

Corrosion Studies on Silver coated Second Surface Mirror Reflectors for Parabolic Trough collectors

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Abstract

Most solar thermal power generation systems use mirrors over a large area to concentrate solar energy onto the absorber tube. The optical properties of the mirrors directly affect the performance of the concentrating system. Corrosion attack was observed on these mirrors exposed to ambient which cause reduction in optical efficiency as well as working life of the mirrors. Stereo micrograph images and Energy-dispersive X-ray spectroscopy (EDS) results of the mirror samples confirmed loss of silver due to corrosion. Accelerated corrosion testing of few unexposed mirror samples confirmed that factors such as moisture permeability and the reaction of silver with chloride ions at the Cu-Ag interface play a key role in the degradation of the thin silver metal coating. Additional polymer coating on back surface of the mirror was found to be effective in resisting corrosion from ozone and UV radiation. This paper presents study of corrosion prevention of the thin silver layer of the mirror by different polymer protective coating given additionally on their back surfaces. To improve the life of mirror the thin metal coatings must have uniform thickness, be contaminant free, properly edge sealed and have protective coating applied on the back surface.

Keywords: concentrated solar power, mirrors, silver, corrosion, pitting, polymer coatings.

Introduction

Global demand for energy has increased many-fold since 19th century after the emergence of all aspects of the industrial revolution. Some statistics forecast the exhaustion of global conventional oil reserves in 50 years as consumption is inversely proportional to available resources. To overcome the fuel crisis, the search for alternate unconventional energy resources, such as energy from the sun, wind and other sources, appears to offer a feasible solution through the development of new technologies [1]. Energy from the sun can be harvested by direct photovoltaic and other indirect solar thermal methods of power production, though these have less conversion efficiency and will require huge investments and installation areas. Among the different solar thermal methods available, concentrated

solar power (CSP) is a known technology in which energy is harvested by means of lenses or mirrors to concentrate incident solar energy on to a heat collection element coupled to a solar tracking system. The mirrors often focus a large area of sunlight into a small beam which is characterized by the concentration ratio. Based on the location of the mirror coating on the substrate surface, mirrors are configured as first-surface and second-surface mirrors. Usually, the second-surface mirrors are best known for their ability to perform at different weather conditions, while first-surface mirrors are known for their structural properties.

The optical efficiency of the mirrors is absolutely vital to focus the concentrated energy onto the collection element. The performance potential of a mirror material for solar concentrator application can be characterized by reflectivity, dimensional stability, and resistance to abrasion as well as corrosion [1].

The major cost component in the fabrication of a mirror is the silvering process and followed by the cost of the glass substrate itself. The mirrors are expected to deliver designed performance at any climatic condition over its lifetime. But, the mirrors fail during prolonged exposure in actual working conditions. Corrosion is resulted by natural weathering including chemical attack and physical damage due to sand abrasion. Though the multiple coatings of paint are applied to protect the thin metal layers, the performance degrades on UV exposure. So, a protective coating resisting corrosion attack of thin metal films of glass mirrors must satisfy the criteria of protection from weathering, chemical attack, durability and water resistance. The protective coating must give satisfactory performance especially under hot and humid climates. Usually, in a solar thermal plant, glass mirrors with poor optical efficiency are replaced frequently either because of breakage of the glass due to heavy winds, or as a result of corrosion damage to the silver coating. The loss in reflectance of mirror by 1% will lead to a change in thermal delivery performance of 1.2%, since the radiation input to the receiver is directly proportional to change in reflectance of the mirror [7]. Currently, many large scale solar thermal applications that are being planned in Asia and other pacific regions. The solar grade mirrors for these plants are imported from the West. This is not a sustainable option for establishing solar power plants, especially in developing countries such as India where not even one solar thermal based power plant is operational. In this present paper, the experience of the author and his team is discussed with the use of custom built second surface mirrors for concentrator solar applications. In this present investigation, an attempt was made to use a clear glass substrate with low iron content that is available in the current Indian market to make mirrors for solar thermal applications without compromising their optical properties or performance. The problem encountered by the team in terms of mirror performance due to

corrosion attack and its reasons for degradation is discussed in detail.

Mechanism of Mirror Degradation

The coating of insulators like glass with metals such as silver is done by baking, CVD, ion sputtering and chemical plating processes [1,2]. The basic step for preparing solar mirrors by the chemical process method consists of a series of steps starting with the selection of glass with low iron content and a high solar transmittance of greater than 98%. The glass surface is then processed for cleaning to remove oil and dirt residues. The properly cleaned surface is then sensitized with tin chloride solution to deposit thin silver layer of thickness of a 0.07- 0.1 μm which forms the reflective layer. It is then followed by deposition of intermediate copper layer to form cathodic protective layer. The thin metal layers are prevented from degradation by multiple layers of paint applied at the back.

Silver layer is transparent to UV at light wavelength of 320 nm and becomes sensitive to parameters like temperature, humidity and the ambient atmosphere [7]. Basically under ambient conditions, silver is thermodynamically unstable compared to silver oxide [Wan et al., corrosion Vol.68, 3]. Also, recent studies on silver corrosion have shown that at 300 K under ambient pressure and 5 mol% Ozone (O_3) present in oxygen, silver gets corroded [25-26]. The ozone (O_3) is split to atomic oxygen, which is a highly reactive species, by UVA light (295-365 nm) [22-23]. Other problems with silver were related to formation of agglomerates and immediate reaction to free radicals in polluted environment. Silver when exposed to highly active chemical species such as hydrogen sulphide, sulphur dioxide and hydrochloric acid result in separation and de-adhesion of the silver layer from the glass since diffusion of the ions into the interfacial layers between the paint, copper, silver and glass takes place [4]. This problem has to be properly addressed to make economically viable and durable silvered mirrors. Mirrors produced by vacuum deposition and vacuum evaporation processes have fewer impurities and possess good optical properties. Many researchers have attempted and devised methods to improve the adhesion strength of the silver layer to the glass substrate. Pitts et al. [4] developed a method for adhering silver to a glass substrate by obtaining a silicon-enriched substrate by bombardment of electrons, ions or a neutron beam and applying a polymer-based protective coating to avoid the use of heavy metal-based paints. Blees and Weert [5] patented a useful method for silver plating on glass substrates used in thin electron displays and thin gas discharge displays, where two layers of silver were reinforced consecutively by immersion in an electroless silver bath and then by electro-deposition from a cyanide-free bath containing ammonia as the complex agent for the silver ions. Also, exterior condensation of water penetrating

through micro pores in the back protective coating support corrosion. It has been reported from neutral salt spray testing that an interfacial de-cohesion may occur between the glass and the silver coating [11]. The prevention of corrosion and degradation of mirror coatings in a solar field is essential as the attack results in poor mirror performance.

A general expression for the damage function involving atmospheric corrodents can be written as equation (1) [13]:

$$R_m = f(K, [H_2O], T, M) k_{i,m} [C_i] \quad (1)$$

where R_m is the rate of damage of material m ; K is a mass transfer coefficient; $[H_2O]$ is some appropriate measure of available water on the material surface (involving relative humidity, precipitation rate, time of wetness, etc.); T is the ambient temperature; M is an appropriate parameter of material morphology; and $k_{i,m}$ is the rate of reaction between corrodent i and material m .

Numerous testing procedures have been invoked over the past few years to assess the durability of silver/glass mirrors and to determine models for their degradation in the various exposure environments. The following summary can be drawn from the previous literature:

Temperature cycling at high humidity causes severe edge corrosion and edge delamination in some specimens. The length of time at high temperature is a critical factor in degradation. The presence of ultraviolet light or typical gaseous pollutants does not accelerate significantly the observed degradation. The combined degradation rates were the sums of the degradation rates observed for the individual parameters. Higher variation in degradation rate can be observed between specimens of a single mirror type and even between different areas of a single specimen. This variability in performance appears to be caused by non-uniformity in the thickness and composition of the various reflecting and protective layers that constitute a complete mirror. The non-uniformity is probably a consequence of the wet chemistry mirroring process used by all commercial silver/glass mirroring companies. Hence, many specimens and measurements are needed to obtain results with high statistical precision [3].

Present Study on Glass Mirrors

A rooftop experimental set up to understand power generation by Solar Thermal systems was installed on the rooftop of SSN Research Centre (SSNRC) located at Kalavakkam, Tamil Nadu, India. The details of the location are given in Table 1. The research centre is located very close to the sea coast, which is one of the most corrosion-prone places in the country, as is indicated on the corrosion map of India [14]. The descriptions of the samples considered in the present study for accelerated corrosion test and different characterization studies are listed in Table 2 and Table 3 respectively. In the present investigation, second surface glass mirrors were fabricated for research purposes to be used as reflectors for a prototype parabolic collector. These mirrors were custom made from 6 mm thick clear glass of Saint Gobain glass India Ltd., make. The 1 meter x 3 meter rectangular plain glass piece was bent into parabolic profile by the gravity method and silver coating was given to the glass substrate using the wet chemical electroless process with the help of a local fabricator. The coated mirrors were mounted at site for experimentation. During prolonged exposure to the outdoor conditions for about 6 months, corrosion attack on the glass mirrors was observed. The thin layers of coating on the mirror tend to become brittle and then peel off from the glass substrate. At some portions, the thin silver coating degraded completely leaving the plain glass as shown in Fig.1a. Since, corrosion was observed on glass mirrors kept outdoor and indoor, mirror samples were carefully picked to perform different characterization tests. Mirror samples were cut from the externally exposed mirrors installed for experimentation purpose, namely type 1. A few spare mirrors were kept indoor for replacement during experimentation and named them type 2. But, on visual examination after a certain period of time, it is observed that almost entire mirror coating surface of type 2 mirror the thin layers of coating was intact except at a few places where edge and pitting corrosion occurred. So, a few samples measuring 2 inch X 2 inch were carefully chosen from the non corroded portions of type 2 mirror for sampling and subjected them to humidity and salt spray accelerated corrosion tests for 150 hours. Type 2 Mirror samples commercially available in the market for domestic applications were considered to know their corrosion behaviour for comparison study. These glass mirrors having 4mm thickness manufactured by Saint Gobain Glass India Ltd. To study the prevention of corrosion, organic coating such as PU, Teflon and PVDE were given to samples measuring 2 inch X 2 inch of type 2 mirror and are considered as type 3. These coatings were considered to have different level of permeability to diffuse external elements through them. Also, the type 3 mirror samples were properly edge sealed to prevent diffusion of moisture.

Accelerated corrosion tests such as Humidity and Salt spray tests were performed on type 2 and type 3 samples to quantify the rate of corrosion. The condensing humidity test with 100% relative humidity was performed for 150 hours for different mirror samples as per ASTM D 2247 [15] with test chamber temperature maintained at 38°C (100°F). Neutral salt spray (fog) test [16] was also carried out for 168 hours on the different mirror samples, as per ASTM B 117a [17] and ISO 9227:2006 [16]. These standard accelerated corrosion tests were usually performed for comparing corrosion resistance of different inorganic and organic coatings. The samples were characterized for film thickness, composition of different elements, etc., using different characterization equipment namely scanning electron microscope (SEM) with energy dispersive X-ray spectrometry (EDX), X-ray Fluorescence (XRF) and Elemental analysis respectively. SEM and EDX studies were performed using Quanta FEG 200 model High Resolution Scanning Electron Microscope from FEI Company. Elemental analysis based on inductively coupled plasma optical emission spectrometry (ICP-OES) technique was performed using Optima 5300DV model from Perkin Elmer Inc. Elemental analysis was performed on the mirror samples before and after subjecting them to corrosion tests to quantify the rate of degradation of each particular element. The analysis was performed considering 1 cm² sample area at different locations of the mirror. The results indicate a drop in weight percentage of silver and copper elements for the samples subjected to corrosion tests compared to weight ratio before corrosion test.

TABLE 1. Details of SSNRC Location

Parameter	Value
Latitude	12°44' N
Longitude	80°11' E
Height from the Sea level	6.7m
Average Insolation	650 W/m ²
Average Annual Temperature	35°C
Average Rainfall	1300mm

TABLE 2. Description of mirror samples used in the analysis

Name of the Sample	Type of Accelerated testing	Thickness of Sample	Protective coating
HT 1	Humidity test	6 mm	Lead oxide based paint
HT 2	Humidity test	6 mm	Lead oxide based paint + Transparent PU coating
HT 3	Humidity test	6 mm	Lead oxide based paint + white PU coating
HT 4	Humidity test	4 mm	Lead oxide based paint + white PU coating
SS 1	Salt spray test	6 mm	Lead oxide based paint
SS 2	Salt spray test	6 mm	Lead oxide based paint
SS 3	Salt spray test	6 mm	Lead oxide based paint + white PU coating
SS 4	Salt spray test	6 mm	Lead oxide based paint + white PU coating
SS 5	Salt spray test	4 mm	Lead oxide based paint
SS 6	Salt spray test	4 mm	Lead oxide based paint + white PU coating

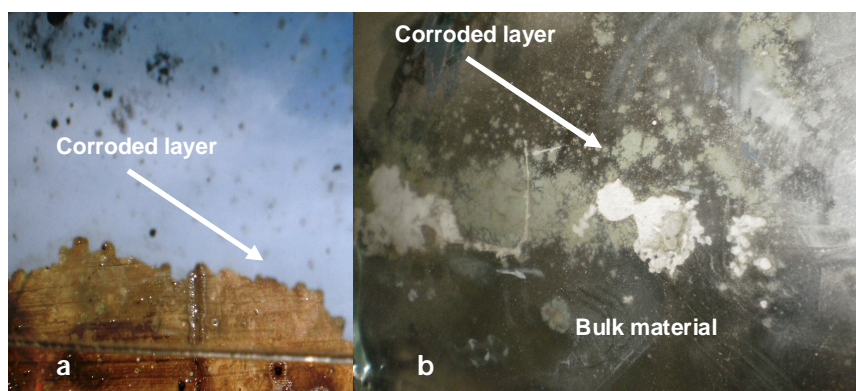


Fig. 1 a) Edge corrosion on the mirrors kept indoor b) Pitting corrosion on the mirrors kept indoor

Table 3. Description of the mirror samples used in the present study

Type	Description
1	Mirror samples exposed to ambient environment
2	Mirror samples kept indoor and subjected to accelerated corrosion tests
3	Samples with protective back coating such as Teflon, PU and PVDE and subjected to accelerated corrosion tests

Results and Discussion

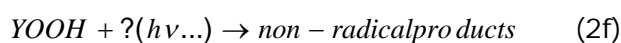
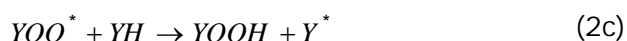
Glass mirrors having parabolic shape was fabricated by gravity method for bending and wet chemical electroless process for coating silver on glass. The glass mirrors were used as reflectors for parabolic trough collector and exposed to ambient environment. Initially the glass mirrors were provided with lead based paint as the back protective coatings. But, over a period of time performance of the installed mirrors degraded due to corrosion. To understand the corrosion aspects of the given mirror coatings, samples measuring 2 inch x

2 inch were cut from three different types of mirrors and named them type 1, 2 and 3 respectively. Edge and pitting corrosion were also observed on the spare mirrors as shown in Fig.1b even though they had been kept indoors for future use. The type 2 and type 3 mirror samples were tested under accelerated environmental conditions. Stereo micrograph images were taken at the corroded regions of all the samples. The type 2 mirror samples exhibited pitting corrosion after subjecting them continuously to 100% RH and salt fog during humidity and salt spray test for 150 hours and 168 hours respectively. It was observed from SEM and XRF analysis of type 1 sample that the thin silver coating on the glass substrate had uneven coating thickness varying roughly from $0.6675\ \mu\text{m}$ to $0.7949\ \mu\text{m}$ as shown in Fig 2. The reason for uneven thickness of the coating must be due to erosion of the thin silver layer along with other coating layers supporting the reflective layer. Also, visual inspection of the mirror showed decrease in reflectance due to erosion of the silver layer. EDX analysis performed on type 1 and accelerated corrosion tested type 2 sample, resulted in presence of Magnesium (Mg) element. The weight percentage of Magnesium present in the sample subjected to corrosion test was observed to be more. The EDX analysis of type 1 and 2 samples had also shown much reduction in weight percentage of silver and complete loss of copper. The elemental analysis results of these samples supported the argument as shown in Table 4 and 5 respectively.

The glass mirrors exposed to hot and humid climate and UV radiation undergo corrosion in a sequential manner. The increase in the amount of magnesium content observed during the EDX analysis of Type 1 mirror sample can be attributed to exposure of the mirror sample to ambient saline atmosphere. The Mg ions present as free radicals in the ambient air were high since the experiment location is in close proximity to the sea coast, within a radial distance of 2 kilometres from the Bay of Bengal. The earlier observations had reported presence of NaCl and MgCl_2 salts as primary aerosols in the atmosphere near the areas close to sea, which are highly saline [18]. Since, the mirror samples were continuously exposed at a location very near to sea, there is relatively higher chance for presence of higher relative humidity in the ambient air. In this condition, a thin film of electrolyte formed on a metallic surface is capable of initiating atmospheric corrosion when exposed to a critical level of humidity. The corrosive contaminants present in the thin film have relatively high concentrations under alternate wet and dry conditions [18]. The layer of magnesium chloride (MgCl_2) and sodium chloride (NaCl) deposits formed on a metallic surface will apparently make the surface wet at 34% RH and 77% RH respectively.

In the case of type I mirror, two reasons can be hypothesized for the corrosion of the mirror. One particular reason was the deterioration of the protective paint layer which is confirmed by the change in colour as shown in Fig.3. The protective paint layer is continuously subjected to photo-catalytic activity of solar radiation and temperature cycling

during the day. When the ultra-violet radiation ($295 < \lambda < 400$ nm) in sunlight is absorbed by paint, it starts to cleave weak chemical bonds, leading to photo-oxidation (bleaching, fading, discoloration, chalking, brittleness and cracking) as shown in Fig 4. The bond cleavages resulting from UV absorption cause the formation of radicals. Each free radical will trigger a chain of reactions (in the presence of air), leading to more bond cleavages and destruction explained by the following reactions [19].



Infra-red radiation causes the resin binder in the paint to dry out leading to the structural failure of paints thereby causing cracking of the paint layer. The second reason for degradation of the Type 1 mirror is the chemical reactions occurring at the different interfaces of the mirror coatings, viz., the paint-Cu interface and Cu-Ag interface [10].

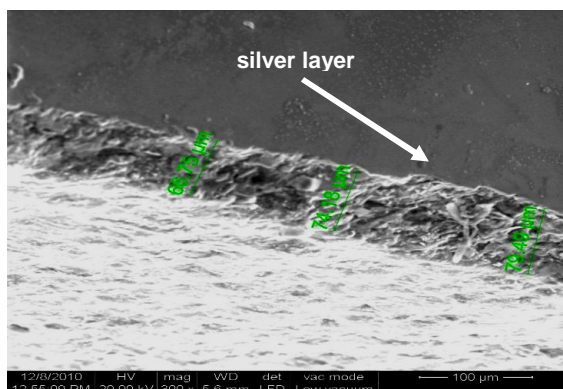


Fig 2. Cross-sectional view of type 1 mirror sample coating

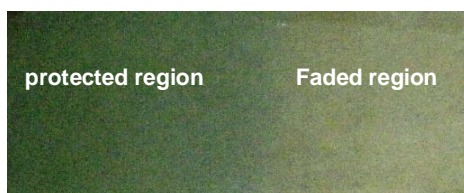


Fig 3. Photograph showing faded and protected regions of the mirror sample

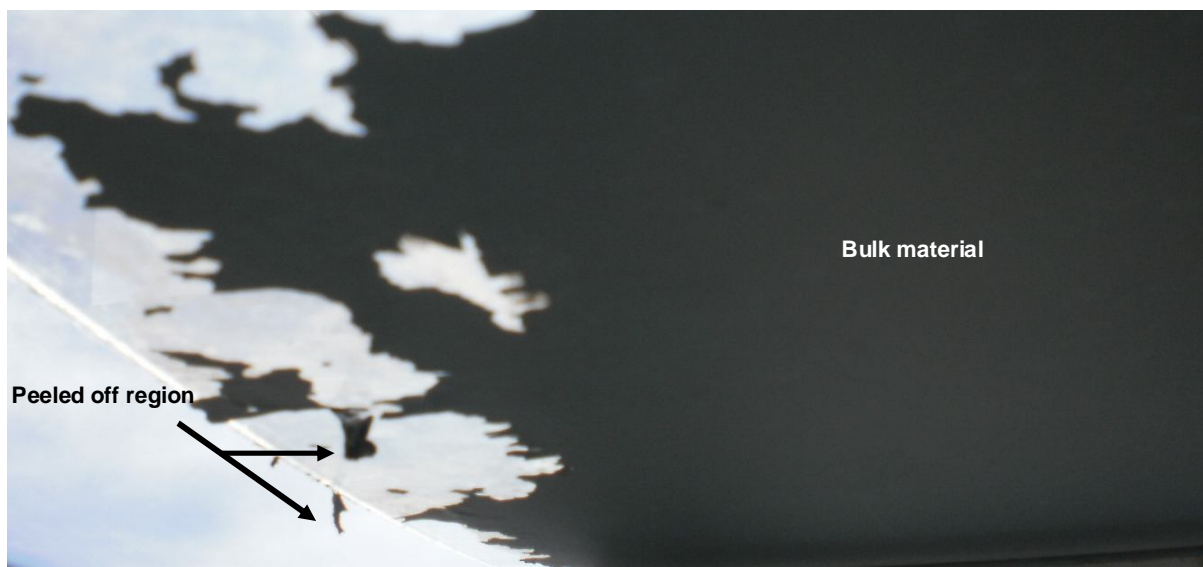


Fig. 4. Photograph showing peeled off regions of the mirror sample due to corrosion

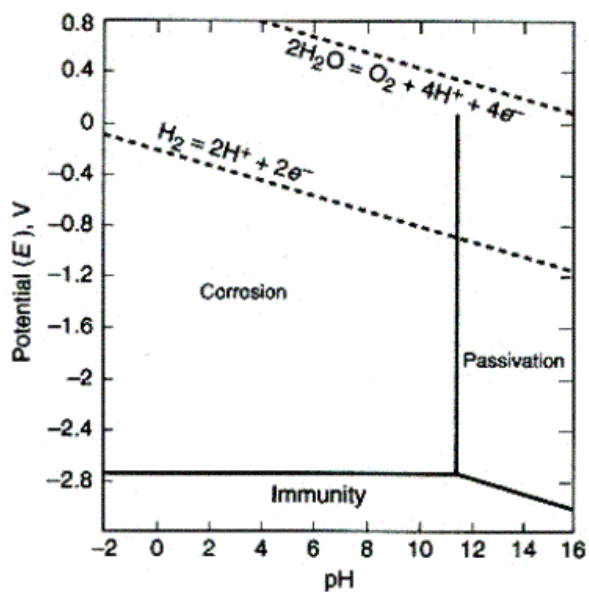


Fig. 5. Magnesium in water Pourbaix diagram at 25 °C

Table 4. EDX Analysis of mirror samples before and after accelerated corrosion tests

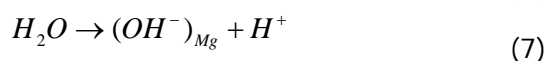
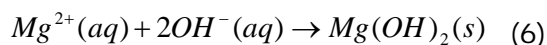
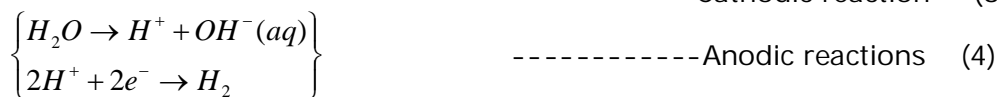
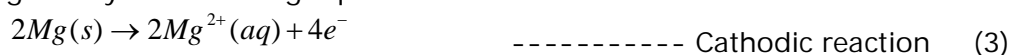
Element	Type 1 Uncorroded Mirror Sample Wt % (A)	Type 1 Corroded Mirror Sample Wt % (B)	$[(A-B)/A]*100$
O K	51.91	35.07	32.44076286
NaK	11.57	1.75	84.87467589
MgK	2.79	7.11	-154.8387097
AlK	0.9	0.33	63.33333333
SiK	27.29	15.09	44.70502015
AgL	0.21	0.15	28.57142857
SnL	0.43	0.21	51.1627907
CuK	0.38	0	100
PbL	Not Estimated	3.4	Not Estimated
CaK	4.94	1.1	77.73279352

Table 5. Elemental Analysis using ICP-OES of type 1 mirror samples before and after accelerated corrosion tests

Element	Weight before accelerated corrosion test mg/l	Weight after accelerated corrosion test mg/l	% Corrosion
Ag	10.84	8.816	18.67
Cu	0.0098	BDL*	BDL*
Pb	Not Estimated	7.431	Not Estimated

*BDL – Below Detectable Limit

Once the cracking of paint begins, the Mg content present in paint and the $MgCl_2$ aerosol in air penetrate through the pores of the paint layer and come in contact with the copper layer underneath. Galvanic corrosion takes place at the Mg-Cu interface, where Mg act as anode because of its high electro-negativity in the electromotive force (EMF) series, further deteriorating the paint layer. The mechanism of the galvanic corrosion is expected and given by the following equations:



The liberated hydrogen collects as bubbles underneath the paint layer causing it to swell slightly finally leading to blistering and peeling of the paint. The failure of the paint layer results in the exposure of Cu to the ambient atmosphere. In the initial stage, magnesium dissolves and Mg^{2+} (aq) cations are produced, possibly through intermediate steps involving

monovalent magnesium ion. In the second reaction, magnesium dissolution is accompanied by hydrogen evolution, since magnesium in neutral and low pH aqueous solutions is well below the region of water stability. Finally, $\text{Mg(OH)}_2(\text{s})$ is formed as pH rises due to release of OH^- ions in the cathodic reaction, as shown in Pourbaix diagram Fig. 5 [20,21].

The whole domain of stability of magnesium is well below that of water. Magnesium therefore dissolves as Mg^+ and Mg^{2+} with accompanying hydrogen evolution. The quasi-passive hydroxide film formed on magnesium is less stable than the passive films which form on metals such as Aluminium and stainless steels. This quasi-passivity provides poor resistance to pitting for magnesium. The films that form on magnesium are slightly soluble in water and do not provide protection over long periods. They also break down in the presence of certain ions like chloride, bromide, sulfate and chlorate, or in water exposed to acid gases such as CO_2 . Since, the standard reduction potential of Mg is -2.4V , magnesium corrodes rapidly at higher potentials. A stable layer of Mg(OH)_2 will form only at pH values higher than 11 which provide protection against further corrosion as shown in Fig.5. This protection is highly dependent on the prevailing environmental conditions.

The corrosion rate of copper is strongly dependent on relative humidity [22]. The chemical mechanism taking place at the copper/paint interface evolves energy due to half reactions [3]. This energy is sufficient to break copper/paint adhesive bonds and produce corrosive reactions at the silver/ glass interface. Chloride ions are the well-known de-passivators of protective oxides. Ionic exchange reactions are expected to occur between hydrogen cations from water and alkali ions from glass at the glass-silver interface. These reactions may cause silver layer delamination in the solar mirrors [11]. Since the silver layer is observed to undergo dissolution in a basic pH environment, the following possibilities are considered:

Chloride from the paint lowers the potentials needed to cause silver to react, and this reaction will continue as a favored process until the chlorine is exhausted. The copper diffuses into the silver and then it reacts with oxygen at the silver surface and grain boundaries causing non reacted metallic silver to agglomerate. At elevated temperatures, increased oxygen absorption by metallic silver may enhance this degradation. The diffusion of copper into the silver may be the rate-determining step in silver corrosion under basic pH conditions during accelerated testing.

The corrosion of silver in an alkaline environment will take place in presence of oxygen and water. The observations reveal that impurities trapped at the interfacial layers of copper/paint and silver/glass are responsible for reducing mirror lifetime. For example, water trapped at the silver/glass interface can be converted by electrochemical reactions or ion exchange reactions to hydroxide ions which can then attack the glass. Reduction of tin

chloride complexes at this interface will also release hydroxides to attack the glass. Calcium hydride and iron trapped in the copper layer can participate in reduction reactions as long as water or counter ions are available. A calcium hydride reaction with water releases enough energy to cause energetic side reactions in the glass that could affect silver-silicon bonds at the silver/glass interface. Thus, if the protective paint forms a permeable film to transport of water through it on the surface and at the edges, degradation due to impurities could still take place as soon as the water diffuses to the metallic layers or interface regions [3]. A comparison of the extent of corrosion damage for different types of mirror samples subjected to accelerated testing reveal that the 6 mm thick type 1 solar reflector mirror with lead-oxide based paint, offered least resistance to permeability of moisture and the corrosive chloride ions as shown in Fig. 6. The 6 mm thick type 3 mirror sample with white polyurethane coating and transparent polyurethane coating over the lead based paint offered moderate resistance to corrosion as shown in Fig. 7 and 8 respectively. Among them, the performance of samples coated with white polyurethane coating is better. The 4mm type 2 mirror sample exhibited high resistance to corrosion because of uniformity in thickness of each layer of coating which was free from impurities. The diffusion of moisture and chloride ions through the back protective coating is observed to be less to prevent the permeation as seen in Fig. 9. The 4 mm thick type 3 mirror samples coated with white polyurethane coating offered best corrosion resistance among all the samples tested as shown in Fig. 10. The humidity and salt spray test results confirm that penetration of water/moisture through the back coating of the mirror resulted in mirror corrosion which agrees with the test results of Daniel and Coleman [10]. The type of corrosion seen after subjecting to humidity and salt spray tests is pitting corrosion.

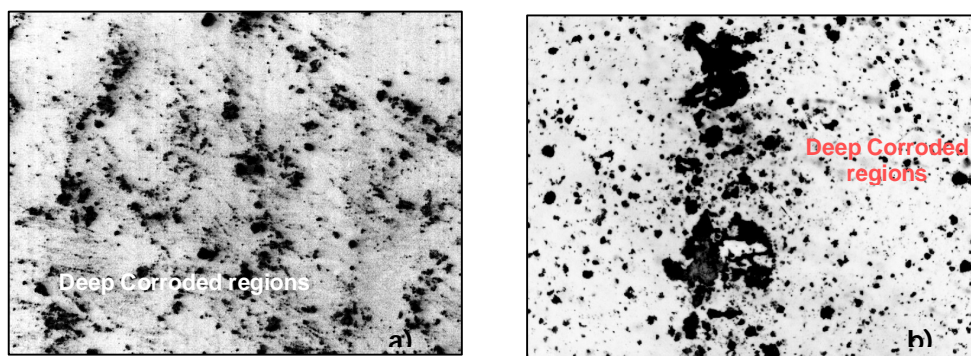


Fig. 6: Stereo micrograph of the corrosion damage to 6 mm thick mirror type 1 sample HT 1
a) After subjecting it to humidity test (100% RH) for 150 h. (X 63)
b) After subjecting it to salt spray test for 168 h. (X 63)

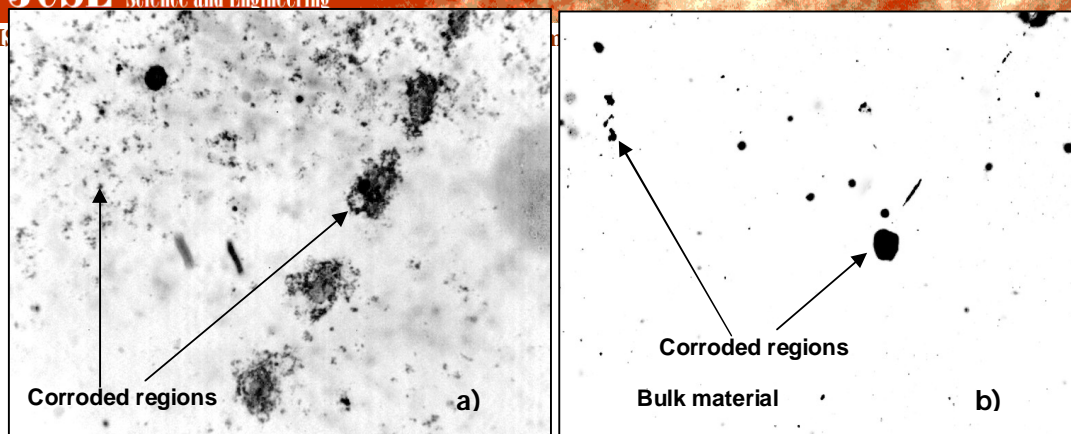


Fig. 7 Stereo micrograph of the corrosion damage to 6 mm thick solar reflector mirror type 3 sample HT 3 coated with white polyurethane a) After subjecting it to humidity test (100% RH) for 150 h. (X 63) b) After subjecting it to salt spray test for 168 h. (X 63)

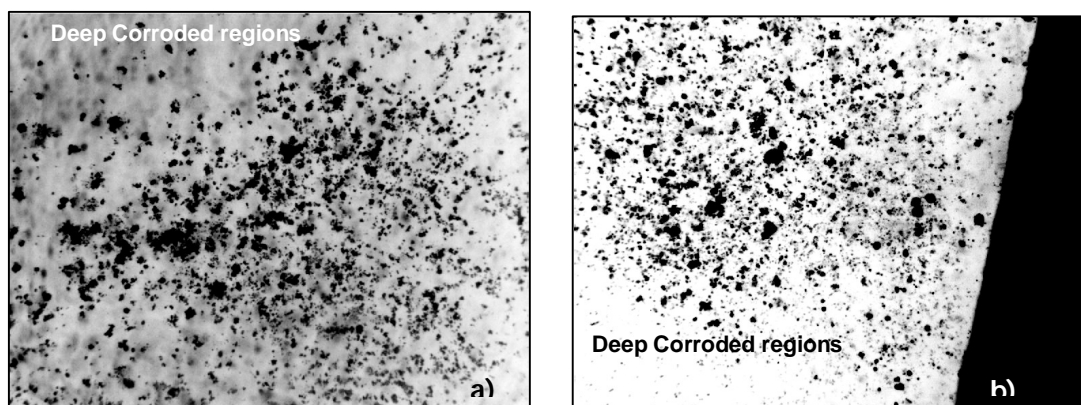


Fig. 8 Stereo micrograph images of corrosion damage observed on the 6 mm thick type 3 mirror sample HT 2 coated with transparent polyurethane coating after subjecting it to humidity test (100% RH) for 150 h. (X 63)

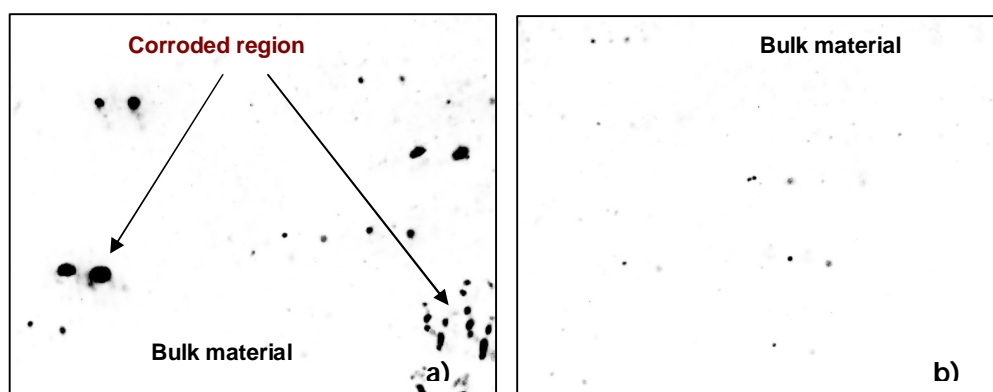


Fig. 9 Stereo micrograph of the corrosion damage to 4 mm thick type 2 commercial mirror sample SS 5 after subjecting it to salt spray test for 168 h. (X 63)

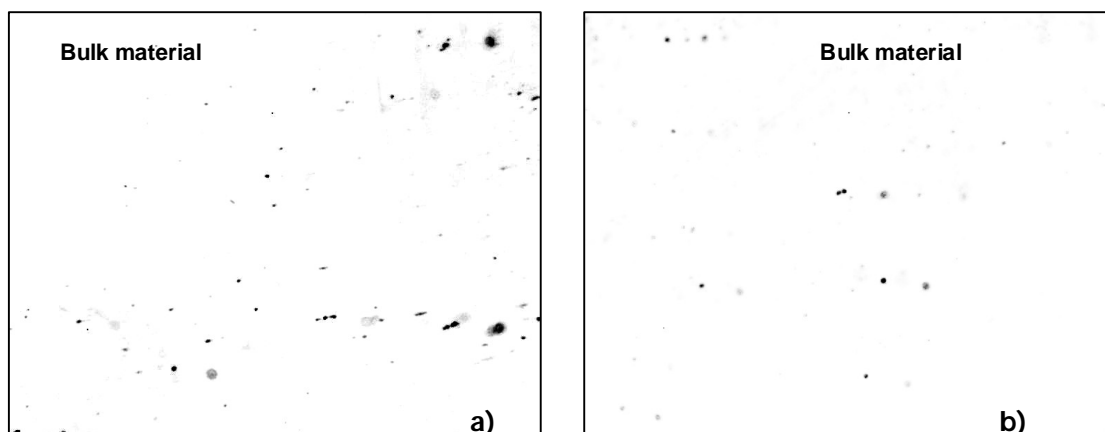


FIGURE 10: Stereo micrograph of the corrosion damage observed at the central region of 4 mm thick commercial type 3 mirror sample SS 6 coated with white polyurethane coating
a) After subjecting it to humidity test (100% RH) for 150 h. (X 63) b) After subjecting it to salt spray test for 168 h. (X 63)

Conclusions

The following conclusions were deduced after carrying out accelerated corrosion tests, humidity test and neutral salt spray test, on locally fabricated glass mirrors by wet electroless process:

There is considerable deposition of magnesium on the back surface coatings of mirror reflectors in the form of $MgCl_2$ in the local saline environment.

Degradation of silver coating is observed due to penetration of moisture and chloride ions present in the exposed environment through the micro pores developed during the pitting corrosion of the paint layer caused by photo-oxidation of paint when exposed to solar radiation.

The mirror samples of Saint Gobain glass India Ltd. has shown better corrosion resistance since those were manufactured in a controlled environment. So, the reflector mirror coating operations have to be performed carefully in a controlled environment so that impurities during each and every coating operation can be reduced there by reactions favouring corrosions can be avoided.

Mirrors have to be provided with film forming paint system as protective coating as it blocks transport of moisture through the paint layer. The film forming paint system should be chosen such that it has high water vapour diffusion resistance coefficient.

Mirrors having a thin layer of polymer coating on the edges and at the back surface offer better corrosion resistance there by increasing the life of the mirror. Single and Multiple layers of protective polymer coating to the mirror help in corrosion prevention even in saline environments.

The cost of the mirrors for solar thermal applications can be significantly reduced if the glass substrate, available in the current Indian market, can be made use for manufacturing such mirrors. Also, it is imperative to follow the above indicated suggestions while manufacturing the mirror. This will reduce the burden of importing the solar grade mirrors from the western countries. Further to this study, extensive measurements of change in optical properties, application of self cleaning coatings and overall performance of the mirrors in actual working conditions are being carried out to justify the approach.

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