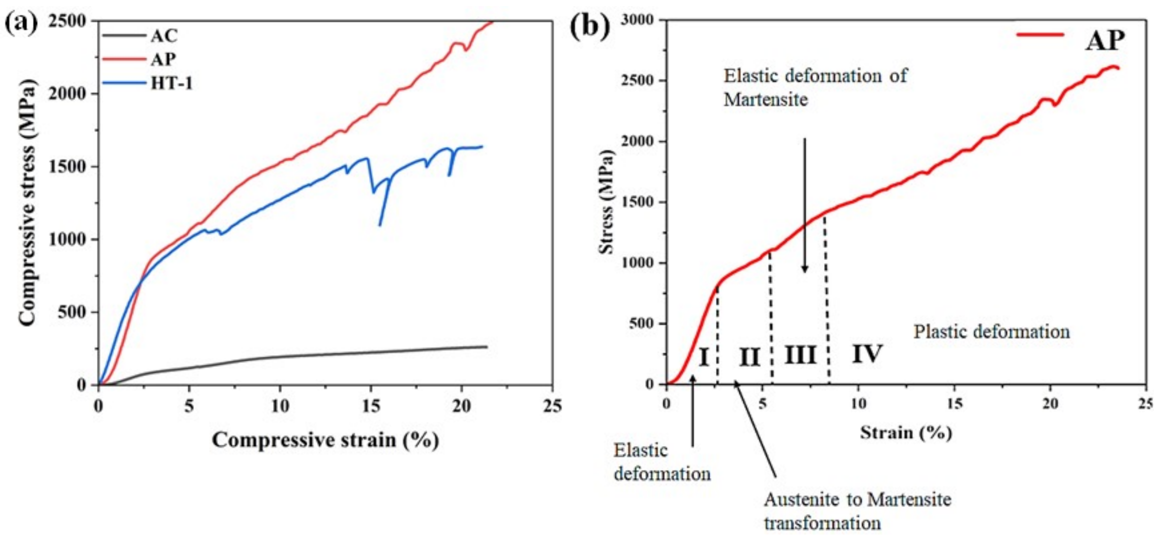


Figure S7. (a) Comparative study for the compression between AC, AP, and HT samples (b) Different regions of the AP sample during compression study.

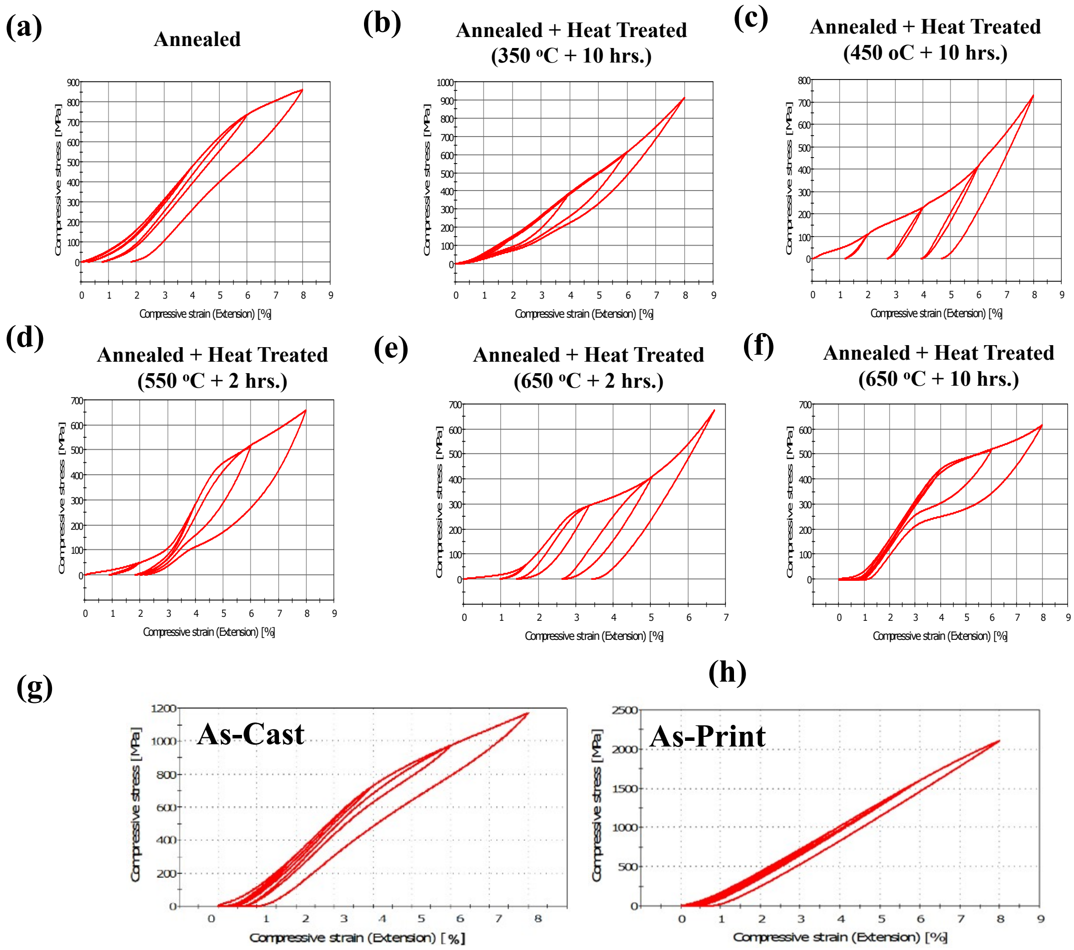


Figure S8. Stress-strain curves obtained depict loading-unloading behavior due to varying prestrain of 2%, 4%, 6%, and 8% for (a) HT-1 (b) HT-3 (c) HT-5 (d) HT-6 (e) HT-8 (f) HT-9 (g) AC (h) AP samples.

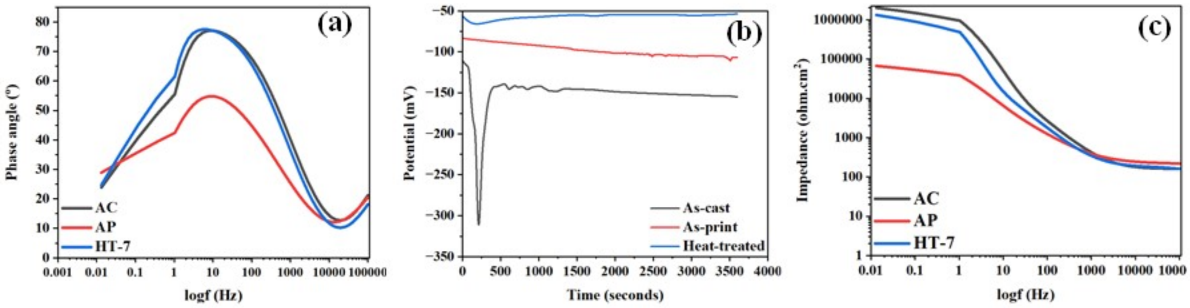


Figure S9. Corrosion studies showing (a) Phase angle plot (b) OCP plot (c) Bode plot for AC, AP, and HT-7 samples.

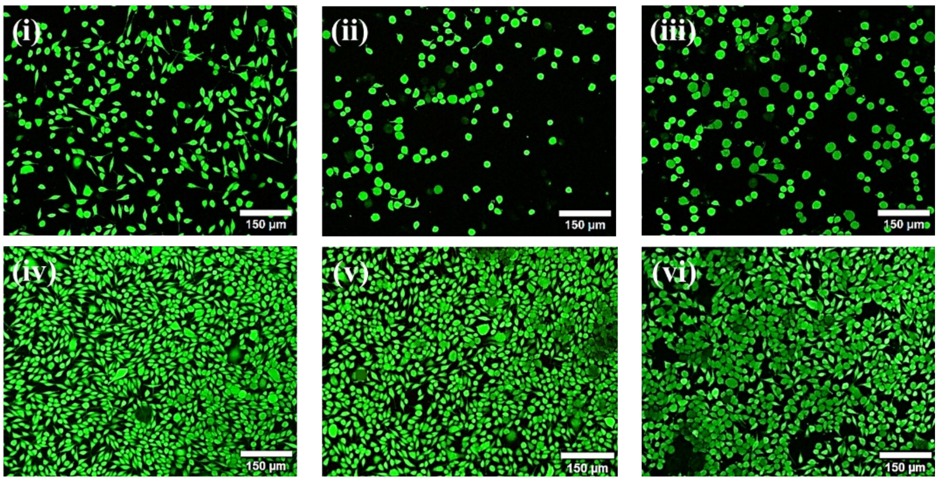


Figure S10. Live/Dead assay showing live cells in green color and dead cells in red color on different samples- AC (i and iv), AP (ii and iv), and HT-7 (iii and vi) on Day 1 and Day 3. (Scale bar represents 150 µm).

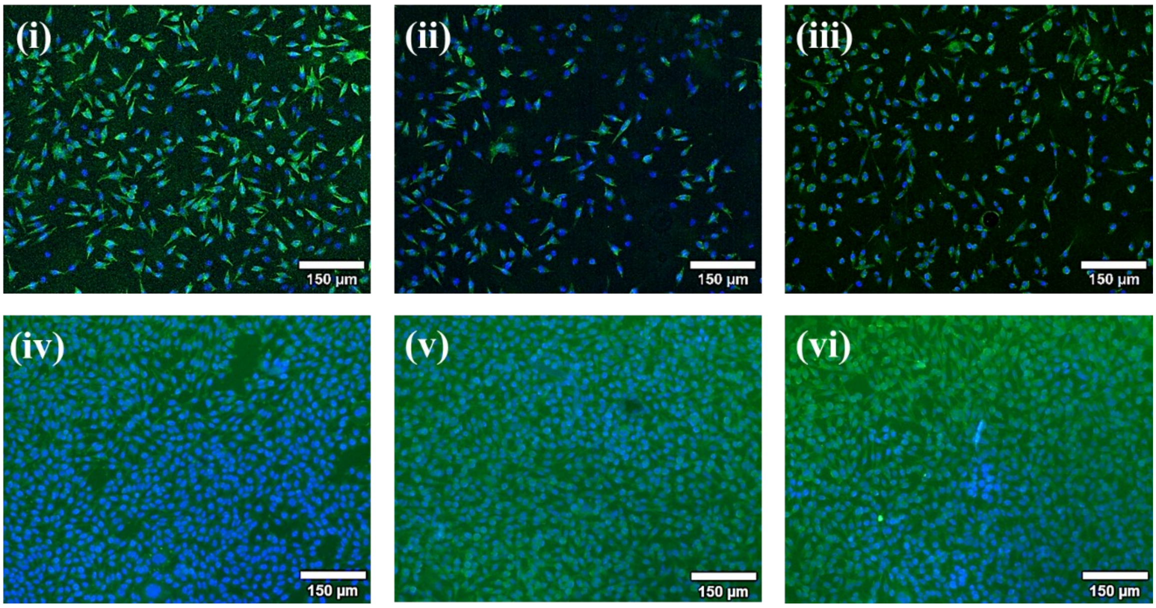


Figure S11. Fluorescent micrographs of pre-osteoblast cells showing cellular morphology on Day 1 and Day 3 for AC (i and iv), AP (ii and v), and HT-7 (iii and vi); the blue and green colors represent the nucleus and F-actin, respectively. (Scale bar = 150 µm).

Table S1. Comparative study between current research result and desired results for stent application

Properties	Desired results for stent applications	Current results
Microstructure	Austenitic B2 at room temperature [1]	Austenitic B2 at room temperature
A_f temperature	(20-30) ^oC [2]	38 ^oC for sample Annealed + HT (450 ^oC + 2 h), 26 ^oC for sample Annealed + HT (550 ^oC + 10 h)
Hardness	300-350 HV [3]	Annealed + HT (550 ^oC + 10 h) sample with hardness of 299.6 HV, Annealed + HT (450 ^oC + 2 h) sample with hardness of 379.8 HV
Desired phases	Ni_4Ti_3 for increasing super elasticity [4]	Same phase obtained for Annealed + HT (550 ^oC + 10 h) sample, Annealed + HT (450 ^oC + 2 h) sample
Preferred grain orientation	<001> type increases super elasticity [5]	<001> type grains found in the sample heat-treated at 550 ^oC for 10 h
YS	600 MPa [6]	588.35 MPa for Annealed + Aged (450 ^oC + 2 h) sample and 555.7 MPa for Annealed + Aged (550 ^oC + 10 h)
Elastic modulus	(50-80) GPa	32.6 GPa for the sample Annealed + Aged (550 ^oC + 10 h)
% strain recovery	(6-8) % [7]	7.5% Annealed + heat treated at 350 ^oC for 2 h, 6.0% Annealed + heat treated at 450 ^oC for 2 h, 6.5% Annealed + heat treated at 550 ^oC for 10 h

VideoV1. Video demonstrating the variation in the superelasticity in the AC, AP, and HT samples

References

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