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Characterization And Micro Mechanical Properties Of Synthesized Polysiloxane Coating On Steel Substrate

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Abstract

The modern automobile maybe a grand assemblage of components made up of a range of materials. Several of those components have a protective coating applied to improve the looks or offer further sturdiness to the substrate. In many coating systems, the uppermost layer is a clear coating (ranging between 5–50 µm in thickness) which not only protects the underlying layers or substrate from chemical and UV degradation, but also provides protection from mechanical damage that can result in surface scratches. Surface properties of polysiloxane coatings are critical to their application in the many fields, which require long-term protection and aesthetics. In this work, synthesized polysiloxane coatings by spray coatingoces prs. Morphology analysis and elements present in the coatings were analyzed by SEM/EDS. Surface roughness and microhardness properties were tested using surface profilometer and Vickers hardness tester. The morphology analysis shows that the dispersion of polysiloxane is uniformly throughout the substrate. The minimum surface roughness of 0.476 µm was obtained. The microhardness value has increased to 242% compared to steel substrate due to the presence of polysiloxane.

Keywords:*Polysiloxane, Spray coating, PTS, DMDS, GPDMS, FESEM, Micro hardness.*

1. Introduction

A coating is a covering layer applied on the surface of an object, usually said as substrate. The purpose of applying the coating may be decorative, functional or both. The coating itself may be an all over coating, completely covering the substrate or it may be cover parts of the substrate [1]. The functional coatings may be applied to change the surface properties of the substrate such as adhesion, wettability, corrosion resistance, wear resistance. The coating adds a completely new property such as a magnetic response or electrical conductivity and forms an essential part of the finished product. A major consideration for most coating processes is that the coating is to be applied at a controlled thickness and a number of different processes. Many industrial coating processes involve the application of a thin film of functional material to a substrate such as paper, fabric, film, foil (or) sheet stock. Different types of coating techniques are available for protecting the surface and to improve the material properties and these coating methods are deposition process (CVD, PVD), conversion coating, plating and spraying process [2]. In Spray coating, where a device sprays a coating through the air onto a surface[3]. The most common types employ compressed gas. It is applied to an object using an air-pressurized spray gun. The air gun has a nozzle, basin and air compressor. When the trigger is pressed, the solution mixes with the compressed air stream and is released in a fine spray. Composite coating is one of the improved methods, which is used to increase the life of the components. It is used in automobiles, marines, aircraft etc., composite coating can be used in automotive panels to improve its surface finish and scratch protection. Polysiloxane is one of the best surface protectors from corrosion and scratch. Some of the researchers investigated composite coating by spray coating process. [4].

2. Literature Survey

Hang hua, et, al,2018[5], studied the summary of functionalized graphene oxide (fgo) was synthesized with 3-glycidoxy-propyl trimethoxy silane (gptms) and subsequently incorporated into polysiloxane coatings to improve the mechanical properties, especially scratch resistance, through the sol-gel and epoxy/amino curing reactions. The result shows that the surface functionalization of graphene oxide (go) was evidenced by tem, ftir and xps. Yu-hui huang, et, al, 2019[6], evaluate the process of preparing anti-glare thin films by spray-coating silica sol-gel to soda-lime glass. The experimental results indicate that the factors of sol-gel deliver pressure, air transport pressure, and displacement speed exhibit a significant effect on the haze, gloss, and ra. Yongqiang, et, al, 2019[7], modified silica nanoparticles (m-sio2) containing epoxy group dispersed homogeneously in polysiloxane coatings by in situ polymerization process. According to the results of macro and nano scratch tests, the first critical loads for polysiloxane coating with 0.75 wt % m-sio2 were improved 66.7% and 73.3% respectively compared to pure polysiloxane coating. Yan liang, et, al, 2011[8], successfully synthesized a new modified polysiloxane, perylene-containing polysiloxane (pcp), by amine-terminated polysiloxane (atp) and 3, 4,9,10 perylene tetracarboxylic dianhydride. The synthesized compound was characterized (ft-ir) and 1h nuclear magnetic resonance (1h nmr). The thermal analysis of the pcp indicates that the modified polysiloxane has outstanding thermal stability.

Based on the literature survey, some of the work has been done on scratch resistance with different Nano-additives over the automobile appliances to increase the lifetime of the material. Overall, the critical performance factors driving the development and use of advanced automotive coatings and coating technologies are aesthetic characteristics, corrosion protection, mass production, cost and environmental requirements and appearance and durability. The main objective of this work is the combination of Phenyltrimethoxysilane (PTMS), Dimethoxydimethylsilane (DMDS), 3-Glycidoxypropylmethyldimethoxysilane (GDS) is used for coating over the substrate using the spray coating process. Scanning electron microscopy (SEM) for microstructure analysis was done. Phase and chemical composition will be carried out using XRD and energy dispersive x-ray spectroscopy (EDAX). Optical microscopy is used to examine the microstructure of the coated samples.

3. Materials And Science

A. Materials

Steel alloy was purchased from M/s. steel house, Chennai-India. Chemical composition of steel substrate is given in Table.1. Phenyltrimethoxysilane, Dimethoxydimethylsilane, and 3-Glycidoxypropylmethyldimethoxysilane were purchased from M/s. Rajendra Scientific, Puducherry-India. Properties of chemicals are given in Table.2

TABLE I
Chemical composition of steel substrate

Fe	Mn	Pb	Al	Cu	Cr	Ni	Mo	others
99.186	0.181	0.08	0.066	0.103	0.045	0.029	0.027	0.283

TABLE II
Properties of PTMS, DMDS, and GDS

Materials	Molecular wt (g/mol)	Boiling point (C)	Specific gravity	Appearance
Phenyltrimethoxysilane ($C_9H_{14}O_3Si$)	198.29	211	1.064	

Dimethyldimethoxysilane ($C_6H_{16}O_2Si$)	148.28	114.5	0.8395	Colourless transparent
3-Glycidoxypropylmethyl Dimethoxysilane ($C_9H_{17}O_4Si$)	217.31	100	1.02	

B. Synthesis of polysiloxane

Initially, 30 ml of phenyltrimethoxysilane, 25 ml of Dimethoxydimethylsilane and 30 ml of 3-Glycidoxypropylmethyldimethoxysilane were dropped into a glass beaker, along with that 4 ml of deionized water and 4 ml of ethanol is added. The mixed solution is then stirred for 6 h at a temperature 60℃ with the help of magnetic stirrer.

C. Experimental procedure

Materials used for making the setup for the spray coating process are pressure regulator, cylinder, airbrush (Spray gun), and air inflator. The air inflator is connected to the input valve of the cylindrical tank and make tight, from the output valve the pipe is connected with the help of the pipe-tightening clip. Pressure regulator is fixed at the end of the pipe by fixing the nipple in it. The nipple is connected to the inlet side of the regulator. The pressurized air is taken from the outlet of the regulator. Another piece of pipe is connected to the airbrush (spray gun) and made tight with the clip. The air inflator is given power supply with Switched-Mode Power Supply (SMPS) and switched on. The air flows from the inflator to the tank and get compressed. The required pressure is set with the help of the knob in the regulator and by pressing the trigger in the spray gun the compressed air is released for setting the pressure. The polysiloxane chemical is poured into the storage cup in the spray gun so that atomized air mixes with the polysiloxane. Pressure could be varied with respect to the convenience. Table 3.2 shows the spray coating process parameters.

Table III
Spray coating process parameters

Sl. No	Parameters	Specifications
1	Pressure	1.75 Kgf/cm^2
2	Substrate distance	30, 25, 20, 15, 10 , and 5cm
3	Spray time	15

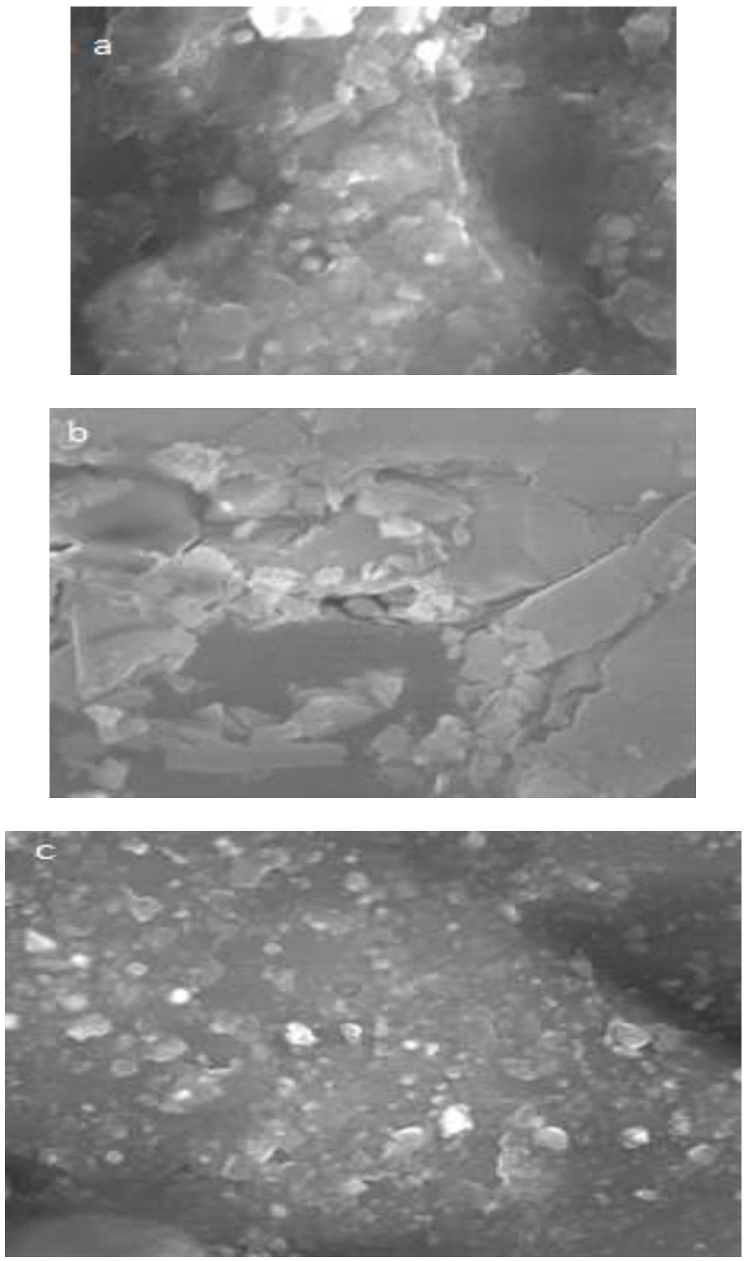
D. Characterization and mechanical properties

Field Emission Scanning Electron Microscopy (FEI QUANTA 200 FEG/SEM) analyzed the morphology and elements present in the coated sample with Energy Dispersive Spectrometer (SEM/EDS) at SRM University- Chennai. Micro hardness tests were conducted in Vicker's hardness testing machine. During the test, a load of 50 g was applied to the material for 10 s. at three different locations on the test material and the average value was taken. The surface roughness was measured using stylus profilometer surface roughness tester at a distance 30 mm length with a probe speed of 0.5 mm/sec. Three different locations and its average value noted as the final surface roughness. Coating thickness was measured using coating thickness (Make: Mitutoyo- Japan).

4. Results & Discussion

A. Characterization study - FESEM

Fig 1(a-f) shows the SEM micrographs of the hybrid composite coated surfaces of the steel substrate. From Fig.1a to Fig.4d, it can be noted that the distribution of Polysiloxane is dispersed uniform without the formation of agglomeration. However, the SEM micrograph of Fig.1e-f shows agglomerations of reinforcement and voids due to the scattering effect and decreasing the distance from nozzle to substrate. It can be concluded that up to 15 cm distance. Up to that distance, spray coating gives good dispersion of fillers uniformly.



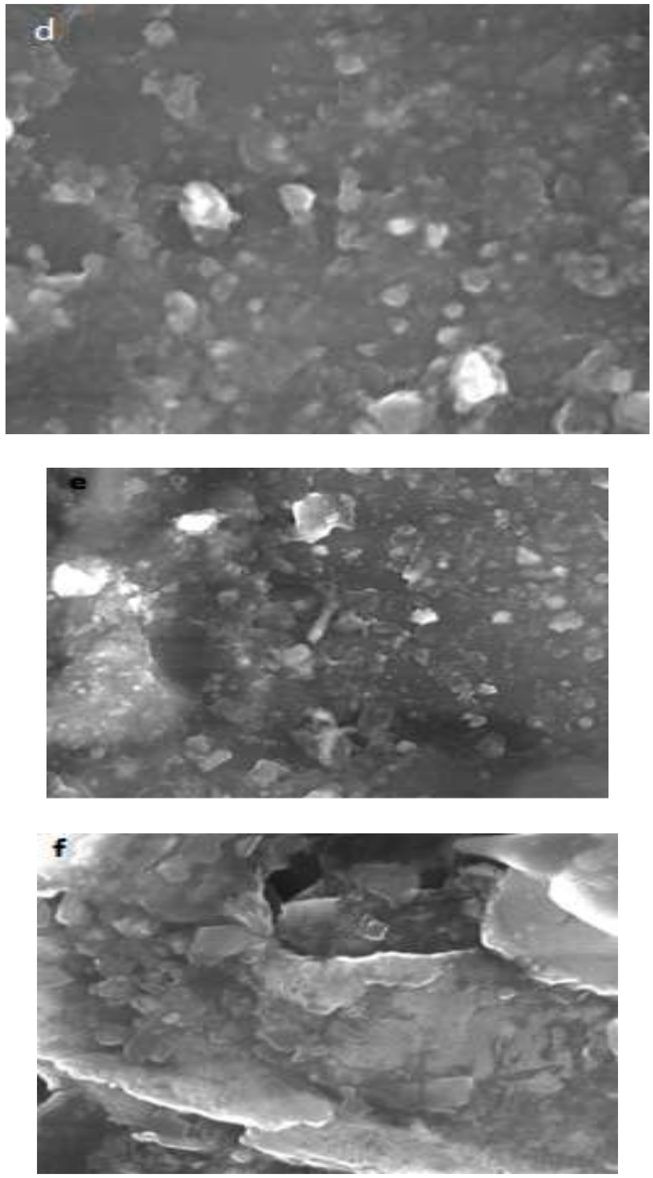


Fig.1 (a-e) SEM Analysis of hybrid composite coatings

B. *EDS*

The EDS analyses were performed to confirm the presence of various elements in the steel hybrid composites. Fig. 2 shows the EDS result of hybrid composite indicates the presence of four elements Al, Si, C, and O and it proves the presence of Al (presented in metallic coating on steel substrate), Polysiloxane in the hybrid composites.

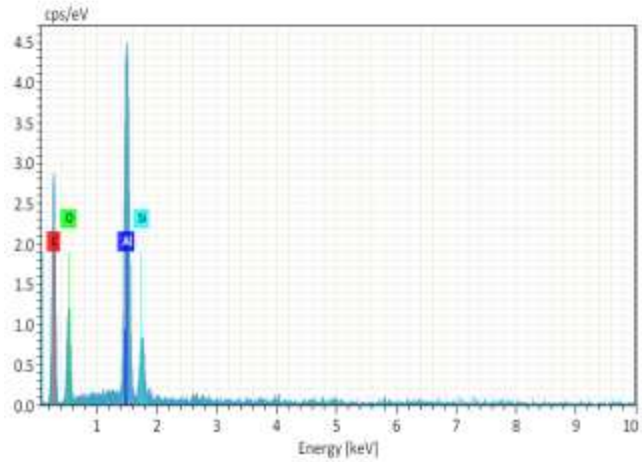


Fig.2 (e) EDS Analysis of hybrid composite coatings

C. Coating thickness

Fig.3 shows that the coating thickness of hybrid composite results in that increase of coating thickness with a maximum thickness of 135 µm at a distance of 10 cm from the substrate. Further, it decreases the coating thickness due to the scattering effect, formation agglomeration and voids as seen in Fig 1-d.

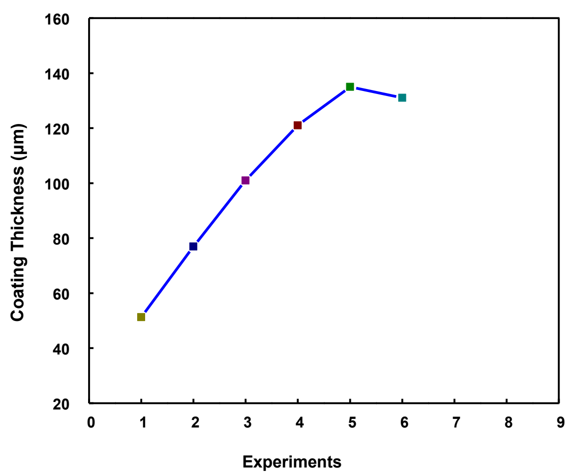


Fig.3 Coating thickness of hybrid composite

D. Surface roughness

Fig.4 shows that the surface roughness of the hybrid composite coating measured using a stylus profilometer. The surface roughness test was performed at a coating length of 30 mm with a probe speed of 0.5 mm/s used. it can be noticed that surface roughness of the hybrid composite coating is smooth (Ref) due to the presence of polysiloxane. The minimum average surface roughness was found to be 0.476 µm at a distance of 15 cm from the substrate.

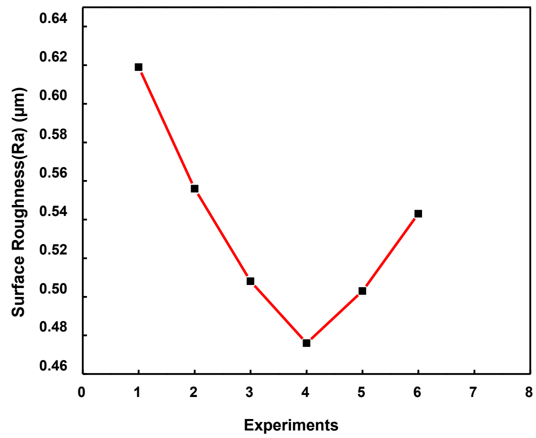


Fig.4 Surface roughness of hybrid composite

E. *Micro-hardness*

Fig 5 shows the micro hardness of hybrid composite. Initially, the microhardness value for uncoated steel substrate is 23.4 HV. After an addition PTS, DMDS, and GPDMS particles into the substrate. The result shows that the increase in % of micro hardness is 242.52 compared to the uncoated steel substrate due to the addition of Polysiloxane coating (Yongqiang, et, al, 2019). Further, it decreases due to the formation of agglomeration and voids as seen in Fig 1-e-f

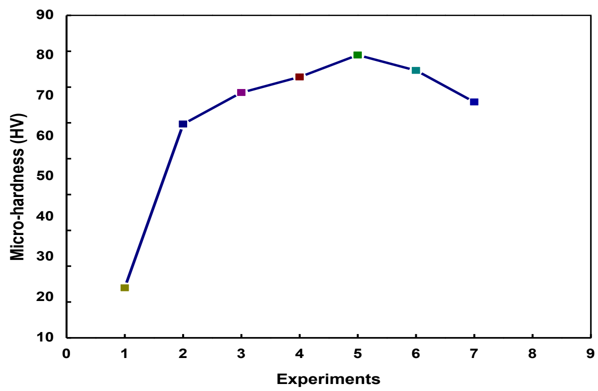


Fig.5 Micro hardness of hybrid composite

5. Conclusion

In conclusion, we demonstrate a simple spraying method for the fabrication polysiloxane hybrid composite coating by six variations (distance between the substrate and the nozzle) and the following results were made; SEM analysis shows good dispersion of polysiloxane on a substrate with a distance of 15 cm and to confirm the presence of elements on the coated substrate by EDS. Minimum surface roughness and maximum micro hardness 0.476 µm, 80.15 HV respectively was obtained at a pressure of 1.40 kgf/cm^2, time of 15s and a distance of 15 cm from the substrate.

References

[1] L.Q. Feng, B. Benhamida, C.Y. Lu, L.P. Sung, P. Morel, A.T. Detwiler, J.M. Skelly, L.T. Baker, D. Bhattacharya, "Fundamentals and characterizations of scratch resistance on automotive clearcoats", Prog. Org. Coat. 125 (2018) 339–347.

[2] Anish, R., Singh, G. R., &Sivapragash, M. (2012). Techniques for processing metal matrix composite; A survey. Procedia engineering, 38, 3846-3854

[3] P. Munzert, N. Danz, A. Sinibaldi, F. Michelotti, "Multilayer coatings for Bloch surface wave optical biosensors", Surf. Coat. Technol. 314 (2017) 79–84.

[4] K. Taeschner, H. Bartzsch, P. Frach, E. Schultheiss, "Scratch resistant optical coatings on polymers by magnetron-plasma-enhanced chemical vapor deposition", Thin Solid Films 520 (2012) 4150–4154

[5] H. Jiang, Y.F. Wei, Q. Cheng, Z.M. Zhu, "Scratch behavior of low density polyethylene film: Effects of pre-stretch and aging", Mater. Des. 157 (2018) 235– 243.

[6] L.F. Yi, Y. Xu, D. Li, J.B. Shen, S.Y. Guo, H.J. Sue, "Fabrication of Scratch Resistant Polylactide with Multilayered Shishkebab Structure through Layer-Multiplying Coextrusion", Ind. Eng. Chem. Res. 57 (2018) 4320−4328.

[7] M.M. Hossain, S. Xiao, H.J. Sue, M. Kotaki, "Scratch behavior of multilayer polymeric coating systems, Mater". Des. 128 (2017) 143–149

[8] M. Zouari, M. Kharrat, M. Dammak, M. Barletta, "Scratch resistance and tribological performance of thermosetting composite powder coatings system: A comparative evaluation", Surf. Coat. Technol. 263 (2015) 27–35

[9] H. Hua, S.Y. Zhao, G. Sun, Y.J. Zhong, B. You, "Evaluation of scratch resistance of functionalized graphene oxide/polysiloxane nanocomposite coatings", Prog. Org. Coat. 117 (2018) 118–129