

# **Corrosion prevention of mild steel in tap water by in-situ deposition of nickel titanate produced by co-precipitation method – A new approach**

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## **Abstract**

Nickel titanate particles were prepared by adding an aqueous solution containing ions of titanium and nickel, to an aqueous alkaline solution containing hydrogen peroxide. The precipitate of nickel titanate formed was in-situ deposited on mild steel surfaces. The surfaces of the specimens were characterized by using XRD and FTIR techniques. The corrosion prevention of mild steel specimen having a surface deposition of nickel titanate particles were evaluated by immersing it in tap water. Weight loss methods, open circuit potential measurements and potentiostatic polarization techniques are used to measure the corrosion behaviour of the specimen. The corrosion rate was found to be drastically decreased and electrochemical behaviour of the electrodes were improved by incorporating nickel titanate on the surface of mild steel.

**Keywords:** Corrosion prevention, Mild steel, Nickel titanate, Corrosion rate, Polarization

## 1. Introduction

Mild steel is widely used material in domestic, industrial, transport and agriculture areas due to its low cost, easy availability and mechanical properties. The corrosion is the major problem associated with mild steel. The corrosion rate of mild steel varies with respect to the environment in which it is exposing, structure and design of the material and the physical, chemical and electrochemical factors associated with it. Corrosion reduces the service life of the system, increases the maintenance cost, the shut down period and the unwanted impurities in the system<sup>1-2</sup>. There are many techniques like alloying, galvanizing, hot dip coating, electro and electroless plating, addition of corrosion inhibitors, cathodic protection, applying paints etc. are used for protecting mild steel. The selection of method depends on design parameters, area of application, cost effectiveness etc.

A new method of corrosion prevention of mild steel was developed by in-situ deposition of nickel titanate on the surface of it. Nickel titanate has been investigated as a tribological coating to reduce friction and wear in high temperature applications without using liquid lubricant<sup>4-10</sup>. Nickel titanate coating was designed to be economical and applicable to many surfaces due to high durability and high resistant to oxidizing atmosphere<sup>7,10</sup>. The nickel titanate particle were prepared by co-precipitation method from a solution containing both nickel and titanium ions. The co-precipitation technique has many advantages over other technique like combustion method, such as homogeneity in the phase of reactant, stoichiometric control, high purity and ease of processing<sup>5</sup>. The nickel titanate particle precipitated by co-precipitation method is simultaneously deposited in mild steel surfaces by dipping the pre-treated mild steel specimen in the solution. The mild steel specimen oxidized to  $\text{Fe}^{3+}$  by dipping in the bath for nickel titanate preparation. Nickel titanate formed will react with oxidized iron species in the surface of mild

steel and there by producing iron nickel titanate on the surface of the mild steel. This iron nickel titanate is responsible for the corrosion prevention of mild steel.

## 2. Experimental Methods

### 2.1. Substrate (Mild steel)

The substrate selected for plating was mild steel. The composition of the substrate is given in Table 1.

**Table1:** Composition of the Metal Specimen.

Sl. No.	Elements	Quantity (%)
1	Carbon	0.1
2	Silicon	0.1
3	Manganese	0.7
4	Chromium	0.02
5	Nickel	0.01
6	Molybdenum	0.10
7	Fe	Balance

Rectangular strips of size 3cm x 1cm x 0.2cm were cut from mild steel. These strips were abraded with fine emery papers. Then all the strips were subjected to alkaline cleaning using 5% NaOH solution, acid cleaning using 3% HCl and sensitization using stannous chloride solution (10 g/L  $\text{SnCl}_2$  + 40 ml/L conc. HCl) Each process was carried out for 1 minutes successively and the strips were cleaned with water and dried.

## 2.2. In-situ Deposition of Nickel titanate on mild steel

For preparing  $\text{NiTiO}_3$ , nickel chloride and titanium tetrachloride were used as the starting material.  $\text{TiCl}_4$  (0.2mol) and  $\text{NiCl}_2$  (0.2mol) are respectively dissolved in 1000 ml of distilled water. An aqueous solution containing ions of titanium and nickel in an equimolar ratio is prepared by admixing 100 ml  $\text{TiCl}_4$  solution and 100 ml of  $\text{NiCl}_2$  solution (solution 1). A mixed solution is prepared by admixing 20 ml of 30%  $\text{H}_2\text{O}_2$  solution, 15 ml of 28% aqueous ammonia solution, and rest of distilled water (solution 2). The mild steel specimen prepared after pre-treatment procedure was immersed in solution 1. The mixed solution (solution 2) is added at a rate of 10 ml per minute to the aqueous solution containing ions of titanium and nickel in an equimolar ratio (solution 1 with mild steel specimen) with stirring to precipitate of nickel titanate on metal surface. The specimen is then dried and kept in desiccators.

## 2.3. Characterization of coatings

The deposited material were carefully scratched from the specimen surface and analyzed by XRD and FTIR techniques. X-ray diffraction was performed on powder scratched out from the metal surface by using  $\text{CuK}\alpha$  radiation (Rigaku XRD instrument). Average crystalline size was calculated from the peak width using Scherrer formula. FTIR spectra have been recorded by using Bruker FTIR instrument.

## 2.4. Evaluation of samples

### 2.4.1. Corrosion rate

The accurately weighed mild steel specimens (bare and coated with nickel titanate) were immersed in 500 ml of water for a period of 30 days. After 30 days of exposure in aqueous

environment, the specimen were taken out cleaned by using pickling solution dried and weighed,

corrosion rate is measured from the difference in weight of the specimen before and after immersion in water.

#### 2.4.2. *Electrochemical parameters*

Cathodic and anodic polarization curves were recorded on the metal electrode surface ( $1\text{cm}^2$ ) immersed in aerated drinking water by sweeping at a rate of  $1\text{ mV/s}$  over a range of  $100\text{ mV}$  vs. Saturated Calomel Electrodes (SCE) where stainless steel ( $20\text{ cm}^2$ ) act as counter electrode. The open circuit potential was measures as  $V$  vs. SCE.

### 3. Results and Discussion

#### 3.1. Surface characterization

##### 3.1.1. *XRD Studies*

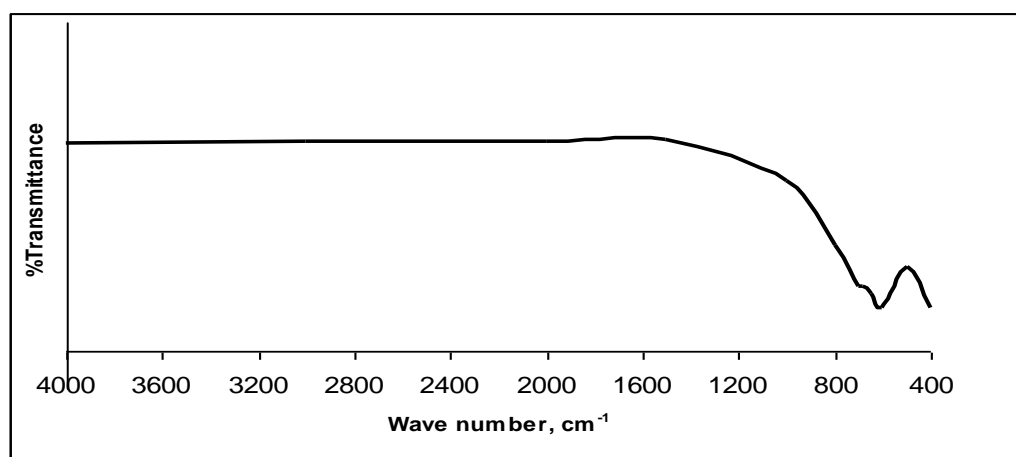
Table 2 shows the XRD data of corrosion product scratched from the mild steel surface with and without incorporation of nickel titanate after exposure to tap water for 5 days. From the result it was very clear that nickel titanate is formed from the intermixing precursor solution and is in situ deposited on the surface of mild steel surface. The particle size calculated by using Scherer equation shows that all the deposited particles are in the range of nano scale.

**Table 2:** XRD data of specimens

Specimens	Peak at 2 $\theta$	Peak corresponding	$\beta \frac{1}{2}$ (radians)	Particle size (nm)
Mild steel without nickel titanate	33.2	Fe <sub>2</sub> O <sub>3</sub>	0.001761	77.7
	35.6	Fe <sub>2</sub> O <sub>3</sub>	0.001668	82.0
	44.9	Fe	0.002562	53.4
Mild steel with nickel titanate	37.8	NiTiO <sub>3</sub>	0.003020	45.3
	33.1	Fe <sub>2</sub> O <sub>3</sub>	0.001861	73.5
	35.6	Fe <sub>2</sub> O <sub>3</sub>	0.001768	77.3
	44.9	Fe	0.002462	55.5

### 3.1.2. FTIR spectra

The FTIR spectra recorded for sample scratched from mild steel with nickel titanate surface impregnation is shown in Fig. 1.



**Fig.1.** FTIR spectra of powdered sample scratch from mild steel surface impregnated with Nickel Titanate.

IR peaks below  $800\text{ Cm}^{-1}$  were assigned to the Ti-O stretching and bending mode of O-Ti-O

bond vibration corresponding to the formation of nickel titanate on mild steel surface.

### 3.2. Nickel titanate coating performances

#### 3.2.1. Corrosion rate

The corrosion rate of mild steel with and without surface impregnation of nickel titanate in tap water for 30 days of exposure is given in Table 3.

**Table 3:** Corrosion rate of mild steel (bare and nickel titanate deposited) in potable water

Specimen	OCP (V vs. SCE)	Corrosion rate (mpy)
Mild steel	-0.510	2.65
Mild steel with nickel titanate on surface	-0.365	1.65

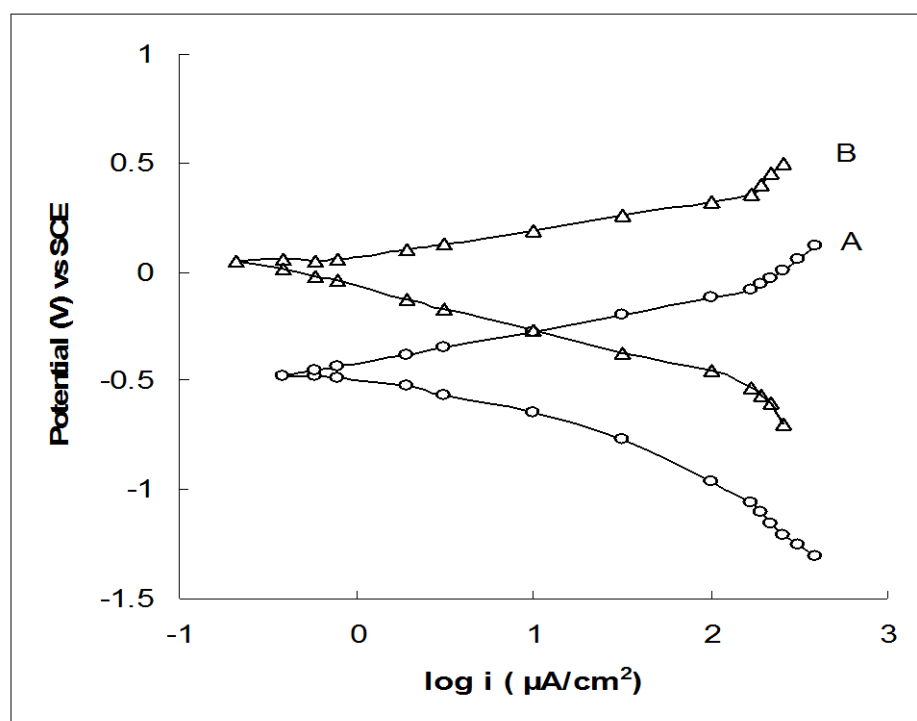
The open circuit potential (V vs. SCE) at the time of immersion of samples were also given in the same table. The OCP shift to anodic value for mild steel samples incorporated with nickel titanate. The corrosion rate also decreased for mild steel samples surface impregnated with nickel titanate. Nickel titanate protects the metal against corrosion in two ways. Nickel titanate act as barrier layer for mild steel samples exposing to electrolyte medium and also shift the corrosion potential of metal to anodic regions and there by reducing the corrosion kinetics of the metal.

#### 3.2.2. Polarization studies

Fig. 2 shows the polariz ability of the mild steel specimen with and without surface

impregnation of nickel titanate. The extent of polarization of mild steel with nickel titanate was

lower than that of mild steel without impregnation of nickel titanate. Impregnation of nickel titanate on mild steel samples shifts the slope of anodic and cathodic polarization curves and there by decreasing the corrosion current density ( $i_{\text{corr}}$ ) of the metal. The corrosion current density is directly related to corrosion rate and hence the corrosion rate of nickel titanate deposited metal was on lower side.



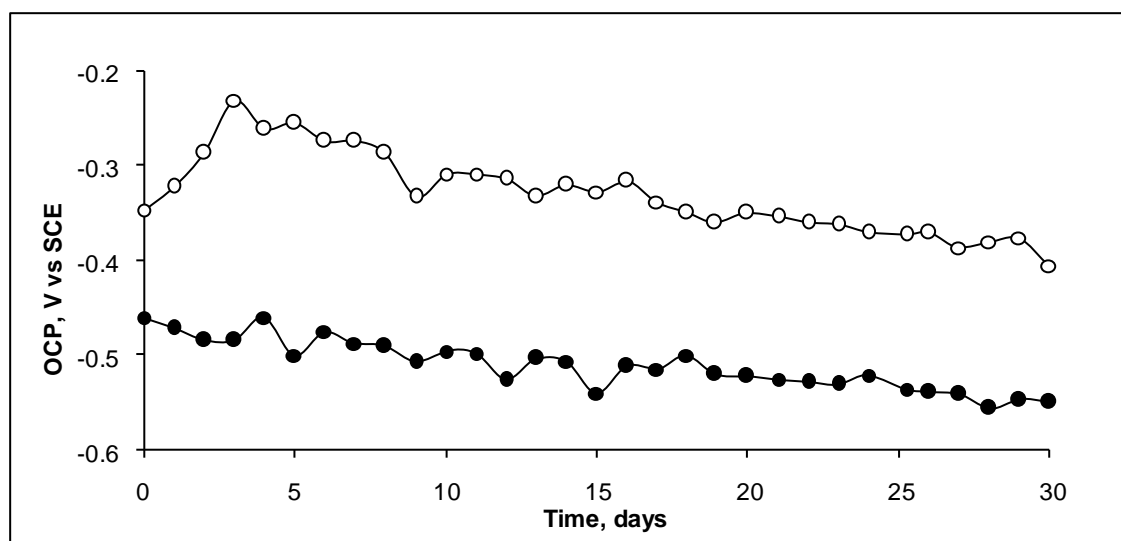
**Fig. 2.** The Tafel plots of mild steel in potable water A: mild steel and B: mild steel deposited with nickel titanate.

### 3.2.3. Open circuit potential (OCP) decay

The open circuit potential (OCP) variation of the electrodes is shown in Fig. 3. The OCP values for nickel titanate deposited mild steel samples are found to be more anodic compared to



bare mild steel specimens. This implies that nickel titanate can shift the potential of the metal to more passive anodic values and hence reduces the corrosion rate. In the OCP decay curve for 30 days, the potential value for nickel titanate deposited mild steel are always shown more anodic value compared to bare substrate. This indicates more durability of presence of nickel titanate on mild steel surfaces.



**Fig. 3.** OCP decay of mild steel samples in potable water.

(● – bare mild steel ○ – mild steel deposited with nickel titanate)

## 4. Conclusion

The nickel titanate particles were prepared by co-precipitation method from an aqueous solution containing ions of titanium and nickel, to an aqueous alkaline solution containing hydrogen peroxide. The nickel titanate particles produced was in-situ deposited on mild steel surface. The formation of nickel titanate and its deposition on mild steel surface were revealed from the XRD and FTIR studies. Impregnation of nickel titanate on mild steel samples shifts the slope of anodic and cathodic polarization curves and there by decreasing the corrosion current

density ( $i_{\text{corr}}$ ) and corrosion rate of the metal. The durability of nickel titanate deposit on mild steel surfaces is revealed from OCP decay studies.

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