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Stronger. Tougher. Better. – Enhanced Corrosion Resistance and Mechanical Strength via Stainless Steel Microfibers

Abstract: *The development of amorphous and nanocrystalline 316-type stainless steel microfibers using a high-speed melt-spinning technique is investigated. These microfibers exhibit significantly enhanced corrosion resistance and mechanical strength compared to conventional stainless steel, particularly in saline environments. Advanced characterization reveals a fully amorphous structure that transforms into a nanocrystalline-amorphous composite upon heat treatment, further improving hardness and structural performance. The study demonstrates the potential of these materials for demanding applications such as marine, biomedical, and composite technologies, emphasizing their scalable fabrication and tunable properties*

Commercial stainless steels (SS) face limitations in harsh environments due to passive layer breakdown and inherent softness. This research overcomes these challenges by fabricating fully amorphous 316-type SS microfibers via multi-nozzle melt-spinning, achieving cooling rates of ~10^8 K/s.

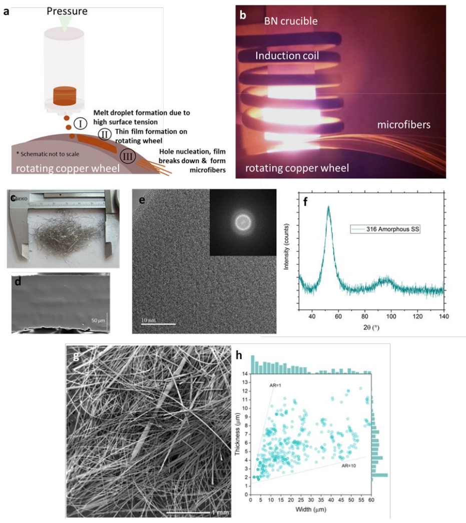

Fig. 1. (a) Fabrication schematic; **(b)** melt spinning setup; **(c, g)** produced microfibers. **(d, e)** SEM/TEM characterization with SAD inset. **(f)** XRD confirming amorphous structure. **(h)** Size distribution.

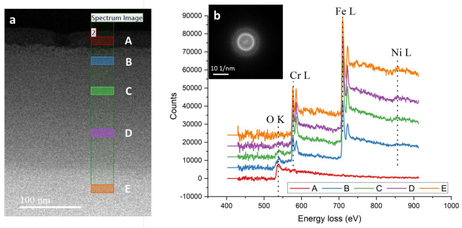

Fig. 2. Nanoscale interface analysis. **(a)** HAADF cross-section with EELS regions (A–E). **(b)** Elemental profiles (Fe, Cr, Ni, O). **Inset:** FFT of the oxide layer.

Spectrum Image	O (at.%)	Fe (at.%)	Cr (at.%)	Ni (at.%)
A	98.2	0	0	1.8
B	32.7	47.4	10.9	9
C	14.6	58.5	17.7	9.1
D	7.6	62.1	20.8	9.5
E	3.6	64.9	24.2	7.3

Table 1. Elemental analysis of regions for the main elements via EELS. Error for each element is <0.5 at.%.

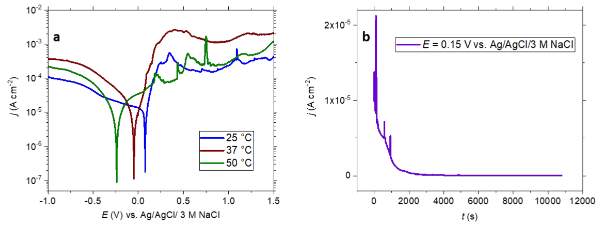

Fig. 3. (a) Polarization curves of amorphous SS316 microfibers at a scan rate of 0.005 V s^{-1} in aqueous 3.5% NaCl solution at various temperatures. **(b)** Stability test of the sample at a constant applied potential of 0.15 V.

Table 2. Corrosion properties of 316-type amorphous stainless steel microfibers at 25, 37 & 50 °C. OCP: open circuit potential, J_{corr}: corrosion current density, E_{corr}: corrosion potential, J_{pass}: passivation current density, E_{pit}: pitting potential, ACR: annual corrosion rate.

Temperature (°C)	OCP (V)	J_{corr} (A cm^{-2}) $\pm 0.3\times10^{-6}$	E_{corr} (V vs Ag/AgCl) ± 0.001	J_{pass} (A cm^{-2}) $\pm 0.1\times10^{-4}$	E_{pit} (V vs Ag/AgCl) ± 0.001	ACR (mm yr^{-1}) $\pm 0.23\times10^{-4}$
25	−0.121	7.7×10^{-6}	0.075	2.7×10^{-4}	N/A	5.93×10^{-4}
37	−0.187	9.2×10^{-6}	−0.048	16.8×10^{-4}	N/A	7.08×10^{-4}
50	−0.224	10.0×10^{-6}	−0.240	3.7×10^{-4}	0.750	7.66×10^{-4}

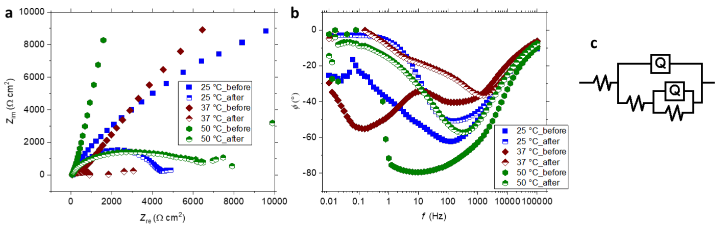

Fig. 4. Electrochemical impedance spectroscopy of the before and after-polarization samples at 25, 37, and 50 °C. (a) Nyquist and (b) Bode angle scattered plots. (c) Equivalent circuit model used to fit the EIS data.

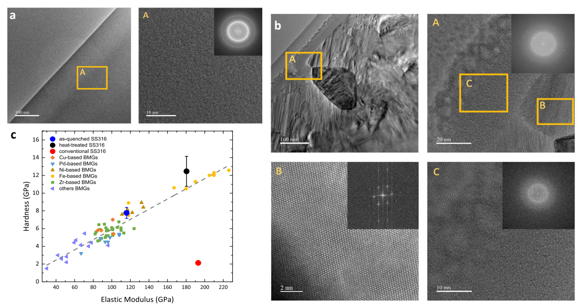

Fig 5. TEM cross-sections of (a) as-cast (amorphous) and (b) heat-treated (HT, crystalline) SS microfibers. FFT insets confirm atomic structures (d = 20.7 ± 2 nm). (c) Nanoindentation results showing hardness and elastic modulus across sample states.

Conclusion: 1) Stable passivation in Cl environments up to 1.5 V; outperforms conventional nanocrystalline SS via homogeneous & amorphous oxide layer (<200nm). 2) Amorphous structure doubles hardness (7.8 GPa) vs. 316 SS; nanocrystallization via HT further boosts hardness to 13.5 GPa. 3) Ideal for high-demand marine, biomedical, and harsh industrial settings.

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