Faculty and PostDoc, Science and Engineering

Novel Electroless NiP-TiNi Nanocomposite Coatings for Corrosion and Anti-bacterial Applications

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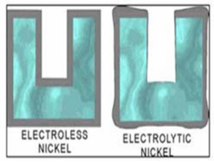
Introduction

- Corrosion is a critical problem in industry. Its failure is a significant challenge for pipelines, which represent about 75% of the transportation means of oil and gas worldwide. Coatings are considered as one of the most efficient methods employed for corrosion protection in industry [1]. However, current traditional coating technology to protect the oil and gas pipelines are not as efficient as electroless nickel-phosphorous coatings
- Electroless plating is an autocatalytic reduction of nickel ions and dose not need an electric current [2].
- Electroless plated Ni-P coatings are currently used because of their unique combined properties such as wear resistance, corrosion resistance and higher hardness. Moreover, its capability to plate the substrate surfaces uniformly regardless its geometry [3].



Methodology

Alkaline degreasing
($NaOH + Na_2CO_3 + NaPO_4$)
T=80 °C, t=5 min

→ Water rinse

Acid etching
(H_2SO_4)
T= room temperature, t=5 min

→ Water rinse

Electroless NiP-TiNi plating
(15 g L^{-1} $NiSO_4$, 30 g L^{-1} NaH_2PO_2, 20 g L^{-1} lactic acid, TiNi (0.2, 0.4 and 0.8 g/L)
T=89 °C, pH=4.5, t=120 min

→ Water rinse and dry

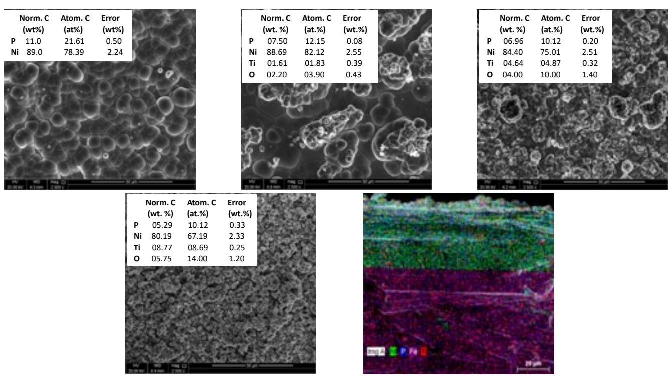
Coatings Characterization
SEM, EDX, TEM, XRD, micro-hardness
Coating Application
Corrosion resistance and Anti-bacterial properties before and after heat treatment at 400 °C for 1 hour

Project Technology

Novel titanium nickel (TiNi) shape memory alloy (SMA) nanoparticles, which possess a bundle of unique features whether in physical, chemical and/or biological performance, will be incorporated, for the first time, to the electroless Ni-P matrix to obtain NiP-TiNi nanocomposite coating with higher performance.

Results and Discussion

Surface Morphology and elemental composition of NiP-TiNi nanocomposite coatings (NCCs)



	Norm. C (wt%)	Atom. C (at%)	Error (wt%)
P	11.0	21.61	0.50
Ni	89.0	78.39	2.24

	Norm. C (wt. %)	Atom. C (at.%)	Error (wt.%)
P	07.50	12.15	0.08
Ni	88.69	82.12	2.55
Ti	01.61	01.83	0.39
O	02.20	03.90	0.43

	Norm. C (wt. %)	Atom. C (at.%)	Error (wt.%)
P	06.96	10.12	0.20
Ni	84.40	75.01	2.51
Ti	04.64	04.87	0.32
O	04.00	10.00	1.40

	Norm. C (wt. %)	Atom. C (at.%)	Error (wt.%)
P	05.29	10.12	0.33
Ni	80.19	67.19	2.33
Ti	08.77	08.69	0.25
O	05.75	14.00	1.20

Fig. 1: SEM images of surface morphology of NiP-TiNi NCCs with (0, 0.2, 0.4 and 0.8 g/L) TiNi concentrations and EDX mapping for the cross-sectional photomicrographs of NiP-0.4 g/L TiNi.

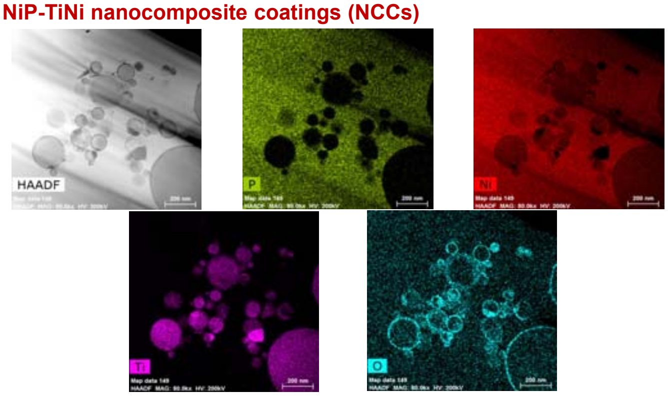


Fig. 2: TEM micrograph for the surface of the NiP-TiNi NCC plated in bath with 0.4 g/L TiNi

Phases and microhardness of NiP-TiNi NCCs

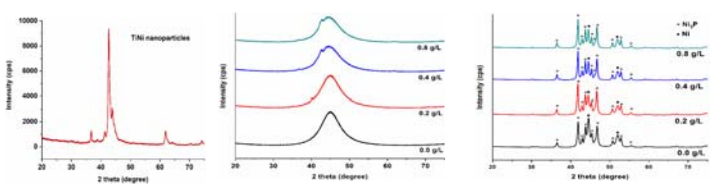


Fig. 3: XRD pattern of TiNi nanoparticles and as–plated as well as annealed NiP–TiNi NCCs with different TiNi concentrations of 0, 0.2, 0.5, and 0.8 g/L. HT occurs at 400 °C for 1 h.

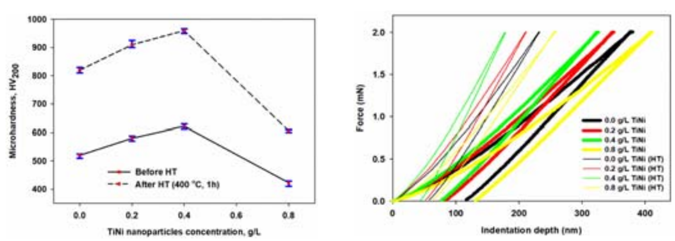


Fig. 4: The microhardness and nanoindentation test of the NiP-TiNi NCCs with different TiNi concentrations of 0, 0.2, 0.5, and 0.8 g/L before and after heat treatment at 400 °C for 1 h.

Corrosion protection and Anti-bacterial properties of NiP-TiNi NCCs

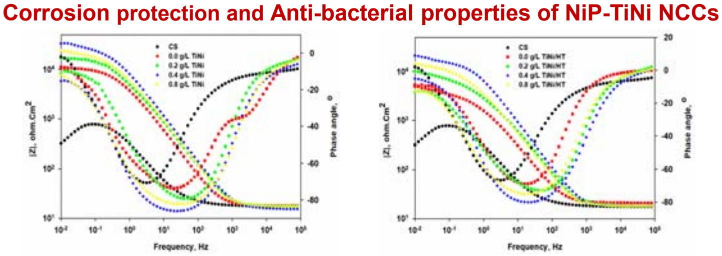


Fig. 5: Bode/phase angle plots of CS and NiP–TiNi NCCs with 0, 0.2, 0.4, and 0.8 g/L TiNi concentrations and immersed in 3.5 wt % NaCl solution at room temperature before and after heat treatment at 400 °C for 1h.

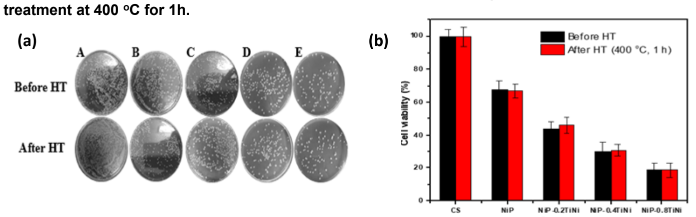


Fig. 6: Antibacterial activity of CS, NiP and NiP–TiNi NCCs coupons. (a) Photographs of *E. coli* exposed to CS (A), NiP (B) and NiP–TiNi plated from bath with TiNi concentration of 0.2 (C), 0.4 (D) as well as 0.8 g L^{-1} (E) coupons incubated overnight at 35 °C. (b) *E. coli* cell viability measurements exposed to coupons' surfaces.

Conclusions

- The NiP-TiNi NCCs with different TiNi concentrations were successfully prepared in a uniform distribution of TiNi in the NiP matrix and good adhesion with no defects.
- The incorporation of lower concentrations of TiNi nanoparticles significantly improved the microhardness and the corrosion resistance of the as-plated and annealed NiP coatings.
- The 0.4 gL^{-1} TiNi have the highest microhardness and corrosion protection efficiency.
- The cell viability of E. coli is decreased from 70% in the case of TiNi–free coating to 19% in the case of NiP-TiNi NCC with a concentration of 0.8 g L^{-1} TiNi.

Acknowledgement

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