# Synthesis of PANI-vinylpolyester composite coatings for corrosion protection of A16065 MMCs

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**Abstract:** Coatings are formulated by mixing of PANI doped pTSA powder to the matrix polymer. PANI-Vinyl polyester composite is laminated on Al 6065 metal surface by using programmable dip coating unit. PANI- Vinyl polyester composite is characterized by SEM. Pani-Vinyl polyester coated Al 6065 metal matrix and its composites are studied by EIS technique. Impedance values in PANI-Vinyl polyester coated specimens are compared to the uncoated ones in 0.1M HCl medium. With increase of percentage of SiC particulates in matrix causes reduction of corrosion rate inhibition efficiency in composites.

**Keywords:** SEM. Pani-Vinyl polyester. Impedance. Corrosion rate inhibition efficiency.

## 1 Introduction

Conducting polymers made its way into the research by its high conductivity, stability, ease of fabrication and good oxidation-reduction properties compared to other organic compounds. These properties gave conducting polymers an avenue for its usage in electronic appliances, rechargeable batteries, sensors, erosion protection and electroluminescence in light emitting devices. An example for conducting polymer is polythiophene employed as charge dissipation coatings in electron-beam lithography, in electrochromic devices, Polyvinylcarbazole used in electro-luminescence devices, pani is used in erosion protection [1]. P and has replaced the conventional system of coating containing chromates which are highly toxic to the environment. In corrosion protection pani can be used as both individual coating as well as a primer in the coatings. Corrosion protection of pani based coatings are studied by using electrochemical technique. Positive shift in the Ecorr indicates that the surface is anodized and decrease in corrosion rate for the PANI and polydimethylsiloxane (PDMS) blend coating. The advantage of this technique is that we can obtain kinetic parameters like rate of charge transfer, double layer capacitance, pseudo capacitance of the polymer film. Coating can act as either barrier protection or anodic protection [2].

## 2 Experimental

### *2.1 Coating*

Pani composites are prepared by blending method, aims to mix an earlier coalesced pani with a polymer matrix. Al 6065 rectangular test coupon of 0%, 2%, 4% SiC and hybrid composite with equal amounts of SiC and graphite are grinded using various grade emery papers to get mirror finish surface. Matrix polymer used in the present work is thermoset vinyl polyester resin (VPoR) acts as binder. Coatings are formulated by the mixing of green color pani doped pTSA powder with incorporation of accelerator and catalyst to the matrix polymer. VPoR and PANI doped pTSA are taken in 50:1 ratio by weight. . PANI-VPoR composite is coated on the Al surface using programmable dip coating unit. Coated Al 6065 rectangular test coupon are cured at room temperature for 10 hours and during curing process thermoset resin transforms from liquid to gel and eventually to a glassy solid. A hole is drilled through coating to display metal surface to corrodents and corrosion rate is determined by following Potentiodynamic polarization studies [3-5]. Fig. 1 shows PANI-VPoR composite coatings on rectangular test coupons.



**Fig. 1.** PANI-VPoR composite coatings on rectangular test coupons placed in a desiccator

## 2.2 Analysis of Corrosion rate in PANI-VPoR composite coatings

PANI-VPoR coated rectangular test coupons were analyzed for corrosion studies in 0.1M HCl solution using potentiodynamic polarization and EIS studies. Corrosion rate of the rectangular test coupons coated with the pani-VPoR composite are analyzed by using the equation 1. Degree of surface coverage (θ) and % of corrosion rate inhibition efficiency (CoRIE) is determined by availing equations 2 and 3.

$$\text{Corrosion rate (mpy)} = \frac{0.128 \text{ X Equivalent weight X Icorr}}{D} \quad (1)$$

Where mpy is mils penetration per year
Icorr is corrosion current density ($\mu A\ cm^{-2}$)
'D' is density of base metal alloy and its composites ($g\ cm^{-3}$) Equivalent weight 8.9933.

$$\text{Degree of surface coverage } (\theta) = \frac{\text{Icorr- Icorr Inhibition}}{\text{Icorr}} \quad (2)$$

$$\% \text{ CoRIE} = \theta \text{ X } 100 \quad (3)$$

Where Icorr = Corrosion current density of uncoated rectangular test coupons

Icorr Inhibition = Corrosion current density of pani-VpoR coated rectangular test coupons

θ = degree of surface coverage

### *2.3 Electrochemical Testing*

Electrochemical experiments are done by using three electrode compartment cell which is made up of Pyrex glass and the description about electrochemical workstation is cited in the paper [6].

## 2.4 SEM Analysis

Emery paper grit size ranging from 80 to 100 are used for grounding the rectangular specimens of Al 6065 surface and later mirror finished. Fig.2. is SEM image of PANI- VPoR composite coating. From the SEM micrograph it is evident that the coating is uniform, adhesive and crack free.




**Fig.2. SEM image of PANI-VPoR composite coating**

## 3 Results and discussion

### *3.1 Potentiodynamic polarization technique*

OCP measurements are performed for coated Al 6065 and its metal reinforcement in 0.1M HCl solution. OCP values are shifted to noble direction in the case of hybrid composite and with rise in % of SiC content in composites potential drifts to less positive values and corrosion rate enhances. In the case of hybrid composite shift of OCP towards noble direction clearly marks the growth of shielding passive film on the Al substrate. From tafel measurements, it was found that there is reduction in Icorr values for pani-VPoR coated Al 6065 base alloy and its composites than compared to the uncoated specimens. The corrosion rate of pani-VPoR coated hybrid composite in 0.1M HCl solution is 1.254 µmpy and uncoated hybrid composite shows $1.4977 \times 10^{-5}$ mpy. Reduction of corrosion rate in the composites and the role played by the pani as filler in the composites is appreciable. Icorr, âa, âc, Rp and corrosion rates are given in the table 1. Polarization curves of pani-VPoR coated Al 6065 and its composites is given in the fig. 3 [7-17].

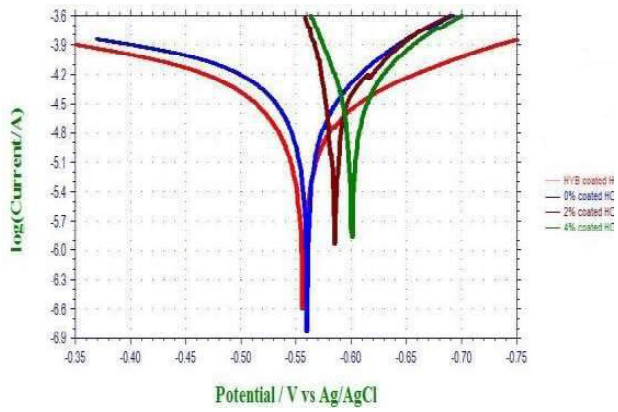



**Fig. 3. Anodic-cathodic polarization curves of PANI-VPoR coated Al 6065 base metal alloy, 2%, 4% and hybrid composite in 0.1M HCl medium**

### *3.2 EIS Measurements*

Fig. 4-7 show Bode impedance plots of Al 6065 and metal reinforcements in 0.1M HCl medium. In both alloy and composites uncoated specimens have low log Z value than that of coated specimens. Enhancement of impedance value in pani-VPoR coated specimens than compared to the uncoated ones, improves the corrosion protection capability. Fig. 8 is the complex plane plot for coated and uncoated Al 6065 rectangular test coupons in 0.1M acid medium.

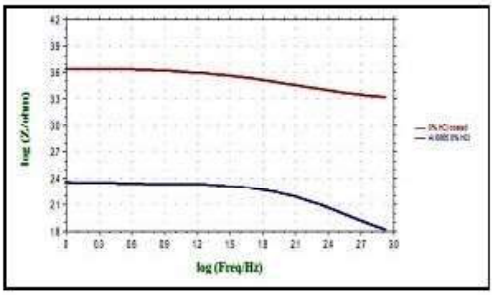



**Fig. 4. Bode impedance plots of coated and uncoated Al 6065 base metal in 0.1M HCl medium**

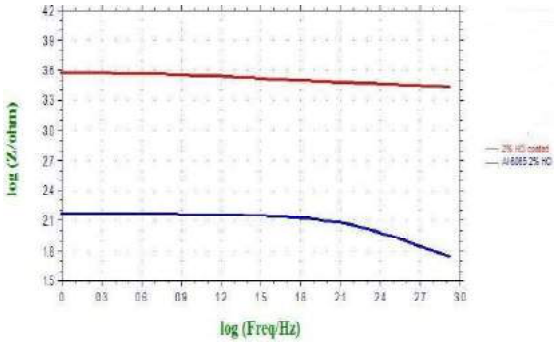



**Fig. 5. Bode impedance plots of coated and uncoated 2% Al 6065 base metal in 0.1M HCl medium**

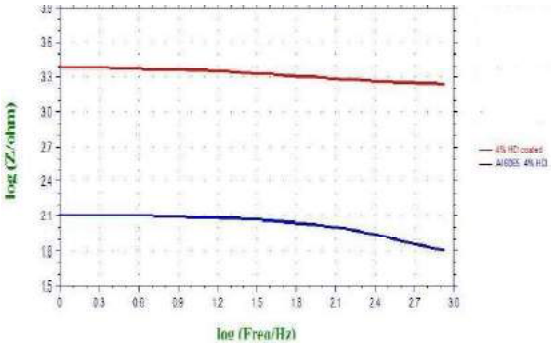



**Fig. 6.** Bode impedance plots of coated and uncoated 4% Al 6065 base metal in 0.1M HCl medium

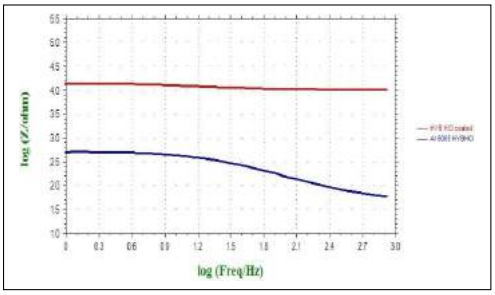



**Fig. 7. Bode impedance plots of coated and uncoated hybrid Al 6065 base metal in 0.1M HCl medium**

**Table 1. Corrosion rates, Icorr, βa, βc and Rp of Al 6065 base metal and its composites in 0.1M HCl medium.**

| Medium | % of SiC | Rp (Ohm) | Icorr(A $cm^{-2}$) X $10^{-6}$ | βa, | βc | Corrosion rate mpy X $10^{-6}$ |
|---|---|---|---|---|---|---|
| 0.1M HCl | 0% | 5987 | 5.927 | 7.186 | 5.067 | 2.436 |
| Medium | 2% | 3890 | 10.99 | 5.110 | 5.508 | 4.505 |
| | 4% | 2115 | 19.95 | 5.394 | 4.910 | 8.156 |
| | Hybrid | 13035 | 3.050 | 6.016 | 4.921 | 1.254 |

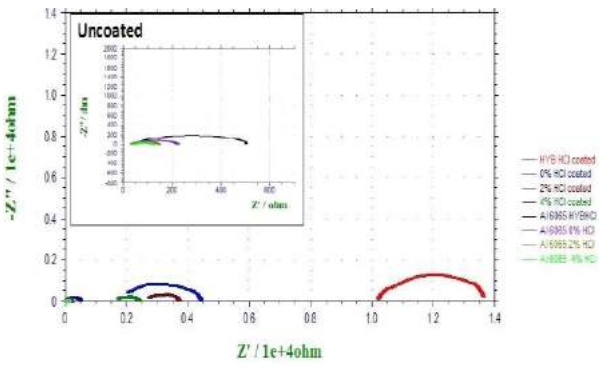



**Fig. 8. Complex plane plots of coated and uncoated Al 6065 alloy and its composites in 0.1M HCl medium**

Presence of single semicircle for the PANI-VPoR coated rectangular test coupons confirms the involvement of single charge transfer in the process [18]. Randel's Equivalent circuit model is used to fit experimental data for pani-VPoR coated composites and the base metal alloy which is given in the fig. 9 and the software used is Z Simp Win 3.21. Table 2 gives the Rc, Rs and Cc parameters for PANI-VPoR coated specimens in 0.1M HCl medium. Impedance parameters like Rc, Cc and Rs represents coating resistance, coating capacitance and solution resistance. High Rc and low Cc value signifies protective nature of pani-VPoR coating on the Al substrate. Hybrid composite with PANI-VPoR coating exhibits high protective nature [19-29].

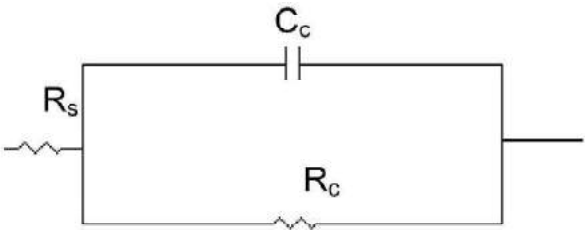



**Fig. 9. Randel's equivalent circuit model for PANI-VPoR Coated Al rectangular test coupon**

**Table 2.** Rc, Rs and Cc parameters for PANI-VPoR coated specimens in 0.1M HCl medium

| % of SiC | Rs (Ohm) | Cc (F) | Rc (Ohm) |
|---|---|---|---|
| 0% | 2167 | $3.065 \times 10^{-6}$ | 2055 |
| 2% | $2.855 \times 10^{7}$ | $4.905 \times 10^{-6}$ | 783.6 |
| 4% | $1.801 \times 10^{8}$ | $6.006 \times 10^{-6}$ | 546.5 |
| Hybrid | $1.044 \times 10^{7}$ | $1.019 \times 10^{-6}$ | 3005 |

### 3.3 Corrosion Protection Performance of Pani-VPoR Coatings

Table 3 lists % CoRIE for different composites and base metal alloy of Al 6065 which are obtained from Eq. 3. With enhancement of percentage of SiC particulates into matrix causes reduction of corrosion inhibition efficiency. PANI-VPoR coating on Al 6065 rectangular test coupons reduces the anodic dissolution reaction by development of passive layer on surface. Coated rectangular test coupons shows OCP value in noble direction than that of uncoated rectangular test coupons because of growth of oxide film. Increase of coating resistance Rc in the pani-VPoR coated specimens than compared to the uncoated ones clearly depicts that the coating is protective in nature. Conducting ability of the coating offers site for $O^2$ reduction reaction and pani-Emeraldine salt (ES) converts into pani-Luecoemeraldine salt (LS) form i.e, conducting ES to non-conducting LS.

**Table 3.** CoRIE for different composites and base metal alloy of Al 6065 in 0.1M HCl medium

| Medium | % of SiC | Icorr ($A\,cm^{-2}$) $X\,10^{-6}$ | Icorr Inhibition ($A\,cm^{-2}$) $X\,10^{-6}$ | θ | % CoRIE |
|---|---|---|---|---|---|
| 0.1M HCl | 0% | 98.1 | 5.927 | 0.9395 | 93.95 |
| | 2% | 103.9 | 1.099 | 0.8942 | 89.42 |
| | 4% | 150.4 | 1.995 | 0.8673 | 86.73 |
| | Hybrid | 36.4 | 3.050 | 0.9162 | 91.62 |

## *4. Conclusions*

PANI-VPoR composite is coated on the Al 6065 rectangular specimens and subjected to Potentiodynamic polarization, EIS and experiments are carried out by using 0.1M HCl medium.

1. Comparing Icorr values for PANI-VPoR coated rectangular test coupons with that of uncoated, it is found there is reduction in Icorr values.
2. Coating offers better corrosion protection which is evident form the ris2e of impedance value in PANI-VPoR coated specimens than compared to the uncoated ones.

3. On comparing corrosion rate of coated ones with that of uncoated ones, PANI-VPoR coated rectangular test coupons offers more corrosion resistance.

4. Research shows that PANI-VPoR composite acts as an effective corrosion protective coating.

**Acknowledgements**

Authors express our sincere thanks to Vision Group on Science & Technology [VGST] Government of Karnataka with grant number GRD114 for funding the research work, R&D center, Department of Chemistry, Ghousia College of Engineering, Ramanagaram.

**Conflict of interest** The authors declare no conflict of interest.

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