Investigation of the anti-corrosive effect of Tannic Acid embedded in silica coatings on Zn substrates

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Introduction

In recent years, investigation of different ways to enhance the anti-corrosive properties of metals has come to the fore. One of the most efficient methods minimizing corrosion is by the development of corrosion protective coatings. Silica is an inorganic material used in both solid and liquid forms for corrosion protection[1],[2]. Tannic acid, used as an inhibitor is known to provide protection to Cu, Zn and mild steel alloys, under mild conditions[3].

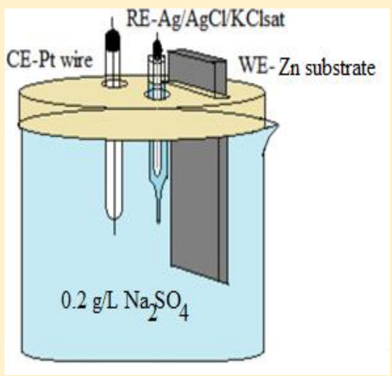
Aim

The main focus was the investigation of compact silica coatings on Zn substrates and the determination of the anti-corrosive effect of different concentrations of Tannic acid in this matrix. The influence of the coatings' aging on their anti-corrosion resistance was also investigated. The characterization of the coatings was achieved by electrochemical measurements, mainly Electrochemical Impedance Spectroscopy (EIS), and the Tafel interpretation of Potentiodynamic Polarization curves. Coating thickness and adhesion of aforementioned coatings were also carried out.

Experimental conditions

Coating preparations:

Silica respectively, Tannic Acid containing silica sol were prepared. Silica sol-gel was prepared from Tetraethyl orthosilicate, Ethanol and 0.1 N HCl. Three different concentrations of Tannic Acid (0.5%, 1% and 2%) were introduced into the silica sols, for investigation. Coatings were produced on zinc wafers, using the dip-coating method after careful polishing and degreasing of the zinc substrates. The coatings were then thermally conditioned at relatively low temperatures. After the coatings were applied, they were then left to age. Coating aging followed by concentration dependence of Tannic acid was studied by electrochemical methods. Measurements were carried out on a PARSTAT 2273, in Na_2SO_4 electrolyte and in a three electrode cell.



Experimental results

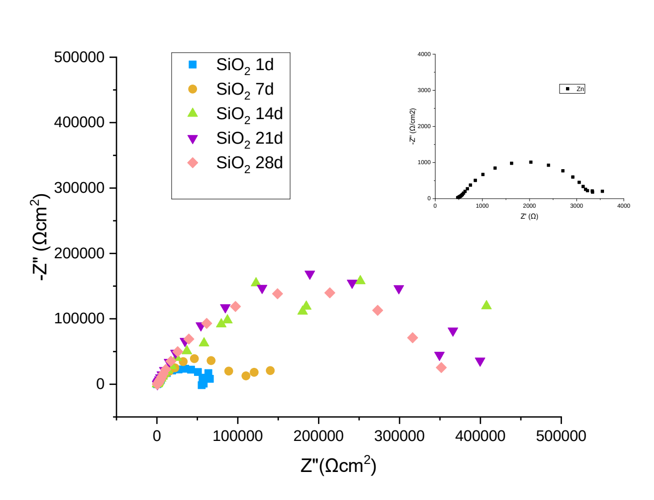


Fig.1. Nyquist diagram of the aged of SiO_2 coatings on zinc substrates, during 28 days

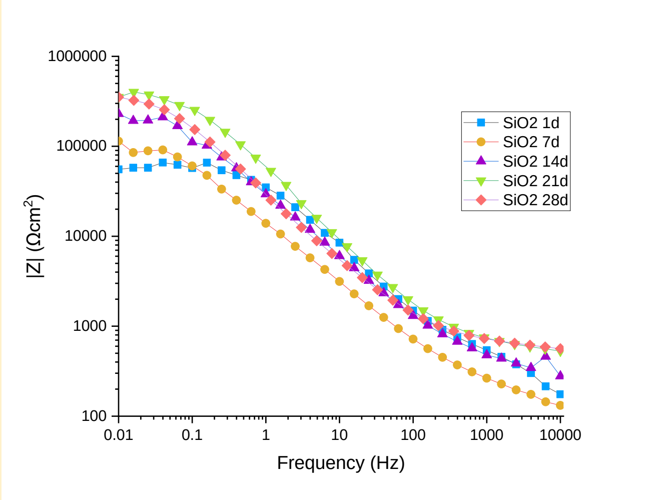


Fig.2. Bode diagram of the aged of SiO_2 coatings on zinc substrates, during 28 days

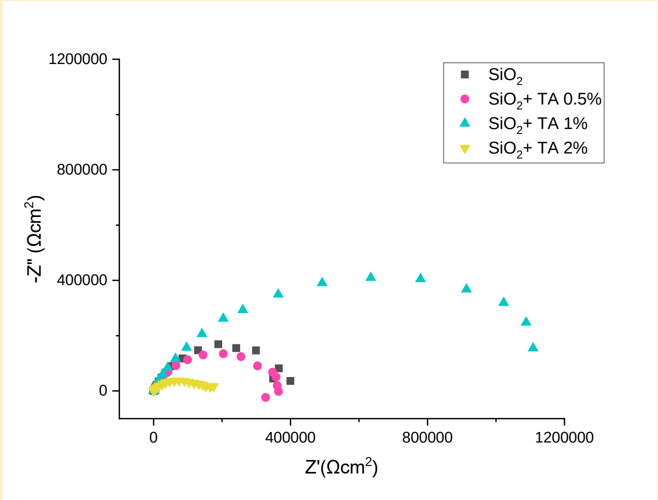


Fig.3. Nyquist diagram of SiO_2 coatings containing different concentrations of Tannic Acid, on zinc substrates

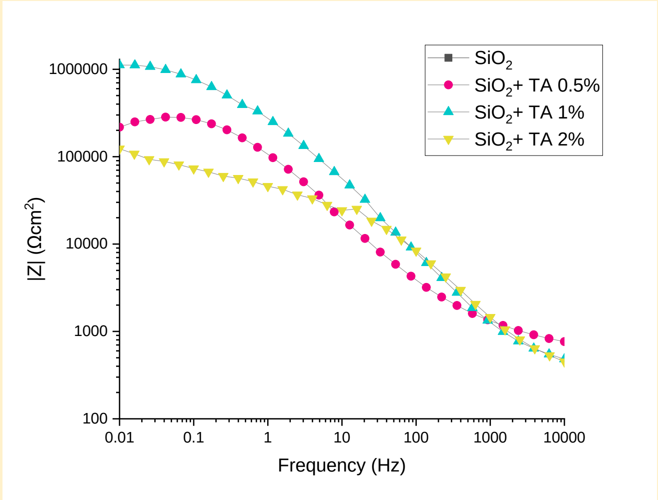


Fig.4. Bode diagram of SiO_2 coatings containing different concentrations of Tannic acid, on zinc substrates

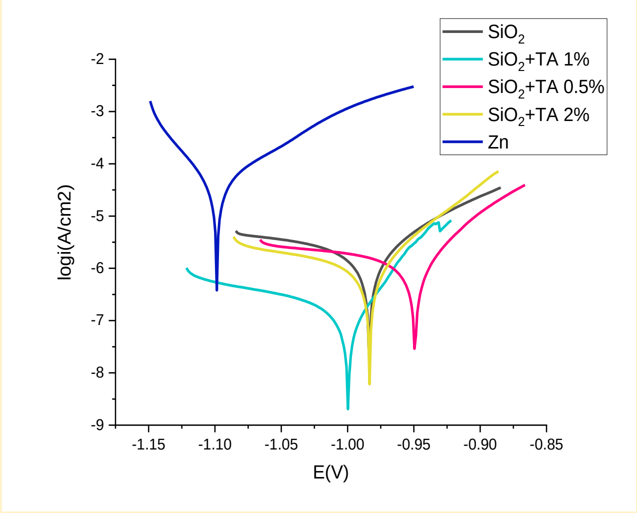


Fig.4. Polarization curves of Zn, SiO_2 and SiO_2 containing 0.5%, 1% and 2% Tannic Acid on zinc substrates

Sample	I_{corr} (A)	i_{corr} (A/cm^2)	Rp (Ohm)	β_a	β_c	Corr. Rate (mm/year)
Zn ref	$7.5639x10^{-6}$	$3.7846x10^{-6}$	331.96	0.0110	0.0110	0.0870
SiO_2	$5.0270x10^{-7}$	$2.5130x10^{-7}$	14091	0.0268	0.0416	0.0058
SiO_2+ TA 1%	$2.8530x10^{-8}$	$1.4260x10^{-8}$	131950	0.0150	0.0205	0.0003
SiO2+ TA0.5%	$4.2665x10^{-7}$	$2.1332x10^{-7}$	15649	0.0210	0.0550	0.0049
SiO2+ TA 2%	$1.9150x10^{-7}$	$0.9577x10^{-7}$	20502	0.0140	0.0240	0.0022

Table 1. Kinetic parameters of Polarization curves measured on Zn, SiO_2 and SiO_2 containing 0.5%, 1% and 2%Tannic Acid on Zn substrates

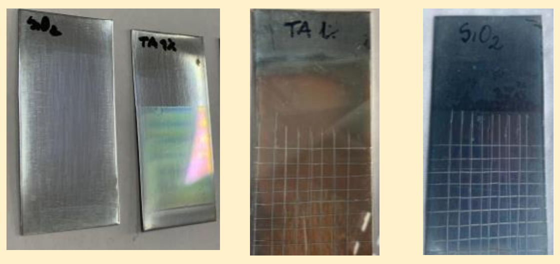


Fig.5. SiO_2 and SiO_2 containing Tannic Acid coatings before and after adhesion measurements

Sample	Coating thickness (μm)	Coating adhesion (%)
SiO_2	<1	≈99.9
SiO_2+ TA 1%	<1	≈99.9

Table 2. Coating thickness and Adhesion measurement values of SiO_2 and SiO_2 containing 1% Tannic Acid on Zn substrates

Conclusions

- As observed on Fig. 1 and Fig. 2, the silica coating aged for a total of 21 days, when it was considered to reach a stable EIS spectrum, since the impedance diagrams did not show any significant |Z| changes until the 28th day, as can also be seen on Fig. 1 and Fig. 2.
- Fig.3 and Fig.4. are representative for the effect of the different concentrations of Tannic Acid embedded into the coating matrix. It can be observed that the optimal concentration of Tannic acid for corrosion protection is 1%, since it determines the largest capacitive loop in Nyquist spectrum and the highest |Z| value in Bode diagram. The 0.5% concentration does not seem to affect the silica in any way, since its values are close to the plain silica coatings', while the 2% exhibits the Tannic Acid's corrosive characteristic, by effectively lowering the EIS value of the coating bellow that of the plain silica coating.
- Polarization curves were plotted for the bare zinc, the plain silica and the 0.5%, 1% and 2% Tannic Acid containing silica coatings (Fig.5). The kinetic parameters, as seen in Table 1. show a considerable lowering of the corrosion current densities and corrosion rates of the coating containing the inhibitor, which shows that the presence of Tannic Acid improves the silica coatings' resistance significantly.
- Adhesion tests performed with the optimal Tannic acid concentration and plain silica coating showed 99.9% adhesion, while coating thickness measurements confirmed that the studied coatings were sub-micrometer thin.

References

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