Polymer Process Engineering
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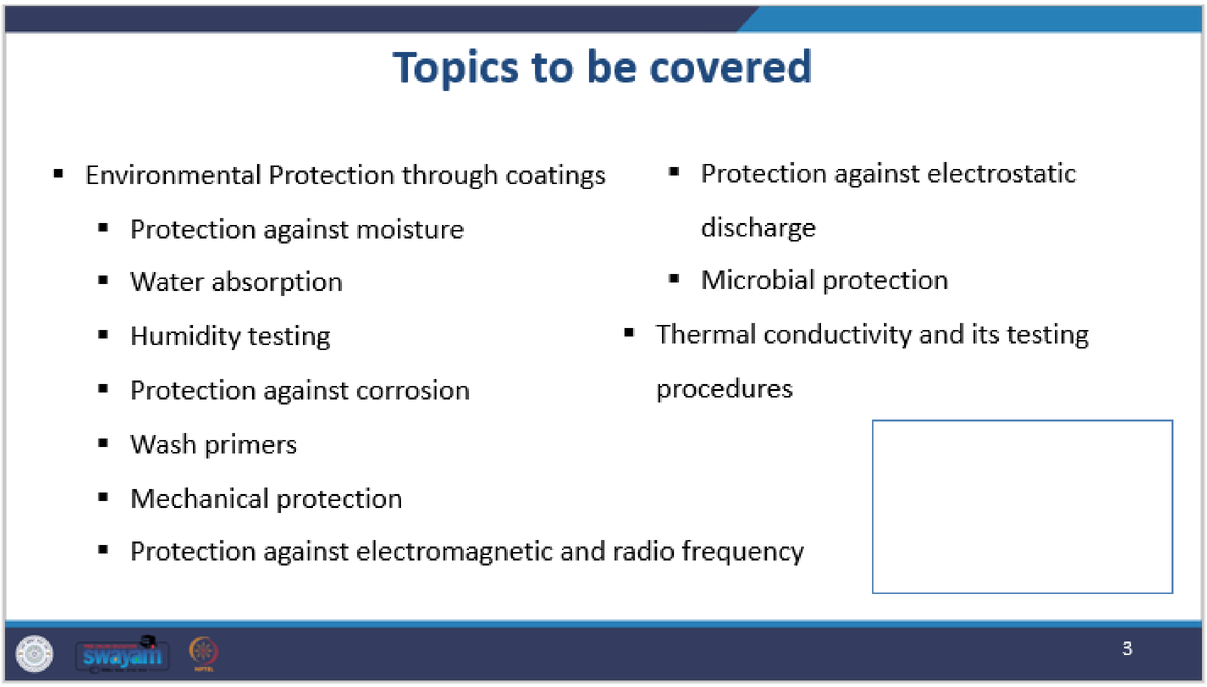
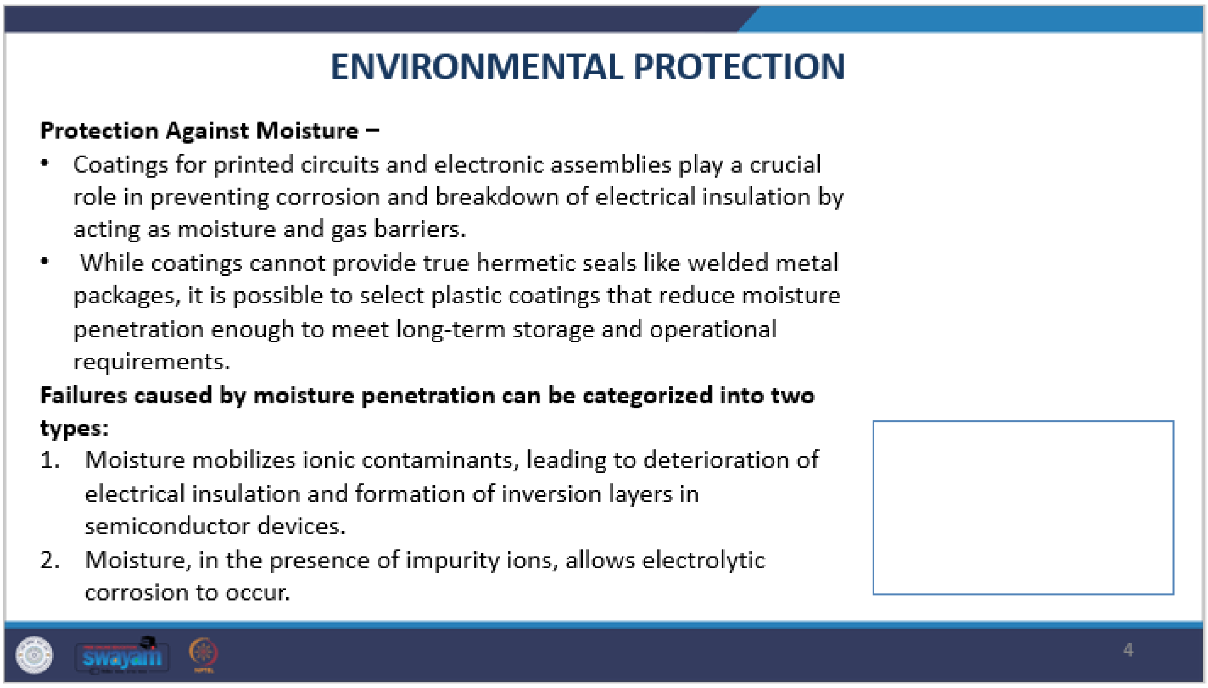
Lecture 53
Functions of Coatings-II

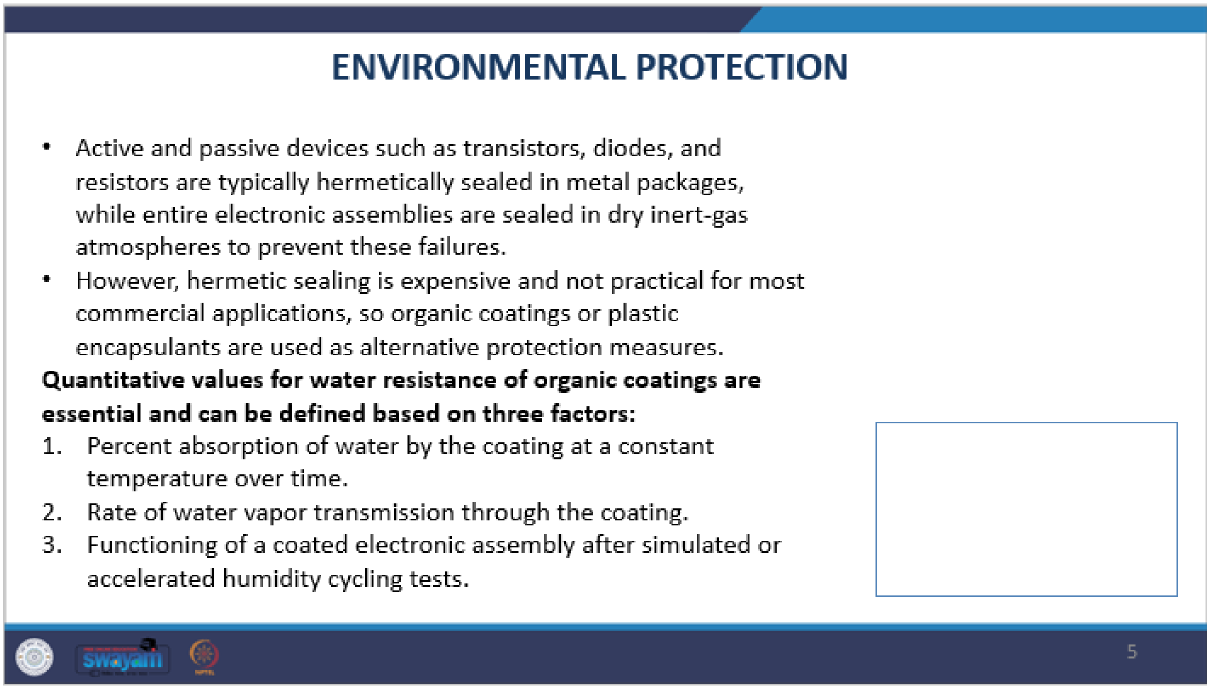
Hello friends, welcome to the next aspect of the functions of coating under the edges of polymer process engineering. In the previous lecture, we covered the coating as insulation and dielectrics, and then we discussed the electrical properties and the useful concepts. Then we talked about the resistance and resistivity effect of variables on resistivity we discussed about. Then, molecularly conductive polymers are taken into consideration. We talked about the metal field polymers and then discussed the capacitance and dielectric constants dissipation factor and power law. In this particular segment, we are going to discuss the environmental protection through the coatings under this edge, the protection against moisture water absorption, we talk about humidity testing, protection against corrosion, wash primers, mechanical protection, and protection against electromagnetic and radio frequency.



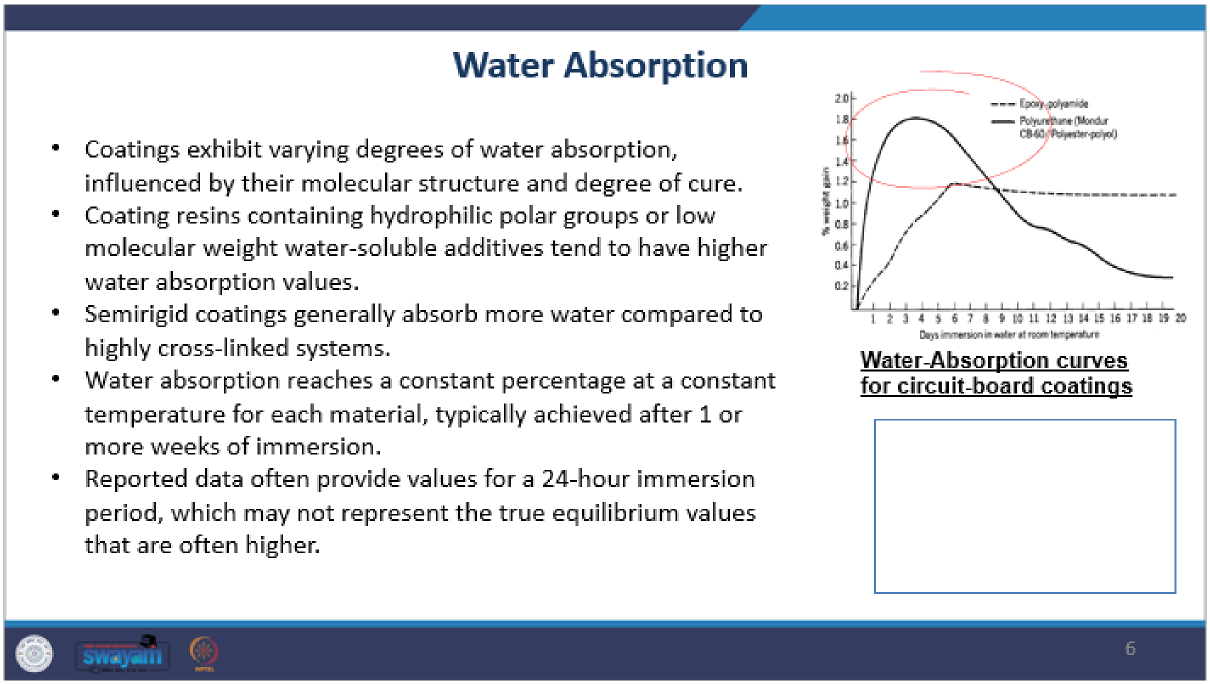
Then, we will talk about the protection against electrostatic discharge, microbial protection, thermal conductivity, and its testing procedures. We will discuss all these things in this particular segment. Now, let us talk about environmental protection, the protection against moisture that is a coating for printed circuits, electronic assemblies play a very crucial role in preventing corrosion and a breakdown of electrical insulation by acting as moisture and gas barriers. While coating cannot provide the true hermetic seals like welded metals, and packages, it is possible to select a plastic coating that reduces the moisture penetration through to enough to meet long-term storage and operational requirements.



Now, sometimes failure caused by moisture penetration can be categorized into two types, one is the moisture mobilizes the ionic contaminants leading to the deterioration of electrical insulation and formation of inversion layers in semiconductor device, then the moisture in the presence of impurity ion allows the electrolytic corrosion to occur.



Now, active and passive devices like transistor diodes, and resistors, are typically hermetically sealed in metal packages, while entire electronic assemblies are sealed in a dry inert gas atmosphere to prevent these failures. The hermetic sealing is expensive and not practical for most commercial applications. So, organic coatings or plastic encapsulants are used as alternative protection measures. The quantitative values for water resistance of organic coating, are essential and can be defined based on three factors, the percentage absorption of water by the coating at a constant temperature over time, the rate of water vapor transmission through the coating, the function of a coated electronic assemblies after a simulated or accelerated humidity recycling test.



Let us talk about water absorption; the coating exhibits varying degrees of water absorption influenced by its molecular structure and degree of cure. Now, coating resins containing hydrophilic polar groups or low molecular weight water-soluble additives tend to have higher water absorption values. The semi-rigid coating generally absorbs more water compared to a high cross-linked water system and the water absorption this reaches is a constant percent at a constant temperature for each material typically achieved say after one or more weeks of immersion. Now, certain coatings such as polyurethane initially reach maximum water absorption and absorptive value but lose weight and stabilize at a lower equilibrium value potentially due to the leaching of water soluble additive or trapped solvents. For practical application 24-hour data, they are meaningful for any kind of a test conditions, they serve as more severe or actual operating conditions.

The percentage of water absorption alone is not a sufficient indicator and it should be considered in relation to a detrimental effect on coating and the protected part. Water absorption is critical for insulation properties or especially electrical insulating properties, but it is not the sole factor ionic impurities and the polar nature of the coating also contribute to the effect, and some coating experience adverse effects on electrical properties with even a small amount of water absorption while others with high water absorption may remain stable electrically.

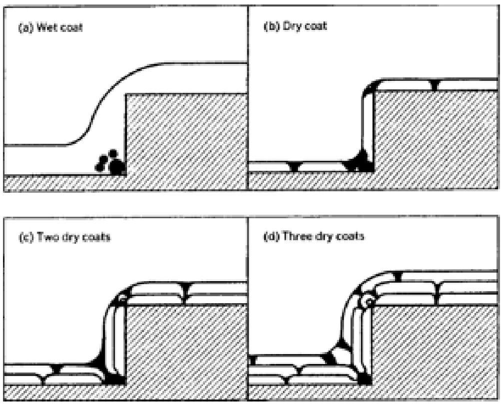
ENVIRONMENTAL PROTECTION

Resin and curing agent	Curing schedule	water absorption, Z	
		1 hour, 100 C	10 days, 20 C
Araldite 502 20 phr HY 956	7 day at 25 C	1.1	0.6
Araldite 6010 85 phr HT 907 + 3 phr XU 183	Gel at 100 C + 1hr at 150 C	0.3 to 0.8	0.2 to 0.3
85 phr HT 907 t 3 phr YU 183 + 400 phr quartz	Gel at 100 C + 1hr at 150 C	0.1 to 0.2	0.1 to 0.2

Water-Absorption Values for Epoxies

Now, here you see that the water absorption values for various epoxies like eraldite this is which is the commercial name 502 and eraldite 6010. The curing schedule is given in this particular column and water absorption at 1 hour and 100 degree Celsius and 10 days and 100 degree Celsius you can see the difference. Similarly, if we took the other we take the other segment then you see the difference in the water absorptivity.

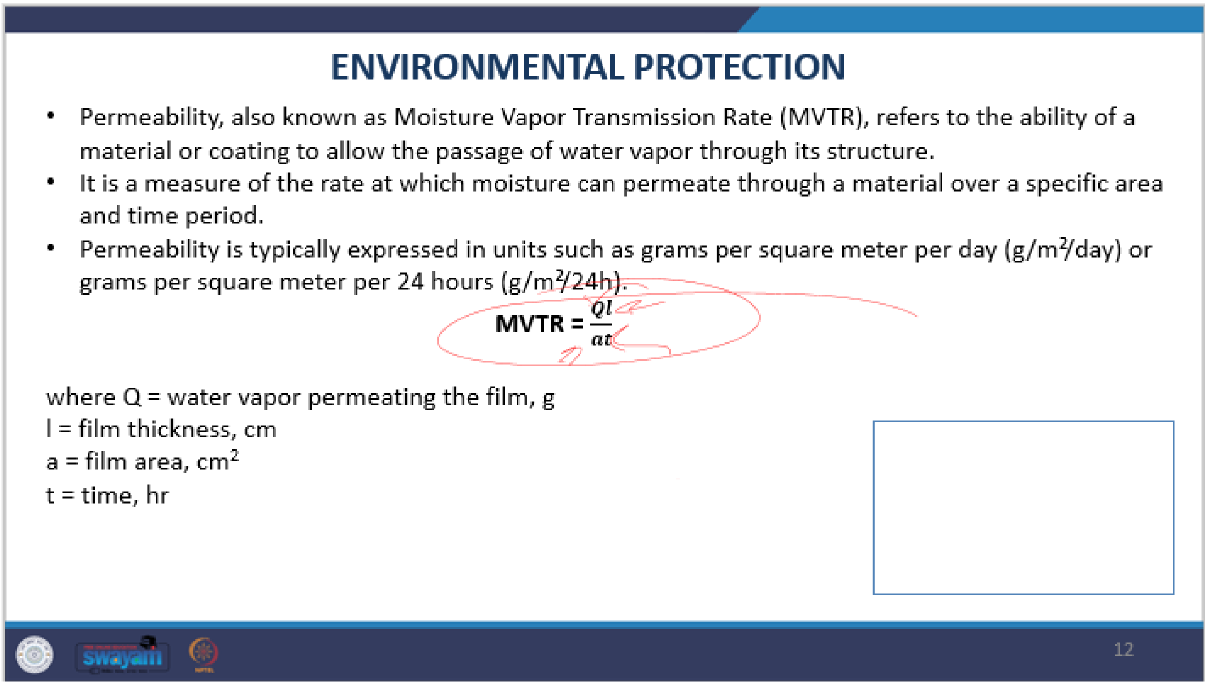
ENVIRONMENTAL PROTECTION



Reduction of pinholes by the use of multiple coats: (a) and (b) illustrate, on an exaggerated scale, the formation of pinholes and the stretching of the coating over sharp edges and protrusions after a single coating application; (c) illustrates a substantial reduction in the number of contiguous pinholes after a second application; (d) illustrates the same component with three coats, showing practically pinhole-free in~ulation

Permeability - Moisture can penetrate a coating through two mechanisms. The first mechanism involves the passage of moisture through microcracks, channels, or pinholes that result from physical imperfections in the coating. The presence of pinholes and pores can be significantly reduced by applying multiple coats of the same material. The second mechanism involves the inherent molecular structure of polymers, where water vapor molecules permeate the spaces between polymer molecules and within polymer structures.

Let us talk about the permeability, moisture can penetrate a coating through two mechanisms the first mechanism involves the passage of moisture through micro cracks channels or pin holes that results the physical imperfection in the coating and the presence of pin holes and pores can significantly reduce by applying the moisture coats of the same material. And the second mechanism this involves the inherent molecular structure of polymer where water vapor molecules permeate the spaces between the polymer molecules and within the polymer structure. This is this permeability known as the moisture vapor transmission rate or MVTR this refers to the ability of a material or coating to allow the passage of water vapor through its structure. Now, it is a measure of the rate at which the moisture can permeate through a material over a specific area and a time period. This typically expressed in units such as gram per square meter per day and this MVTR is equal to QL over AT where Q is the water vapor permeating the film in grams, L is the film thickness, A is the film area and T is the time.



The lower permeability value indicates a material that is less permeable to moisture vapor while a higher permeability value indicates a material that allows greater moisture vapor transmission. The permeability of a material is influenced by a factor such as the molecular structure, thickness, temperature, humidity gradient and any other barrier or coating applied to that particular surface. The permeability of a coating is influenced by various factors and the type and amount of the pigment or filler used. In general, the pigmented coating have the lower permeabilities compared to the unpigmented coatings because the water molecule have to travel a longer path to penetrate the film thickness. The nature of pigment also play a very vital role apart from this its geometry that is whether it is a spherical or a plaque and the packing density all affects the moisture permeability of the coating.

So, for instance the flag shaped pigments like aluminium, this can significantly improve the resistance to moisture penetration. Now, the permeability values tend to decrease as a pigment concentration increases until reaching a minimum at a crucial pigment volume ratio. Beyond this ratio, the permeability sharply rises. The moisture permeability properties of the polymer coatings they are commonly quantified using moisture vapor transmission rate and this this can be discussed in due course of a time.

ENVIRONMENTAL PROTECTION

Factor	Usual effect on permeability
Solvent entrapment	Increase
Plasticizers	Increase
Structure of film	
Polar, hydrophobic	Decrease
Polar, hydrophilic	Increase
Nonpolar	Decrease
Degree of cross-linking	Decrease
Crystallinity	Decrease

Factors Affecting Moisture Permeability

Now, in this particular table, there are various factors we have enlisted affecting the moisture permeability like solvent entrapment, this increases the permeability, then the plasticizer increases the permeability, then the structure of film like polar hydrophobic, polar hydrophilic, and non-polar they decrease increases and decreases respectively and then the degree of cross-linking increases the permeability and crystallinity again that it decreases the permeability.

Humidity Testing

- Humidity testing for polymers in electronics is a crucial step in assessing their performance and reliability in humid environments. It involves subjecting the polymer materials or electronic components to controlled humidity conditions to evaluate their resistance to moisture absorption, dimensional changes, electrical properties, and overall durability.
- The humidity testing process typically follows standardized procedures, such as those outlined in industry standards like ASTM D2247 or IEC 60068-2-3. These standards provide guidelines for conducting humidity tests, specifying parameters such as temperature, relative humidity, duration, and test setups.

Let us talk about the humidity testing. The humidity testing for the polymers in electronics is the crucial step in assessing their performance and reliability in a humid equipment. It involves the objecting to the polymer materials or electronic component to controlled humidity condition to evaluate their resistance to moisture absorption, dimensional changes, electrical properties and overall durability. The humidity testing process this typically follows the various standard protocols like ASTM D2247 or IEC 6006823. Now the common humidity testing methods this includes the constant humidity test.

Humidity Testing

Common humidity testing methods include:

1. **Constant Humidity Test:** This involves exposing the polymer or electronic component to a constant humidity level for a specified duration. The relative humidity is maintained at a set level, typically ranging from 85% to 95%, depending on the specific test requirements.

2. **Temperature-Humidity Cycling Test:** This test subjects the samples to cyclic changes in both temperature and humidity. The specimens are exposed to alternating high and low humidity levels, combined with temperature variations, simulating real-world conditions.
   This test is useful for evaluating the performance of materials under moisture-induced stress and thermal cycling.

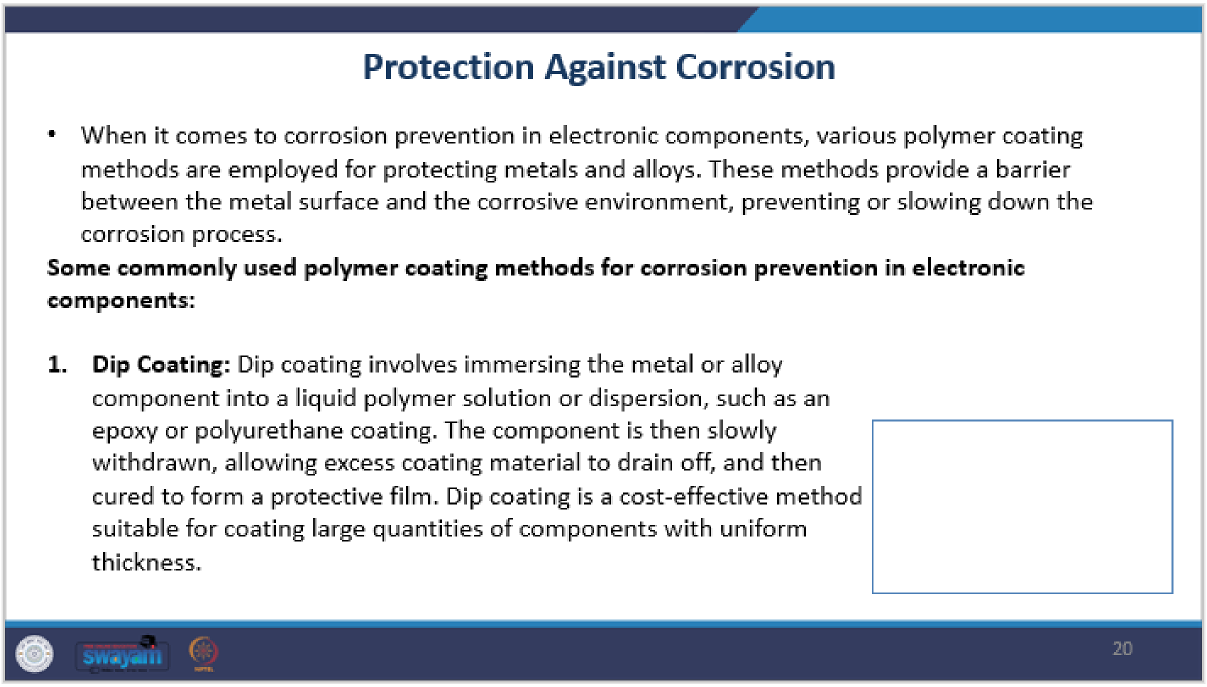
This involves exposing the polymer or electronic component to a constant humidity test of for a specified duration. The relative humidity is maintained at a set level and typically ranging from 85 percent to 95 percent depending on the specific test requirement. And the temperature humidity cyclic test this is again subjected to the samples of the cyclic change in both temperature and humidity and the specimens are exposed to alternating high and low humidity levels. Now this test is useful for evaluating the performance of materials under moisture induced stress and thermal cycling. Now during humidity testing various parameters are monitored and evaluated.

Humidity Testing

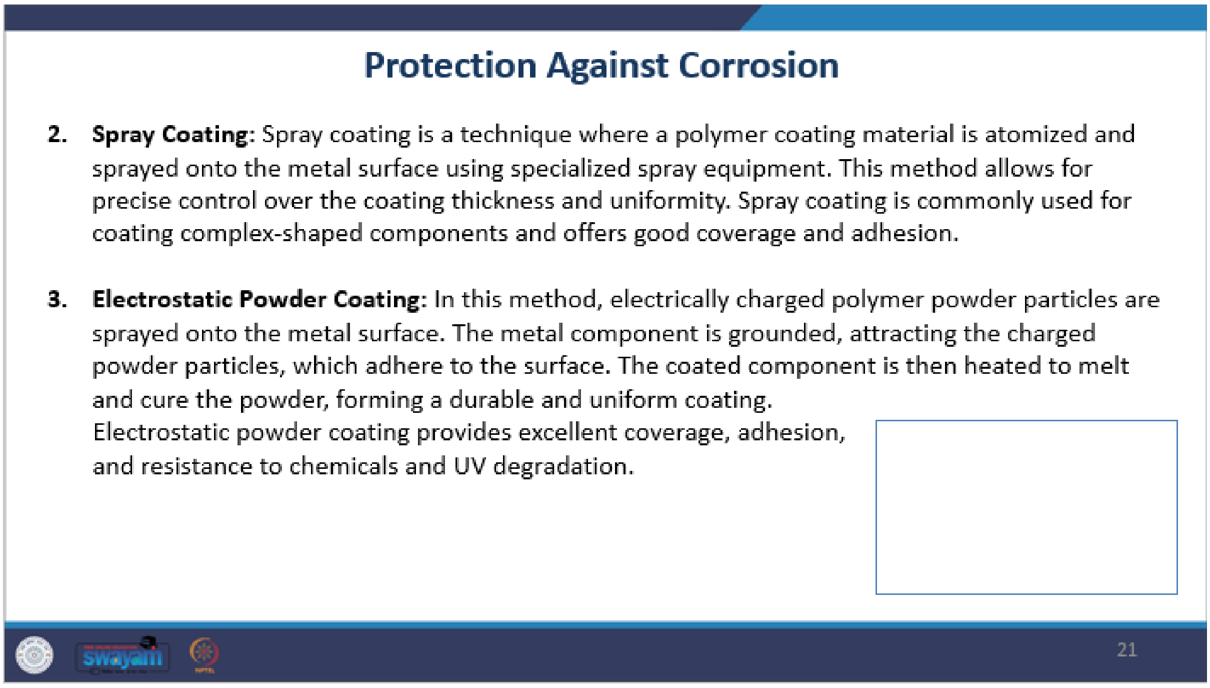
During humidity testing, various parameters are monitored and evaluated, including:

- **Weight gain or loss:** The change in weight of the samples due to moisture absorption or desorption.
- **Dimensional changes:** Measurements of the size or shape changes of the materials, which can indicate the potential for warping, swelling, or shrinkage.
- **Electrical properties:** Assessments of conductivity, insulation resistance, dielectric strength, and other electrical characteristics, which may be affected by moisture.
- **Visual inspection:** Examination of the samples for signs of delamination, blistering, cracking, or other visible defects.
- By exposing the materials to controlled humidity conditions, manufacturers can identify potential weaknesses, improve material formulations, and ensure the reliability and performance of their products under humid operating conditions.

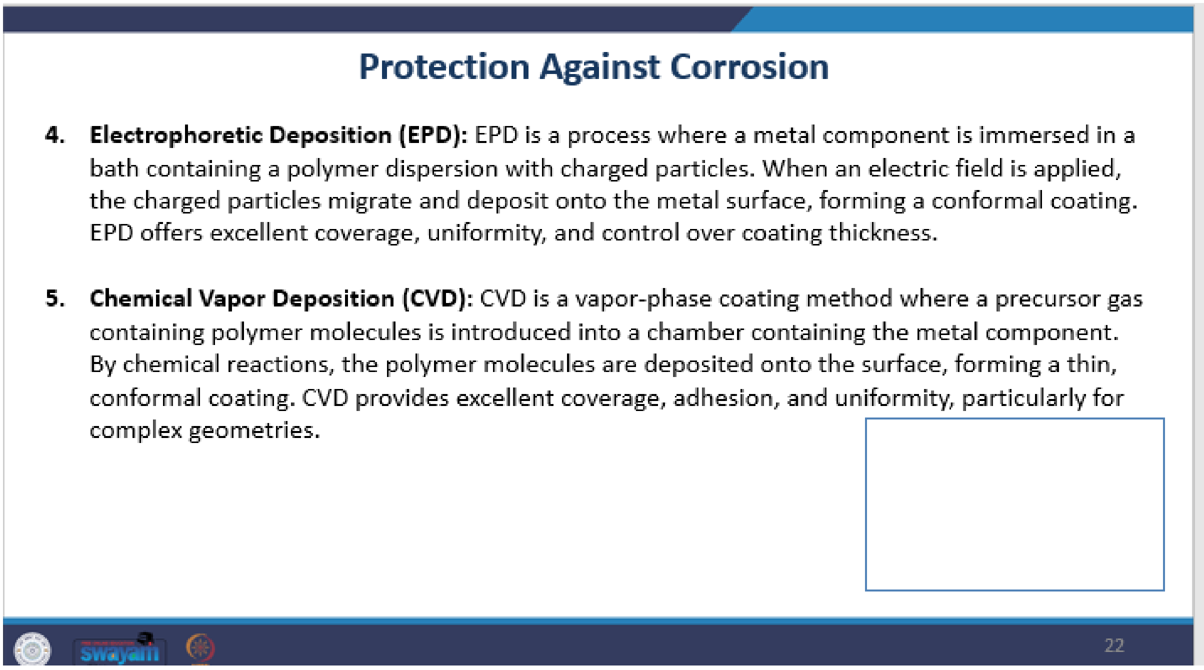
This includes the weight gain or loss, the change in the weight or the sample due to the moisture absorption or desorption, then dimensional changes, the measurement of the size or the shape change of the material which can indicate the potential of wrapping, swelling and shrinkage, electrical properties, the assessment of the conductivity, insulation resistance, dielectric strength and other electrical characteristics which may be affected by moisture. Visual inspection, the examination of the sample for signs or delamination, blistering, packing and other visible factors. Now let us talk about the protection against corrosion. When it comes to corrosion prevention in electric electronic component various polymer coatings methods are employed for protecting metals and alloys. Now these methods provide a barrier between the metal surface and the corrosive environment and preventing or slowing down the corrosion process.



Now some of the commonly used coating methods for corrosion prevention they are enlisted. One is the dip coating. Dip coating this involves the immersing of the metal or alloy component into a liquid polymer solution or dispersion such as epoxy or a polyurethane coating. The component is then slowly withdrawn and allowing excess coating material to drain off and then cure to form a protective film. This is the most cost effective method suitable for coating large quantities of component with uniform thickness.

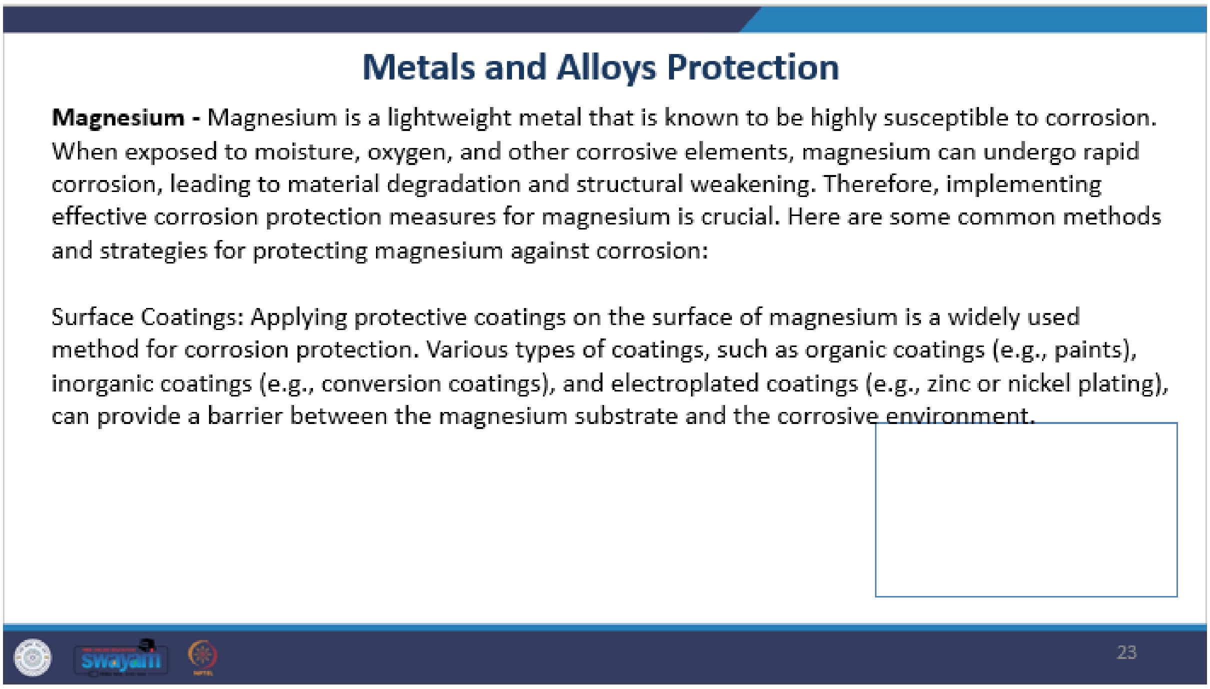


Another thing is that spray coating. This is the technique where the polymer coating material is atomized and sprayed onto the metal surface using specialized spray equipment and this method allows for the precise control over the coating thickness and uniformity. This spray coating is commonly used for coating complex shaped component and offers a good coverage and adhesion. The electrostatic powder coating in this method the electrically charged polymer powder particles are sprayed onto the metal surface and the metal component is grounded attracting the charged powder particles which adhere to surface and the coated component is then heated to melt and cure the powder forming a durable and uniform coating. The electrostatic powder coating provides excellent coverage, adhesion and resistance to chemical and UV degradation.

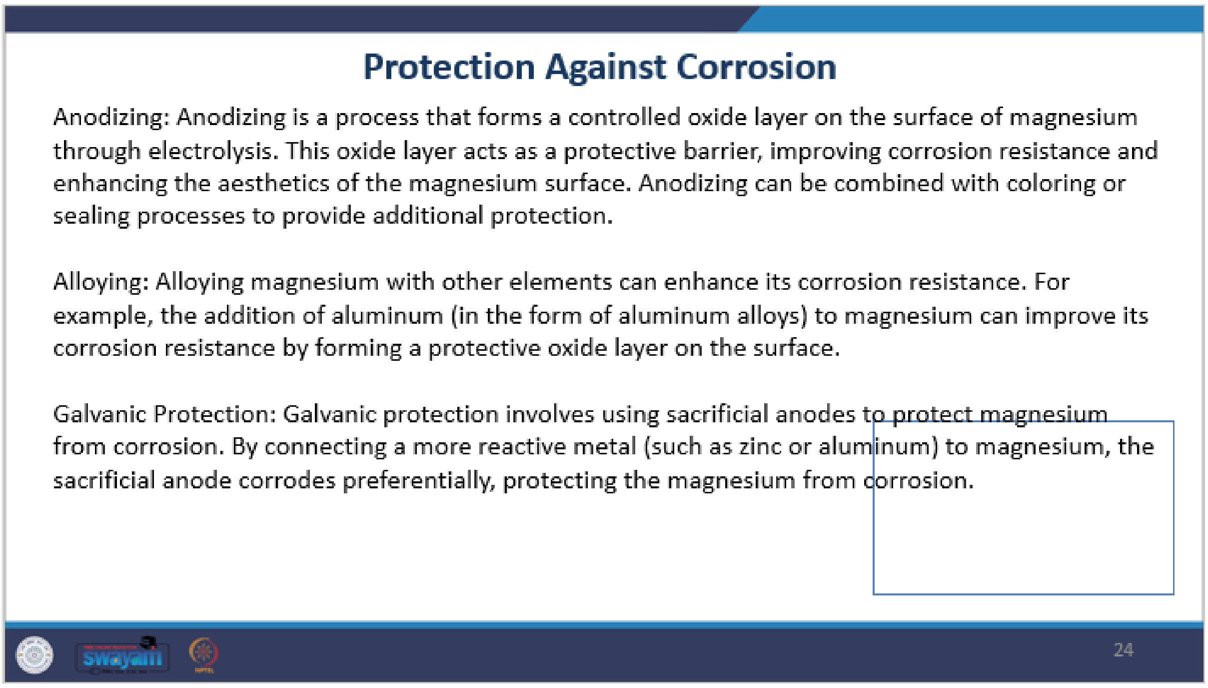


Electrophoretic deposition EPD this is the process where a metal component is immersed in the bath containing a polymer dispersed with the charged particles. When an electric field is applied to the charged particle migrate and deposit onto this metal surface forming a conformal coating EPD of conformal coating. Now this EPD offers excellent coverage, uniformity and control over coating thickness. Then CVD that is chemical vapor deposition. This is a vapor phase coating method where a precursor gas containing polymer molecule is introduced into a chamber containing the metal component by chemical reactions and the polymer molecules are deposited over the surface forming a thin conformal coating.

This CVD provides excellent coverage adhesion and uniformity particularly for the complex geometries. Let us talk about the metal and alloy protection. The magnesium this is a lightweight metal that is known to be highly susceptible to corrosion when exposed to moisture, oxygen and other corrosive environment. The magnesium can undergo a rapid corrosion leading to the material degradation and structural weakening. Therefore, implementing the effective corrosion protection measure for magnesium is crucial.



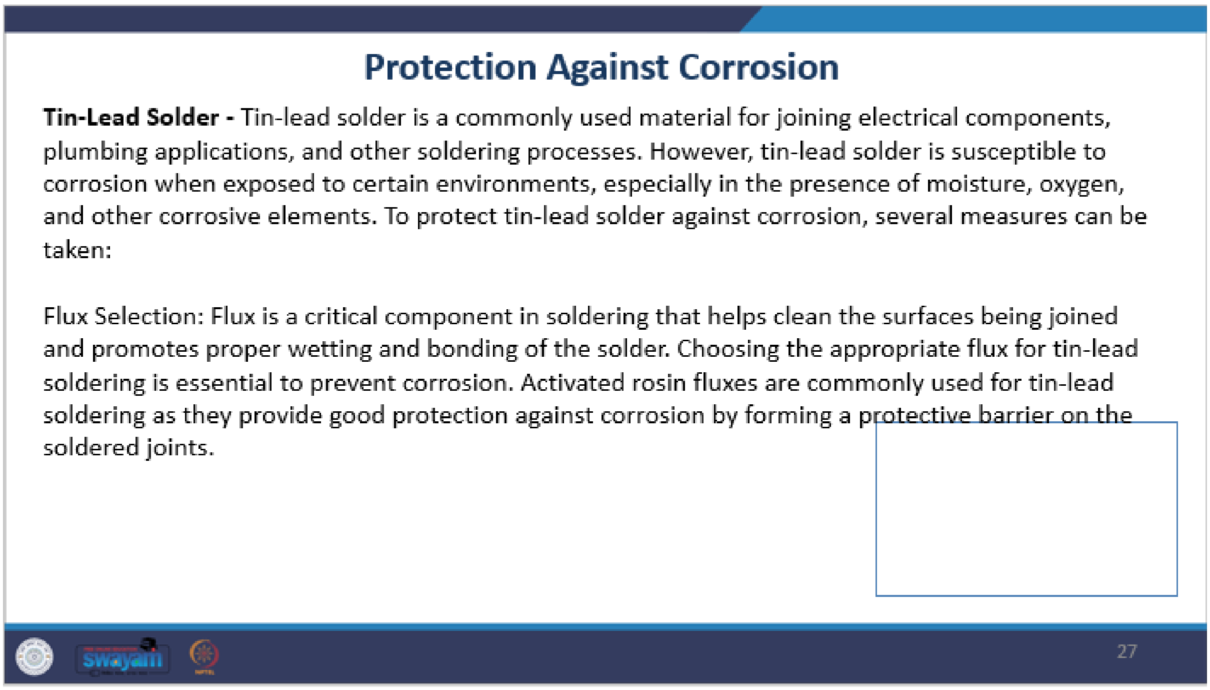
Now, there are some common methods we are going to discuss for the protecting magnesium against corrosion. One is the surface coating, the supplying the protective coating on the surface of magnesium is widely used method for corrosion protection and different type of the coating such as organic coating like paints, inorganic coating like conversion coating, electroplated coating.



This can provide a barrier between the magnesium substrate and corrosive environment. Anodizing anodizing this is the process that forms a controlled oxide layer on the surface of magnesium through the electrolysis and this oxide layer acts as a protective barrier improving corrosion resistance and enhancing the aesthetic of the magnesium surface. This anodizing can be combined with the coloring or sealing processes to provide the additional protection.

Alloying this alloying magnesium with other element can enhance the corrosion resistance for like example of addition of aluminium in the form of aluminium alloy to the magnesium. This can improve its corrosion resistance by forming a protective oxide layer on the surface. Galvanic protection, this galvanic protection involves using the sacrificial anodes to protect the magnesium from corrosion and by conducting more reactive material to the magnesium, the sacrificial anode the corrodes the preferentially protecting the magnesium from corrosion. There are certain corrosion inhibitors, this can be used to reduce the corrosion rate of magnesium. These inhibitors can be applied as a coating and incorporated into the protective film or used as adhesive in the corrosive environment and these inhibitors works by forming a protective layer on the magnesium surface or by altering the electrochemical reactions.

Environmental control, the controlling the environment condition which the magnesium is used can help prevent the corrosion and this includes the minimizing the exposure to the moisture, humidity, corrosion, corrosive chemicals and proper ventilation, drainage, moisture control. This can also be contribute towards the reducing the risk of corrosion. Regular maintenance is again very integral part, regular inspection, housekeeping, cleaning, maintenance, they are important for identifying the addressing any sign of magnesium surface. Now, it is essential to select and implement the appropriate corrosion protection methodology based on the specific application, environmental conditions, requirements and by employing the effective corrosion protection measures, magnesium can be safeguarded ensuring the durability, performance and safety in various application.



Then tin-lead shoulders, this tin-lead shoulder is commonly used material for joining the electrical components, plumbing applications and other soldering processes and tin-lead solder they are susceptible to the corrosion when exposed to certain environment especially in the presence of moisture, oxygen and other corrosive elements.

To protect tin-lead solder against the corrosion several mechanisms can be adopted, one is the flux selection. Flux is a critical component in soldering that helps the to clean the surface being joined and promoted proper wetting and bonding with the solder. Now, choosing the appropriate flux for tin-lead soldering is essential to prevent the corrosion. Proper cleaning, prior to soldering it is important to clean the surfaces to be soldered to remove any contaminants or oxides, oil which can hinder the proper bonding and lead the corrosion. Solder alloy selection is again very important while tin-lead solder has a good soldering property it is more prone towards corrosion compared to the some other solder alloys.

Consideration can be given to alternative solder alloys for better corrosion resistance, which are lead-free solders like tin-silver-copper or tin-copper alloys. Coating or encapsulation, applying a protective coating or encapsulation encapsulating the solder joints, can provide an additional layer or protection against corrosion. This can be done using conformal coating, epoxy resin or other protective material that act as a barrier between the solder and corrosive environment. Obviously, environmental control plays a very vital role which we have already discussed that proper storage, handling, installation practices, and humidity control all play a very vital role. Regular inspection also inspection and maintenance also play a very vital role in such kind of protection against corrosion.

It is important to note that tin solder is regulated for many reasons due to its lead content and there is a global trend towards the use of lead-free solder alloy. However, for the application where tin-lead solder is still in use, implementing and mentioning protection measures can help the minimization under the corrosion environment. This ensures the reliability and longevity of the solder connections.

Protection Against Corrosion

Aluminum - Like magnesium, aluminum is widely used because of its low density. It, too, must be protected from corrosion, although the normal oxide film which forms on its surface on exposure to air is highly protective and prevents deterioration of the bulk of the metal. A number of oxide coatings (anodize) may purposely be formed as protective coatings and as surface treatments to improve the adhesion of subsequent organic coatings (MIL-A-8625).

Primers such as wash primer, phenolic, and epoxy are useful in serving as a bridge between the anodized surface and a topcoat paint. As with magnesium, epoxy primers and epoxy or acrylic topcoats offer outstanding long-term corrosion protection. A proven finish system for outdoor use consists of MIL-(3-5541 chemical surface treatment, MILP-23377 epoxy polyamide primer, and MIL-L-81352 acrylic topcoat. This system has been successful for the protection of many types of aluminum alloys, both clad and nonclad. For interior use, this finishing system may be employed without the Topcoat.

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Let us talk about the aluminium like magnesium aluminium is widely used because of the low density it is too much, it too must be protected from the corrosion although the normal oxide film which forms on its surface on exposure to air is highly protective and prevents the deterioration to the of the bulk of the metal. A number of oxide coating anodized this may purposely be formed as a protective coating and the surface treatment to improve the adhesion of the subsequent organic coating.

Protection Against Corrosion

Magnesium-Lithium Alloys - Magnesium-lithium alloys such as LA 141 are attractive to designers of airborne electronic equipment because of their stiffness and high strength-to-weight ratio. These alloys afford a 20 to 25 percent weight saving over magnesium or other magnesium alloys. However, the high reactivity of magnesium lithium with moisture and carbon dioxide limits its use to hermetically sealed boxes with dry inert-gas ambients. Often, even in an enclosed box an incompatible situation can arise owing to the evolution of moisture from plastics or from electronic components within the box. Moisture reacts with the lithium portion of the alloy, forming hydrogen gas and lithium hydroxide. In the presence of carbon dioxide, white lithium carbonate is formed on the alloy surface. In addition to the formation of these corrosive products and deterioration of the alloy, a secondary, perhaps even more harmful, effect may result from reaction of evolved hydrogen gas with active devices, chemically sensitive thick- or thin-film resistors, and other components.

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Primers such as wash primers, phenolic epoxies they are useful in serving the bridge between the anodized surface and the top coat pen. As with magnesium epoxy primers and epoxy are acrylic top coats with the outstanding long-term corrosion protections. So, this can be used. Now let us talk about the magnesium lithium alloys. Magnesium lithium alloys sometimes referred as LA 141 they are attractive to the designers of airborne electronic equipment's because of their stiffness and high strength to weight ratio.

These alloys offer 20 to 25 percent weight saving over magnesium and other magnesium alloy. Now the high reactivity of magnesium lithium with the moisture and carbon dioxide limits its use to hermetically sealed boxes with the dry inert gas ambient. Often even in an enclosed box an incompatible situation can arise owing the the evolution of moisture from the plastic or from the electronic component within the box. So, the moisture reacts with the lithium portion of the alloy forming the hydrogen gas and a lithium hydroxide in the presence of the carbon dioxide while white lithium carbonate is formed on the alloy surface. And in addition to the formation of these corrosive products and the deterioration of the alloy a secondary perhaps even more harmful effect may result from reaction to evolve the hydrogen gas with active devices chemically sensitive thick or thin film resistance and other components.

ENVIRONMENTAL PROTECTION

Ingredients	Percent by weight
Pigment base	
Polyvinyl butyral resin	9.2
Basic zinc chromate	8.8
Magnesium silicate	1.3
Lampblack	0.1
Butyl alcohol, normal	20.5
Isopropyl alcohol	57.7
Water	2.4
Total	100.0
Acid Diluent	
85% phosphoric acid	18.5
Water (maxium)	16.5
Isopropyl alcohol	65.0
Total	100.0

Table: WP-1 Composition

Wash Primers - Wash primers consist of rust-inhibiting pigments, chiefly basic zinc chromate or lead chromate, in an alcoholic solution of polyvinyl butyral resin, as one part of a two-part system. The second part consists of a phosphoric acidwater-isopropyl alcohol solution. The first solution is acidified with the second just prior to use. This primer is commonly referred to as WP-1, and its precise composition is given in Table. Wash primers provide effective corrosion protection for many metal parts, such as aluminum, magnesium, steel, zinc, and tin.

Although there are reported to be several coatings which will protect magnesium lithium in normal environment no organic coating or coating system is known to provide the sufficient protection to the pass the military environment test. Now here in this particular aspect we have discussed the different type of wash primers. The wash primer consists of rust inhibiting pigment cheaply mainly basic zinc chromate or lead chromate in an alcoholic solution of polyvinyl butyryl resin as one part or a two part of system. The second part consists of phosphoric acid water isopropyl alcohol solution. Now these wash primers may be used alone or where the superior protection against the salt spray or moisture is required in conjunction with the top coat such as epoxy, vinyl or alkyd.

Wash Primers

- They may be used alone or, where superior protection against salt spray and moisture is required, in conjunction with a topcoat such as epoxy, vinyl, or alkyd.
- They are applied in thicknesses of 0.3 to 0.5 mil by spraying, brushing, or swabbing. The best corrosion protection is provided by using a wash primer followed by a topcoat.
- A wash-primer-epoxy topcoat system provides protection for either magnesium or aluminum for over 800 hr of salt-spray exposure, performed according to MILSTD-881.
- Over 2,000 hr of salt-spray exposure without deterioration has been reported for a vinyl (VAGH) coating applied over either a wash primer or a red lead primer.
- Wash primers may be purchased from paint manufacturers according to military specifications, chiefly MIL-C-8507, MIL-C-8514, and MIL-C-15328.

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Wash primer top coat system provides protection for either magnesium or aluminum for over 800 hours of salt spray exposure. Over 2000 hours of salt spray exposure without deterioration has been reported by some of the scientist for vinyl coating applied over either wash primer or a red lead primer. Other type of primers are also employed to improve adhesion of top coat hence provide better corrosion protection and the performance of vinyl coating for instance is greatly improved by priming metal surface. Now the primers may consist of other specifically formulated vinyl phenolics epoxies and butadiene acrylonitriles. These epoxy primers are very effective in improving the adhesion of the polyurethanes and in the protection of the either aluminum or steel.

Other Primers

- Other types of primers are also employed to improve adhesion of topcoats and hence provide better corrosion protection. The performance of vinyl coatings, for instance, is greatly improved by priming metal surfaces.
- Primers may consist of other specifically formulated vinyls, phenolics, epoxies, or butadiene acrylonitriles.
- Epoxy primers are very effective in improving the adhesion of polyurethanes. In the protection of either aluminum or steel, the use of an epoxy primer followed by two topcoats of moisture-curing polyurethane resulted in panels which passed 800 hr of 20 percent salt spray exposure, according to ASTM B 117-57.

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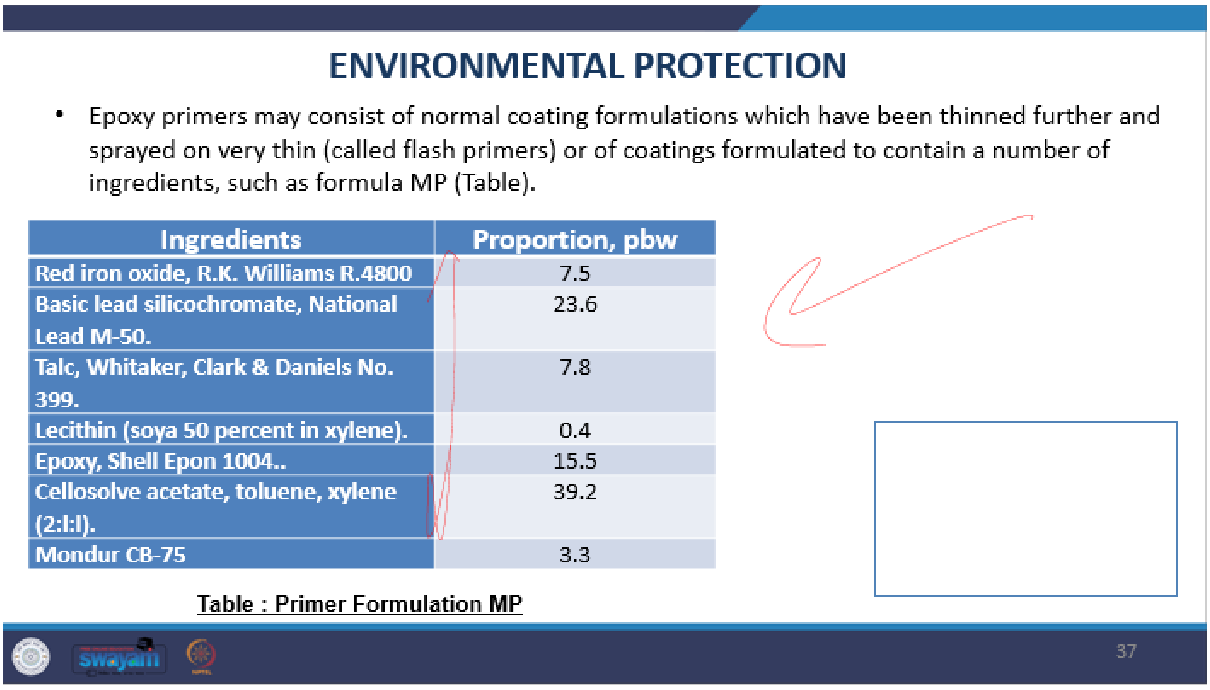
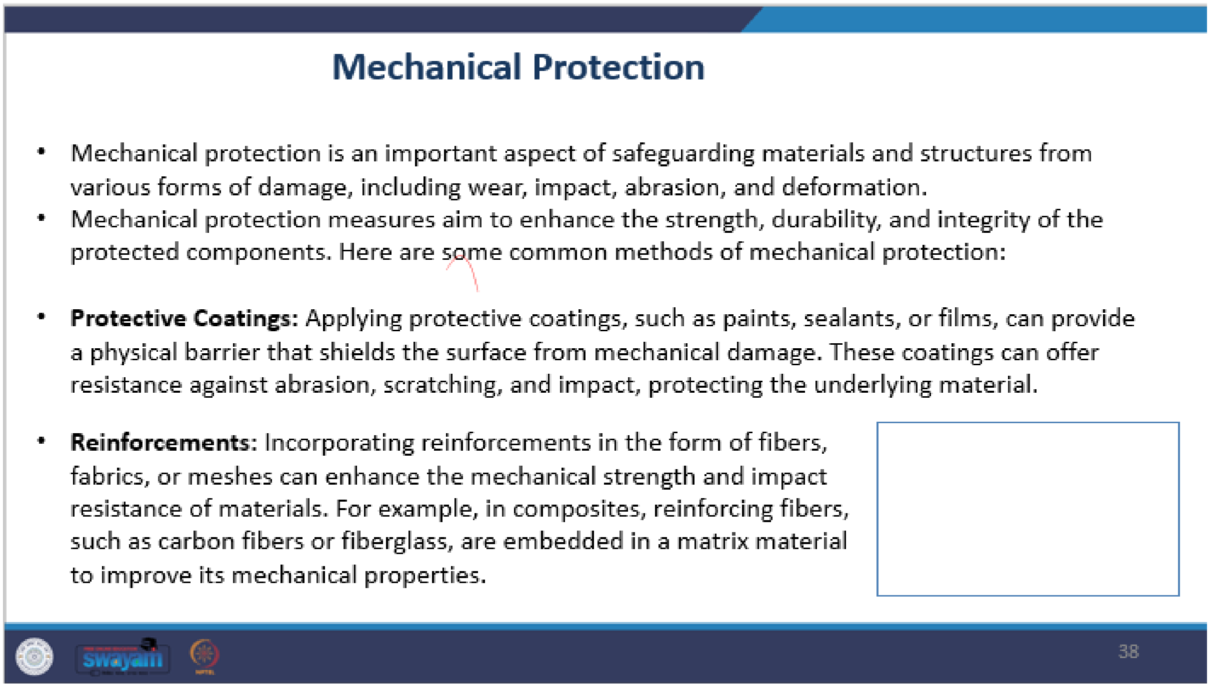
The use of an epoxy primer followed by the top coat of moisture curing polyurethane resulted in panel which passed say 800 hours of 20 percent salt spray exposure as per ASTM standards. Now these epoxy primers some of the primer formulation is enlisted. Now epoxy primers may consist of normal coating which have been through thin further and sprayed on a very thin or coating formulated to contain a number of ingredients in like we have enlisted some of them over here. Let us talk about the mechanical protection. The mechanical protection is an important safeguard material in a structure form and a various form of the damage including wear and tear impact abrasion deformation.



The mechanical protection measures aim to enhance the strength, durability and integrity of the protected component. Now some of the common methods for mechanical protection are given like protective coating applying a protective coating like paint sealant or film. This can provide a physical barrier that shield the surface from mechanical damage. Then reinforcement the incorporation of reinforcement in the form of fiber fabric meshes this can enhance the mechanical strength and impact resistance of the material. Then impact absorbing materials use the impact-absorbing materials such as rubber or foam These can provide cushioning and absorb the energy of impact and these materials are commonly used in applications where protection against impact or shock is crucial.



Structure design the implementing appropriate structural design principle can help distribute loads and stresses evenly and reducing the risk of mechanical failure. This includes the designing component with sufficient strength, stiffness and a load bearing capacity based on the expected operating conditions. The reinforcing enclosures the enclosing sensitive components or structure within the reinforced casing or enclosure can provide the protection against the mechanical impacts vibration etcetera. Then protective covers and guard this can shield the vulnerable component from direct contact with the external object or substance. Then the shock mounts you utilizing shock mounts or isolators this can reduce the transmission of the vibration shocks and impacts from the external environment to the sensitive component.

Then the maintenance and inspection the regular maintenance inspection and repair of mechanical system they are quite essential to identify and address the potential area of weakness or damage. Now abrasion resistance the application in which there is an excessive handling rubbing contact with other object this requires the surface to have a high degree of abrasion resistance. This may be determined by the periodic examination while the coating is in actual use. Now this includes the projection of a controlled stream or abrasive such as carborundum or a sand this against the sample.

Abrasion Resistance

- Applications in which there is excessive handling, rubbing, or contact with other objects require that surfaces have a high degree of abrasion resistance. Abrasion resistance may be determined by periodic examinations while the coating is in actual use.
- However, excessive time would be required to obtain meaningful data by this method, and results would be more or less qualitative.
- Fortunately, several accelerated and quantitative methods are available that may be correlated with actual service performance or used to compare the relative abrasion resistances of coatings.

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Abrasion Resistance

Taber abrasion tester

- These include projection of a controlled stream of abrasive such as carborundum (ASTM D 658-44) or sand (ASTM D 968-51) against the sample, use of an abrasive tape (Armstrong test, ASTM D 1242), controlled scraping with a metal tool until the coating is penetrated, or the use of rotating abrasive wheels.
- This last method, referred to as the Taber abrasion test, is the most widely used for plastic coatings and is described in Federal Standard 141, Method 61 92, and ASTM D 41 2 and D 1044.
- According to the Taber method, two standardized abrading wheels rotate against a coating sample which consists of a 4-in.square coated metal panel with a center spindle hole.

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Now here, this is the taper abrasion resistance. Now, this method is referred is the most widely used for plastic coating and is described in the various standards. The panel usually the pre-weight to the nearest milligram is placed on the turntable operating condition at a constant speed while two abrasion wheels are fixed on each side of the spindle and direct contact with the coating. So roughly a 1000-gram load may be placed on wheels, and a built-in tachometer requires a number of turntable revolutions and a vacuum attachment removes the plastic particles as they are abraded from the surface, and the instrument is operated for a specific number of cycles or until a portion of the substrate becomes exposed. The result may be reported in either a number of cycles to failure per mil thickness of coating or the weight loss in the milligram for a specified number of cycles. Now friction resistance, when repeating sliding or insertions must take place as in the electronic drawers or console surfaces with a low coefficient of friction.

Friction Resistance

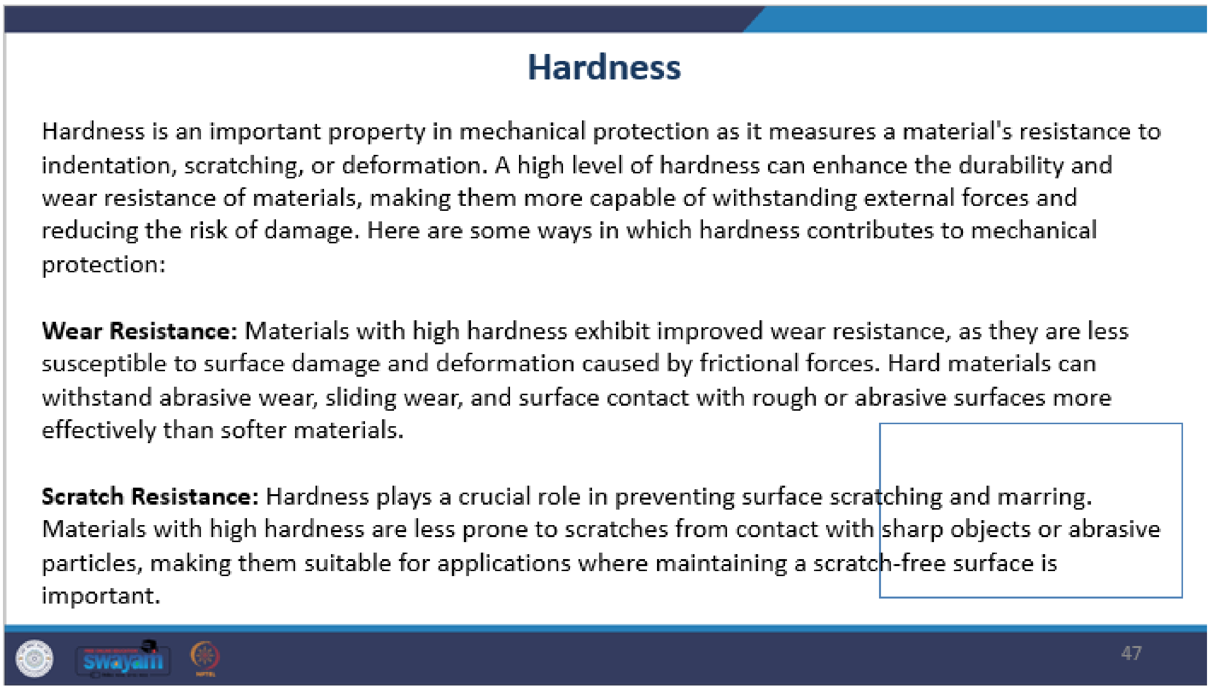
- When repeated sliding or insertions must take place as in electronic drawers or consoles, surfaces with a low coefficient of friction will facilitate operation and will minimize surface abrasion and deterioration- of the coating.
- The best way to assess the friction resistance of materials is by comparing their coefficients of friction; the lower this value, the greater the resistance to friction (Table). Theoretical treatments of both friction and abrasion are reported elsewhere.
- With the exception of some of the fluorocarbon polymers, plastics have coefficients of friction of the same order of magnitude as metals. Values for plastics, however, depend more on test conditions, such as temperature, humidity, loading, and operating speed, and on material conditions, such as degree of cure and moisture content.

This will facilitate the operation with and will minimize the surface abrasion and deterioration of coating. The best way to assess the friction resistance of the material is by comparing their coefficient of friction, the lower the this value the greater the resistance and theoretical treatment of both friction and abrasion which can be reported over here.

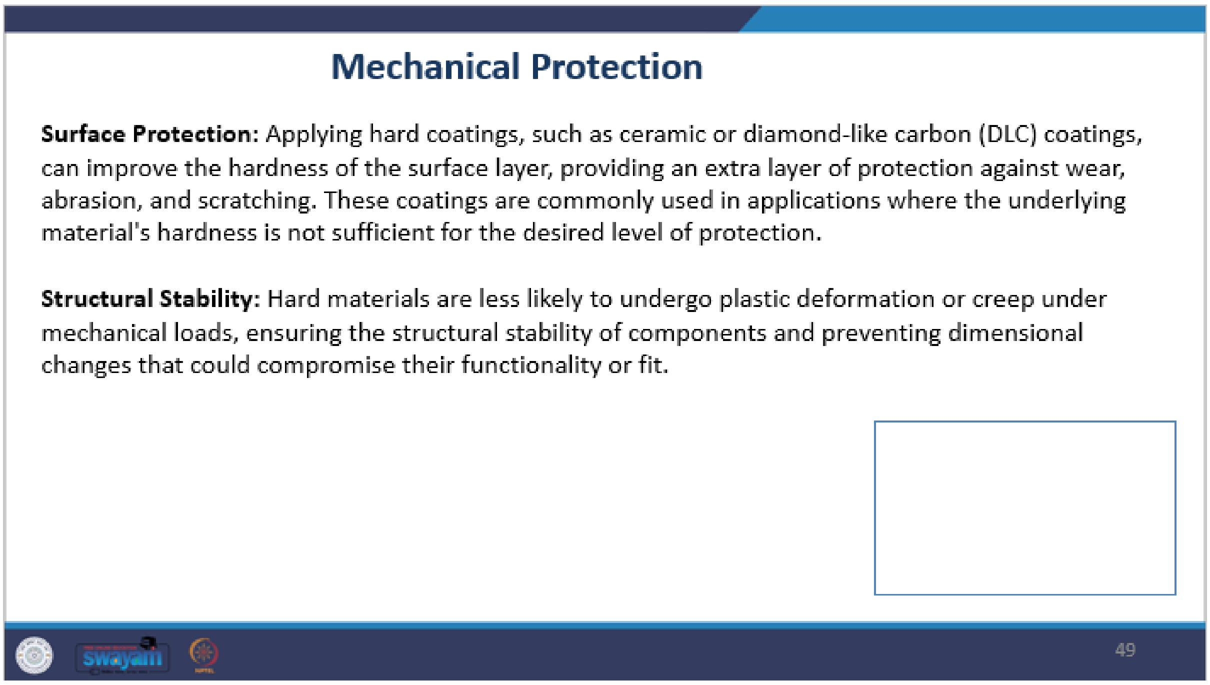
Coefficients of Friction of Typical Coatings

Material	Coefficient of friction	Source
Coationg		
Epoxy, air-dried coating with Teflon filler	0.15	a
Polyamide, nylon.	0.3	b
Polyethylene	0.6-0.8	b
Polyimide (Pyre-M.L.)	0.17	c
Poly methylmethacrylate	0.4-0.5	b
Polystyrene	0.4-0.5	b
Polytetrafluoroethylene (Teflon TFE)	0.05-0.1	b
	0.04	d
	0.016	e
Polyvinyl chloride	0.4-0.5	b
Polyxylylene, parylene N	0.25	Union Carbide
Parylene C	0.29	Union Carbide
Parylene D	0.31-0.33	Union Carbide
Other materials for comparison		
Graphite	0.18	c
Molybdenum disulfide	0.12	f

Now in this particular table we have reported the coefficient of friction with the typical coating. Now here these are the coating and you can see the different coefficient of friction. Now the coefficient of friction let us for an example varies for nylon varies from 0.912 to 1.19 with the variation of the moisture content from 2.2 to 10 percent. The surface against which the sample is tested is also an important variable.

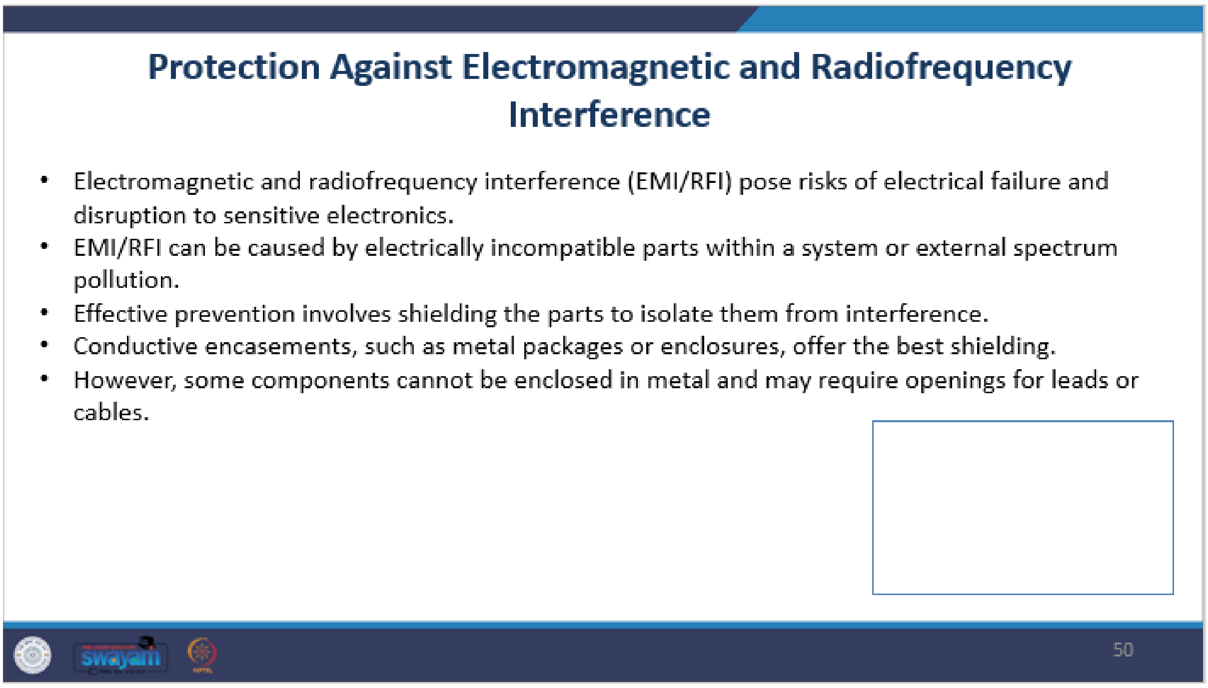


Hardness is again an important property of the in the mechanical protection. It is the measure, it measures a materials resistance to the indentation, scratching or deformation.



A high level of hardness can enhance the durability and a wear resistance of material making them more capable of withstanding the external forces and reducing the risk of damage. Here are some ways in which the hardness contributes to the mechanical protection. One is the wear resistance, the materials with the high hardness exhibits an improved wear resistance as they are less susceptible to the surface damage and deformation caused by the frictional forces. Scratch resistance, hardness display a very crucial role in preventing the surface scratching and and bearing. The materials with high hardness they are less prone to scratch from the contact with the sharp object or abrasive particles.

Impact resistance, although the hardness is a primary associated with the resistance to indentation and it can also indirectly contribute to impact resistance. The hard materials are less likely to deform or dent when subjected to impact or high-pressure forces providing the better protection and underlying component structure. Cutting and machining performance component strength, all these things play a very vital role. The surface protection, applying the hard coating, this prevents the surface, this is a useful practice. Then structural stability, the hard materials they are less likely to undergo the plastic deformation to creep under mechanical load ensuring the structural stability of the component and preventing the dimensional changes that could compromise the functionality to fit.



Now let us talk about the protection against electromagnetic and radio frequency interface. The electromagnetic and radio frequency interface pose risk of electrical failure and disruption to the sensitive electronics and this can be caused by the electrically incompatible part within the system and external spectrum pollution. Now plastic with the conductive material they are commonly used for EMI and RFI shielding and silver is the most frequent used metal filler followed by the nickel, copper, stainless steel, carbon fiber, carbon black coated graphite and aluminum flake and fibers. Here are some of the typical examples of the product used for EMI or RFI protection like different type of elastomer oriented with wire, then the plastic fillers and shielding performance.

Table: Examples of Products Used for EMI/RFI Protection

Product	Plastic/Filler	Shielding Performance (dB)* at Different Frequencies
Elastomet oriented wire in gasket material	Silicone or fluoro-silicone/Monel or phosphor bronze	100 kHz: 75 (Monel); 80 (Phr brz) 10 MHz: 130+ (Monel); 130+ (Phr brz) 1GHz: 110 (Monel); 100 (Phr brz) 10 GHz: 115 (Monel); 100 (Phr brz)
Consil-C custom gaskets	Silicone/silver-copper	100 kHz: 75; 10 MHz: 120+; 1 GHz: 115; 10 GHz: 110
Consil-N custom gaskets	Silicone/silver-nickel	100 kHz: 75; 10 MHz: 120; 1 GHz: 110; 10 GHz: 100
Consil-A custom gaskets	Silicone/silver-plated aluminum particles	100 kHz: 75; 10 MHz: 120+ 1 GHz: 110; 10 GHz: 100
SC-Consil custom gaskets	Fluorosilicone/carbon	100 kHz: 40; 10 MHz: 100; 1 GHz: 60, 10 GHz: 50
ECTC windows	Acrylic/thin-film metal	100 kHz: 20; 10 MHz: 90; 1 GHz: 30
Teckfilm transparent sheets	Polyester/thin-film metal	100 kHz: 20; 10 MHz: 90; 1 GHz: 30
Teck-bond RTV sealant	Silicone/silver-plated copper	—
Conductive caulking joints/seals	Polyolefin acetate/silver-coated inert particles	—
Epoxy adhesive gasket bonding, sealing	Epoxy/silver	—
Conductive coatings coating plastic enclosures	Acrylic or latex/silver, nickel, or graphite	—

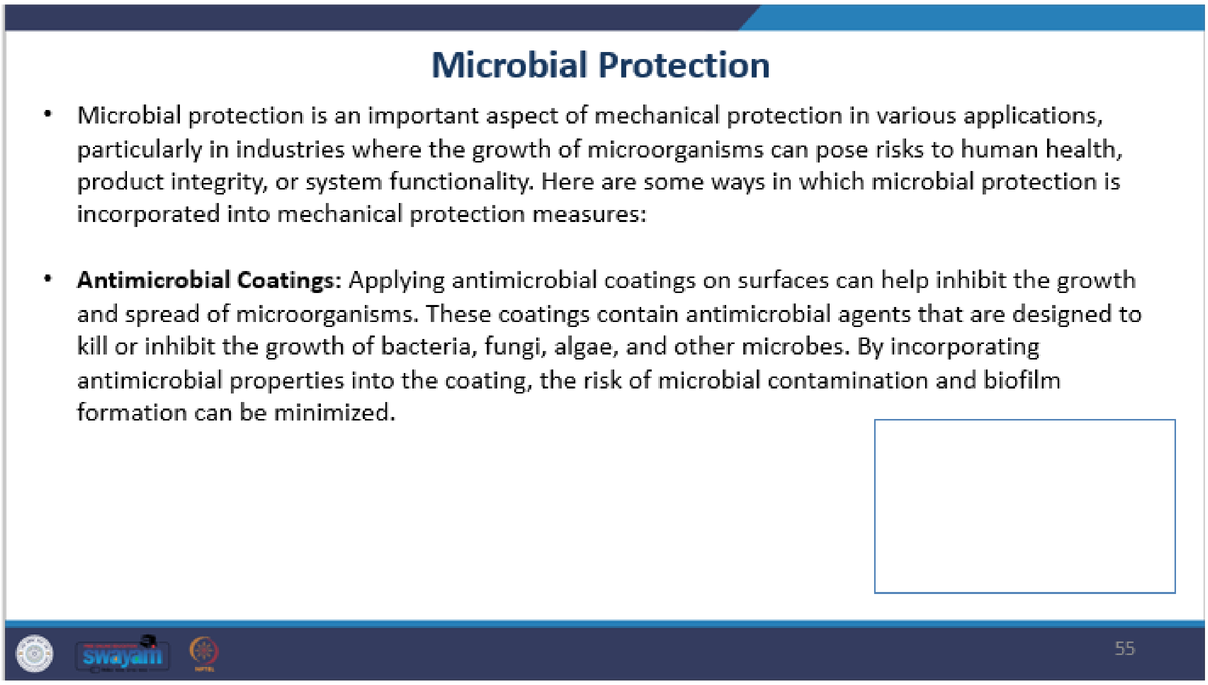
*Test methods used either from MIL-STD-285 or MIL-G-83528.

So, the test method which was given as per these standards. Now let us talk about the electrostatic protection, protection against the electrostatic discharge.

Protection Against Electrostatic Discharge

- **Protection Against Electrostatic Discharge -** Each year millions of dollars are lost by the electronics industry because of electrostatic damage to devices and circuits. This loss can come from damage to semiconductor devices causing a product to fail or, in a more extreme case, an explosion due to a static spark in a combustible atmosphere.
- To minimize this problem electrostatic-sensitive devices such as integrated circuits, transistors, and diodes are stored and transported in specially treated plastic enclosures.
- These plastic enclosures are manufactured primarily from polyethylene (PE), polypropylene (PP), or Aclar.

Now each year millions of dollars they are lost by the electronics industry because of electrostatic damage to devices and circuits and this loss can come from the damage of the semiconductor devices causing to a product to fail or in more extreme cases an explosion due to the static spark in a combustible atmosphere. Now to minimize this problem the electrostatic sensitive devices like integrated circuits, transistors and diodes are stored and transported in a specially treated plastic enclosure. Now in order to dissipate the electrostatic charge that develops on the plastic surface the plastic must be formulated or coated with electrically conductive or semiconductive fillers such as graphite or ionic surfactants such as long chain fatty amines or carboxylic acids.



Let us talk about the microbial protection, microbial protection is an important aspect of a mechanical protection in various application particularly in the industry where the growth of microorganism this can pose risk of human health, product integrity and the system functionality.

Some of the ways in which the microbial protection is incorporated one is the antimicrobial coating this you can apply the antimicrobial coating on the surface this helps to inhibit the growth or spread of a microorganism. Then we must go for the hygienic design by incorporating the hygienic design principle in mechanical system or equipment this can be prevent the accumulation of microorganism. Then smooth and non-porous surfaces, these the surfaces that are smooth and non-porous they are less likely to harbor the microorganism compared to the rough and porous surfaces. Then sealant and gaskets the proper sealing of mechanical component or system using the sealant and gasket this can prevent the entry of microorganism into the sensitive areas. By adoption of a regular cleaning and maintenance practice this the regular cleaning and maintenance procedures they are all quite essential to remove the microbial contaminants and maintain a clean and hygienic environment.

Then the proper material selection the choosing the material with the inherent antimicrobial properties can provide the built-in microbial protection. Then UV sterilization then certain application the ultraviolet light technology can be used to provide the microbial protection. Now polymers play a crucial role in providing the microbial protection of electronic components by acting as barrier against the microbial growth and preventing the contamination. They are used in the various form like coating, films, adhesive to create the protective layer that inhibits the growth and survival of microorganism. One is the silver based polymer, silver is excellent antimicrobial properties it can be incorporated into the polymer to enhance their microbial protection capabilities.

Then quaternary ammonium compounds they are also used as antimicrobial agent in the polymer formulation and these compounds are positively charged quaternary ammonium group that interacts with the negatively charged microbial cell membranes and disrupting the integrity and leading to cell death. The polymeric biocides the certain polymers are formulated with specific biocidal additives to impart the antimicrobial properties and these additives release the active ingredient that target and inhibits the microbial growth. Sometimes antimicrobial silicon rubbers this can be modified with the antimicrobial agent to create the antimicrobial silicon products. Then antimicrobial films the polymer films such as polyethylene, polypropylene, polyvinyl chloride these can be modified with antimicrobial agents to create the protective film that can be applied to the electronic components.

THERMAL CONDUCTIVITY

THERMAL CONDUCTIVITY - The total amount **of** heat a material can conduct is directly proportional to the surface area, time of contact, and temperature gradient and is inversely proportional to the thickness of the sample, "according to the equation

$$Q \propto \frac{(T_2 - T_1)At}{d} \qquad Q = \frac{k(T_2 - T_1)At}{d}$$

Where, Q =total lieat flow
A =surface area, cm^2
d =thickness of sample, cm
T_2 =temperature of the hot surface, ºC
T_1 =temperature of the cold surface, ºC
t =time, *sec*

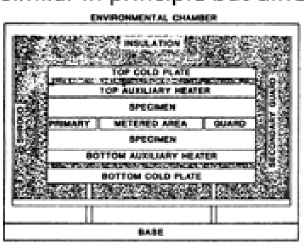
The constant k is a material constant called the **coefficient *of* thermal conductivity.**

THERMAL CONDUCTIVITY

Test Methods - Several methods of measuring thermal conductivity are available, of which the guarded-hot-plate and heat-flow meter methods are the most widely used. The most accurate method for plastic samples having thermal conductivities of 3.4 x 10-3 cal/(sec.)(cm.)(ºc) or less (most filled or unfilled plastics are in this category) is the guarded-hot-plate method described in ASTM C 177. This and other methods are discussed elsewhere.

The Guarded-hot-plate Method. Two different types of guarded-hot-plate apparatus can be used for thermal conductivity testing. They are similar in principle but differ somewhat in construction.

One example, shown in Figure, consists of three sections: a central heating plate, guard heating plates, and cooling plates.



Various testing protocols are available. Let us talk about the thermal conductivity, thermal conductivity the total quantum of amount of heat and the material can conduct is this is directly proportional to the surface area and time of contact and temperature gradient and which is inversely proportional to the thickness and sample and this is the mathematical representation given for the total lead flow. There are various test methods measuring the thermal conductivities are available for which the guarded hot plate and heat flow method they are most widely used. Now this is the one of the example of the guarded hot plate apparatus. The guard section ensures the unidirectional heat flow from the central heater and eliminates any influence from the edge of the sample. So, to evaluate the thermal conductivity we have given several references in the reference section you can go through further reading.

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Apart from this the heat flow meter method is again useful to evaluate the thermal conductivity and for all these studies we have enlisted several references and which you can use for your convenience. Thank you very much. Thank you.