Peelable Coatings: A Versatile Solution for Industrial Applications

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Abstract:

Coatings play vital role in our daily lives and their importance cannot be overstated. Coatings are available for functioning as protective coatings (corrosion protection and weather protection), decorative coatings, functional coatings (friction reducing coatings), specialized coatings (antimicrobial and antireflective coatings) and energy related coatings. Coatings are of different forms: liquid or paste and can be applied on the substrate either in dip form / brush or spray form. Coatings once adhered to the substrate form a thin layer of few microns thickness.

One such class of coatings is peelable coatings which once stuck to the surface can be peeled off as a continuous sheet at the end of the service period. Peelable coatings reduces friction by the formation of thin film between two surfaces in contact and thereby improve efficiency and reducing wear. Peelable coatings are flexible, removable and cost-effective solution for protecting surfaces. Peelable coatings are either solvent or water based and have a wide compatibility of substrates and can be applied on metals, wood, glass, concrete, etc. Composition of the peelable coatings are mainly vinyl- based copolymers. Peelable coatings also find its end use in a number applications like automotive, floor coatings, electronics, food and cosmetics.

In this article, we shall discuss a novel process for formulating solvent -based resin based peelable coating with end application use on metal substrates, plastics, wood. The coating is based on resin family and developed coating once applied on the substrate has a thickness from 10 micron to 50 micron depending on the end application. Details of the peelable coatings either in dip form or spray form have been discussed followed by testing and interpretation of results.

Key words: Coating, Peelable coating, lubrication, Dip / spray method.

1. Introduction:

Coating assists in reducing friction between two surfaces in contact by forming a thin layer of few microns in thickness and thereby lowering the coefficient of friction. Coatings can have a impact on reliability by increase in shelf life of equipment, energy efficiency, thereby reduction of different machinery wear and friction. Peelable coatings which when applied on the substrates serves as a temporary protective layer that can be easily removed from the substrate surface either at the end of its lifespan or after. Peelable coatings are characterized by their low adhesion, high cohesion, elasticity, controlled thickness and chemical resistance, which collectively enable easy and residue-free removal without damaging the underlying surface. Coating whether solvent based or aqueous based is a layer of specified material which when applied to the substrate surfaces enhances the look, performance properties and also provides an protective barrier to the substrate. Flame retardant coatings[1], thermochronic coatings[2] and antimicrobial coatings[3] are the upcoming trends in coating industry. For the coating to peel off without a residue on the substrate, the cohesive force between the layers of the peelable film must be larger than the adhesive forces between the film and its substrate[4]. The peelable film once formed is such that it can be removed from the substrate in one continuous film. Peelable coating technology protects diverse surfaces such as concrete, metals, ceramics, wood, glass from dust, dampness, moisture and scratches during product storage and transit. The coating is used on flooring and windows during projects to protect them until the entire job is finished. Technology applied is emulsion polymerization technology, ensuring product consistency and quality for users[5]. Peelable coatings are typically solvent based polyvinylchloride or vinylacetate copolymers which cure on the substrate upon evaporation of the solvent to give a strippable coating of few micron thickness. Peelable coatings also finds its application in radiological contamination[6 to 8], whereby the radioactive particles are packed by the curing of the peelable coating and removed when the coating is peeled off. Peelable coatings find applications in decontamination of nuclear reactors, optics, automotive, floor coatings, electronic protection, food coatings, cosmetics and labels for plastics[9]. Most important part of the peelable coatings are selection of the right polymer resin and compatible solvent[10]. Wang et. al. showed that polyvinyl alcohol hydrogels with good peelability were prepared and efficiently removed by mechanical peeling[11]. Polyvinyl alcohol film was encapsulated on the surface of expandable graphite to enhance the dispersion of the graphite in the coating by Tang et. al[12] and further Polyvinyl alcohol / graphite coating exhibited better flame retardency, heat insulation properties.

Here we report the use of a commercially available resin peelable coating developed for the end use in a number applications like automotive, floor coatings, etc. Metal panels were coated either in dip or spray form, allowed to cure and coating once formed were then peeled from the substrates to obtain a coating varying from 10 microns to 50 microns.

2. Materials and Chemicals:

Resin (Specification: Colorless powder and Molecular weight less than 50,0000) were procured from a local Indian based vendor.

Resin used in the present experimentation could of various types and chosen one among or a combination of these: Polyvinyl Acetate (PVA), Ethylene Vinyl Acetate (EVA), Polyurethane (PU), Acrylic Adhesives, Polyethylene Vinyl Acetate (PEVA), Vinyl Acetate-Ethylene (VAE), Polyvinyl Chloride (PVC), Thermoplastic Polyurethane (TPU), Polyvinyl Butyral (PVB), Polyolefin Elastomers, Styrene-Butadiene-Styrene (SBS), Styrene (SIS), Acrylate-Based Polymers, Polybutadiene, Polyisobutylene (PIB), Ethylene-Propylene-Diene Monomer (EPDM).

Solvents selected are aliphatic and aromatic which were commercial grade sourced from local sources. Plasticizer chosen for the experimentation was either from phathalate / adipate or combination of both which was procured locally. Silicon based defoamer were also obtained from local sources and used in the formulation.

3. Experimentation:

Peelable coating was developed using a resin (selected from the ones mentioned earlier and could be a single resin or a combination of two resins) of molecular weight less than 50,000.

Table 1: Specifications for the peelable coating prepared inhouse for the dip / spray method.

Parameter	Specification	Inhouse Formulated Product
Appearance	Transparent Liquid	Transparent Liquid
Film thickness, microns	30 to 40	30
Type of film	Peelable	Peelable
Flash Point	Flammable at room	Flammable at room

	temperature	temperature
Coverage Area, Sq. Mt./Ltr.	7	8.56
Drying time	5 to 6 minutes	Less than 5 minutes
pH	8 to 9	8
Density, g / ml	0.87 to 0.88	0.87
Viscosity, B4 Ford Cup, Seconds	88 seconds	87 seconds
Salt Spray Test, hours	>200	>200

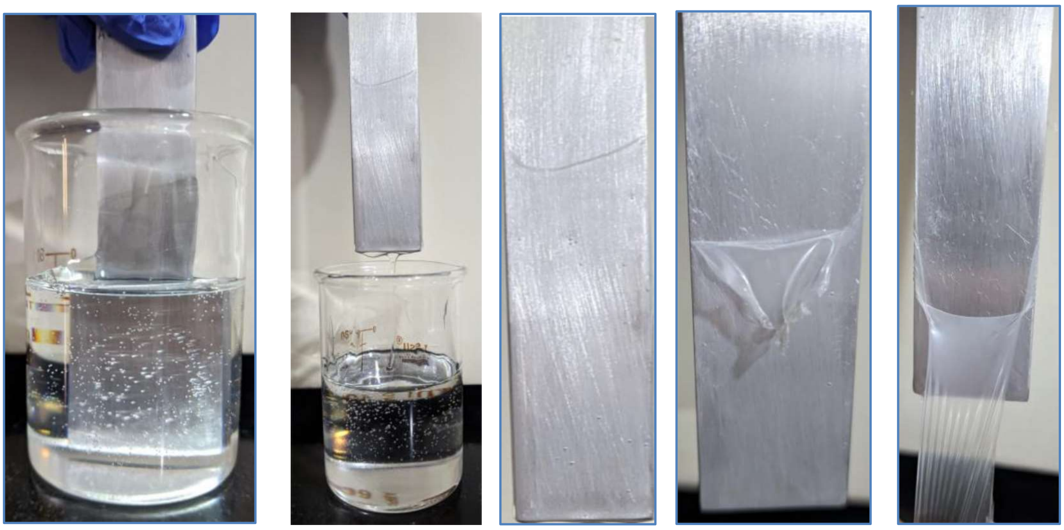
In the laboratory based experimentation, a clean glass beaker was taken, cleaned with pentane to remove any debris if any. To it both the solvents (aliphatic and aromatic) were added with constant stirring ranging from 100 to 500 rpm. The beaker was covered with a glass lid to avoid solvent evaporation and stirred with a magnetic bar. All the mixing was done at room temperature. To this, resin was added slowly in the glass beaker and stirred between 60 to 90 minutes at 800 to 1500 rpm stirrer speed till complete dissolution of the resin in the solvents. Silicon based defoamer and plasticizer was added to the above and mixed until entire mixture turned homogenous. The entire mixture becomes transparent with no solids or resin chunks remaining after 90 minutes of total stirring. Stirring was done at high speed and dissolution of the resin were checked visually. Continue stirring if lumps of resin seen undissolved. Once completely dissolved, coating was filtered with using a 50 micron filter cloth (under vacuum pressure). Coating bath after formulation is extremely stable. Stability was checked keeping the formulation as is and no separation was observed for a long period of time (1 month). Photo of the coating as is and with the dye incorporated in it is shown below (Photo 1).

Photo 1: Formulated samples for the coating : Left sample is the transparent blend and right sample is the blend with the dye incorporated in it.

3.1 Application:

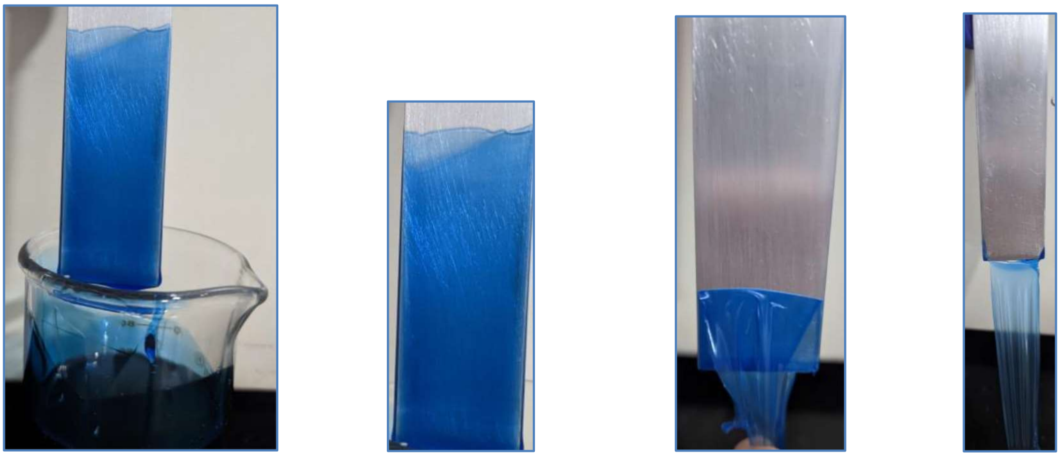
To examine if coating is developed for the dip method process, small amount of coating material was taken in a glass beaker. A aluminum metal strip was taken for coating purpose (shown in Photo 2) which was cleaned with Isopropanol to ensure that there was no debris was present on it. Metal strip was dipped into the coating for 5 seconds and dried on the metal stand with a hook for 5 minutes. After drying of the coating, coating was peeled off from the metal strip with hand (shown in Photo 3 and 4). The coating was peeled off the metal substrate in a continuous film. Repeatability was checked using the above process and further testing of the coating material done as per guidelines. The coating once peeled off from the substrate could be reused but would need further Lab trials which is in the next phase of development.

Photo 2: Aluminum panels taken for the tests



a b c d e

Photo 3: Sample being coated: (a) Aluminum panel being dipped in the coating blend. (b) Aluminum panel being removed out of the coating material for drying (c.) Coating sample dried and ready for peeling off (d) Sample being peeled off from the aluminum panel. (e.) Sample peeled off completely from the aluminum panel.



a b c d

Photo 4: Coating blend imparted with blue dye color: (a) Aluminum panel being dipped in the coating blend. (b) Coating sample dried and ready to be peeled off the metal substrate (c) Sample being peeled off from the aluminum panel. (e.) Sample peeled off completely from the aluminum panel.

For the Spray method coating, resin concentration was lowered (compared to the dip method) as per need and a spray gun (shown in Photo 5) with compressed air was used to spray the coating onto the substrate. The pressure of the compressed air could be varied as per need of the application. For preparation of the coating standard procedure was used as above.

Photo 5: Spray gun used for the experimentation.

Coating developed using the spray gun in shown below in Photo 6.

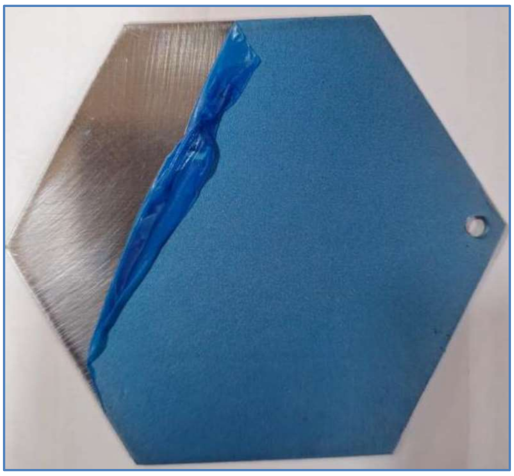


Photo 6: Coating developed using the spray gun.

Table 2: Formulation for the peelable coating for the dip and spray method.

Material (Chemical used in formulation)	Percentage in weight (Dip /Spray Form)	Percentage in weight (Spray Form)	Role
Aliphatic / Aromatic Solvent	60 to 90	60 to 90	Solvent
Resin	5 to 15	2 to 10	Resin
Plasticizer (Adipate / Phthalate)	4 to 10	4 to 10	Plasticizer
Silicon based Defoamer	0.1 to 5	0.1 to 5	Defoamer

Present formulation is very well thought of taking into account the end application and is mixture of solvents, plasticizer, resin, etc. There are different formulations available in literature which take into account different additives, plasticizers. So our formulation is unique and different as mentioned in other literature.

4. Results and Discussion:

Two grades of coatings were prepared obtained either in spray form or dip form.

Resin (molecular weight less than 50,000) resin was used to develop the coating. Resin with a molecular weight of 50,000 or less would be preferred for this type of application since they can form a stable coating. It is found that the resin with molecular weight more than 50,000 were not forming stable coatings and not compatible with solvents. Coating when developed was obtained either in the dip form or spray form. The dip form coating had a thickness of 30 micron and sometimes varied to 60 microns whereas the spray coating had a thickness of 20 microns. The coating thickness can be varied as per need of the end user application.

The solvent selected in the formulation are a mixture of aromatic and aliphatic solvents. The ratio of both solvents are varied with the resin to form a uniform peelable coating on the metal substrate. This avoids the incompatibility between the resin and the solvent blend. Resin material interacts with the substrate through strong adhesion, mechanical bonding and chemical interactions depending on the substrate material. These interactions are important for adhesion and performance of the coating. Specific type of interaction depends on the substrate material and the composition of the resin material.

Low boiling solvents were used in the formulation for quick evaporation and fast drying of the coating. In the dip coating process thickness varied from 30 to 60 micron. Coating obtained is transparent in color. Color dye can be imparted into the coating as per need for better look of the coating. In the present case a blue color dye was mixed in the coating and finally and a blue color peelable coating is obtained. The coating were tested for salt spray test as per ASTM B117 which withstood for more than 250 hours in the salt spray chamber. We can conclude that the developed coating can withstand corrosion for a long period of time of more than 12 months in humid conditions.

Viscosity of the coating was measured using a B4 Ford cup and measured 88 seconds (for the dip coating). Density of the coating was 0.87 g/ml and pH measured was 8. There was no mechanical tests done for the coating since coating was soft in nature. Product developed is easy to handle with fast drying time of 2 to 3 minutes. Other solvent based coatings available in the market take over 10 minutes to dry on the metal substrate.Water based coatings would take more than 15 minutes to dry and time consuming. Coating once applied to the metal substrate is extremely durable.

For the spray coating, various methods were tried out using Liquid petroleum gas (LPG) and carbon dioxide as the propellant medium for the coating media. Intensive trials were conducted and concluded that liquid petroleum gas and carbon dioxide was not compatible with the resin at a specific concentration. Challenges faced was that the coating material was sagging when sprayed on the metal surface vertically and large quantity of coating material getting wasted. Other difficulty faced was that coating material was not getting sprayed properly onto the substrate even after trying out different nozzles. There may have been incompatibility issues between the resin and the gases.

Spray method worked well when coating material was applied using a spray gun and compressed air at specific pressure. Coating thickness could be varied depending on the end use (10 micron to 50 micron).

Infrared spectroscopy for the formulated coating material was taken and their interpretation as below in Fig. 1

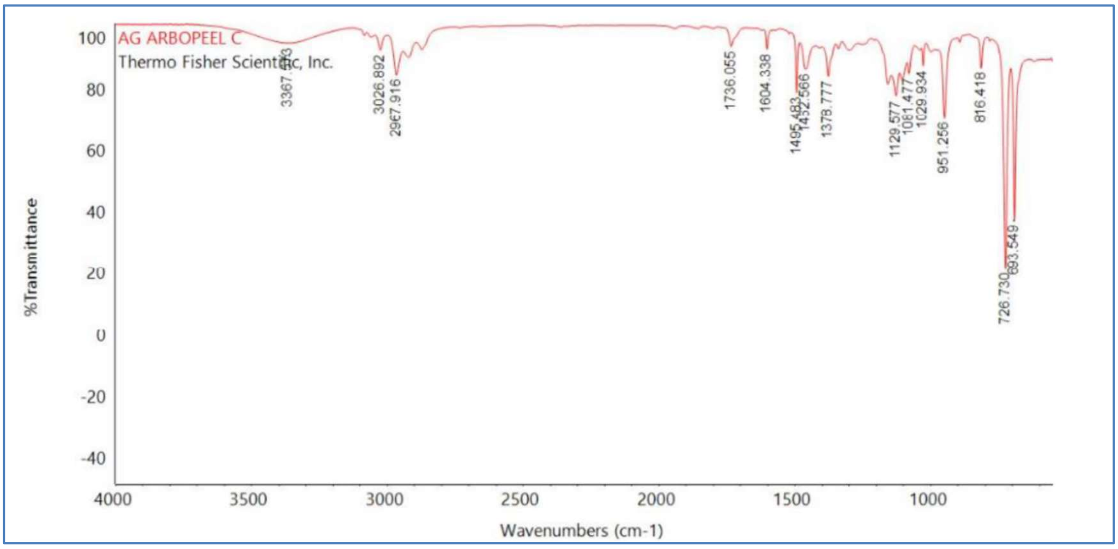


Fig. 1. Infrared Spectroscopy for the Blended Coating Material

Peak at 2800 to 3000 cm^{-1} represents CH_2 and CH_3 stretching. Peak at 1736 cm^{-1} represents C=O stretching vibration of the resin group. Peak at 1606 cm^{-1} is C=C stretching of the resin group. Peak at 1000 to 1150 cm^{-1} represents stretching vibrations of the resin group.

Aromatic solvent helps dissolve resin and transport it to the substrate. Aliphatic solvent helps to dissolve and stabilize the resin in formulation. The aliphatic solvent is also known to reduce the surface tension of the coating and ink, improving its wetting and spreading properties[13]. The solvents used aliphatic and aromatic are flammable in nature. However, in future we do intend to develop a peelable coating which would be biodegradable and using non flammable solvents. Silicon based defoamer acts as a release agent helping reduce the adhesion of the coating to the substrate and making it easier to peel off. It also acts as a slip agent, reducing the friction between the coating and the substrate[14]. Plasticizer helps improve the flexibility and toughness of coating and also helps to reduce the adhesion of the coating to the substrate, making it easier to peel off[15]. Plasticizer selected for the formulation is not considered a hazardous substance.

One of the resins which is from the polyvinyl alcohol family which is polyvinyl family is formed from the reaction of an aldehyde and alcohol[16]. Resin provides adhesion properties and peelability of the coating allowing it to be easily removed from the substrates like metal, glass, wood and fabric. Peelable resin coating are useful in various fields due to its strong bonding strength, excellent toughness, flexibility and transparency. It has excellent acid and alkali resistance and has applications in automotive, coating agent, etc[17].

Conclusion:

This paper is aimed at developing resin based peelable coating either in dip form or spray form. Accordingly, a novel peelable coating was developed with end applications in automotive, packaging, floor coatings, electronic protection, food coatings, etc. The obtained coating could be peeled off easily as a continous film from the metal substrate forming a transparent coating of variable thickness as per end application. The base coating material is non toxic and coating material can be disposed safely after use. The peelable coating were obtained from solvent based non toxic polymeric blends which do not harm the substrate to which they are applied. The coating material were characterized using FTIR. Viscosity, pH, salt spray test and density tests were conducted for the coating material. The formulated coating matches to the specification and works well in application.

Future studies would be focused on preparing peelable coating using non flammable / biodegradable resources and studying its applications in varied fields.

Authors Contributions

Idea conception, discussion was by M. H. Mehta and V. M. Mehta. Literature search, experiment formulation and paper writing done by Y. B. Mahajan and experimentation by P. R. More.

Conflict of Interest

The authors hereby declare no conflict of interest in the matter published in the paper.

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