

**Polymer Process Engineering**  
**Prof. Shishir Sinha**  
**Department of Chemical Engineering**  
**Indian Institute of Technology-Roorkee**  
**Lecture- 46**  
**Polymeric Materials used in Electronics**

Hello friends, welcome to the next edition of Polymeric Process Engineering. Here we are going to discuss about the different polymeric materials used in electronics application.

You see that there are wide spectrum of uses of polymeric materials and in this category the electronics arena is a very prominent user of these polymeric materials, like from packaging to the PCBs to the housing to the casing in all spectrum you will find those of the polymeric materials like the monitor you are seeing in this particular lecture or the mobile phones on all day to day spectrum you will find the polymeric materials are closely associated with the electronics. So, in this particular segment we are going to cover and there is no need to discuss that where these polymers are associated. So, that is why we are straight away going to the different type of polymers those are being used for the electronics application in different field of life. So, in this particular segment we are going to cover about the polyurethanes.

**Topics to be covered**

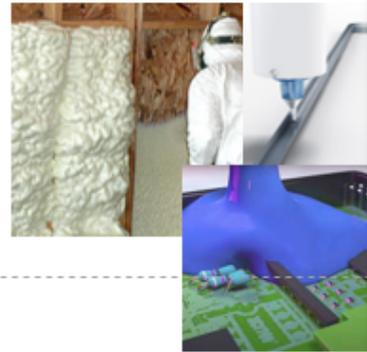
- **Polyurethanes**
  - Introduction
  - Methods
  - Catalyst selection mechanism
  - Classification of polyurethanes
  - ASTM testing methods
  - ASTM standard-based classifications

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Here we will have the introductory part, the method and because of the synthesis involves a catalysis operation of the process. So, how we can select the catalyst? So, we will discuss about the catalyst selection mechanism. Then we will discuss about the classification scheme of polyurethanes. Apart from this there are various tests associated.

## Polyurethanes

- Polyurethanes can be used in electronics for a variety of purposes, including insulation, adhesion, and encapsulation.
- One of the primary advantages of polyurethanes is their ability to provide excellent electrical insulation properties while maintaining flexibility and toughness.
- Polyurethane coatings and adhesives are commonly used in electronics manufacturing to protect components from moisture, chemicals, and mechanical stress.

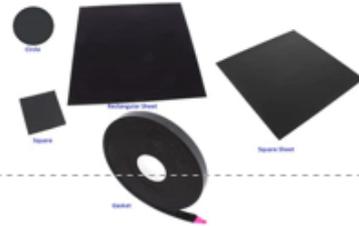


So, we will discuss all these tests under the umbrella of ASTM. Now, the polyurethane, the polyurethane can be used in electronics for variety of purposes. This may include the insulation, adhesion, encapsulation and one of the primary advantage of polyurethane is their ability to provide the excellent electrical insulation. They are being used for the insulation purpose. Previously the glass wool being used for the insulation purpose, but nowadays polyurethane they are the best you can say they acquire the best place in the insulation material.

Now, the polyurethane coating and adhesives they are commonly used in electronics manufacturing especially to protect the components from the moisture, chemical and mechanical stress. And these adhesives are also used in the electronic industry for bonding the various components. Now, these adhesives offer excellent adhesion to the variety of substance that can be used for the to bond the metal, plastic and ceramics because sometimes you need to join the metal plastic in the electronic application. Now, these poly polyurethane adhesive offer a best candidacy in this aspect. Polyurethane foam this can also be used in electronics for insulation, vibration damping because sometimes like fan and other things they impart the vibration and they create the damping.

## Polyurethanes

- For example, polyurethane foam can be used to protect delicate electronic components from shock and vibration during transportation.
- Overall, polyurethanes are versatile materials that can be tailored to specific electronics applications and provide a range of benefits, including electrical insulation, adhesion, and mechanical protection.



So, this vibration damping can be used as by the help of polyurethane foams. Now, polyurethane foam can be used to protect the delicate electronic component from shock vibration. So, overall polyurethanes they are versatile materials that can be tailored to specific electronic application and provide a range of benefits like from insulation to adhesion to the mechanical protection all these spectrum even from the it may create a barrier between the atmosphere and the material in question. Now, another thing is that the polyurethane can be used in the electronics application like in conformal coating of PCBs. They are the thin layers of material that are applied to the surface of the printed circuit board to protect it from the environmental factor like moisture, dust and chemicals.

## Polyurethanes

- One of the primary uses of polyurethanes in electronics is as a conformal coating for printed circuit boards (PCBs).
- Conformal coatings are thin layers of material that are applied to the surface of a PCB to protect it from environmental factors such as moisture, dust, and chemicals.



Now, the polyurethanes they are preferred in this application because of the excellent moisture resistance. So, they create the barrier between the moisture and the component in question. Now, the these polyurethane can be used as a sealant and these sealant are used to seal the gap and joint

in the electronic enclosure. This helps to prevent the moisture and dust. Now, encapsulation the polyurethane resin they are commonly used material for encapsulating the electronics component to protect them from the external factor like moisture heat chemicals because they are very good insulating material.

## Polyurethanes: Encapsulation

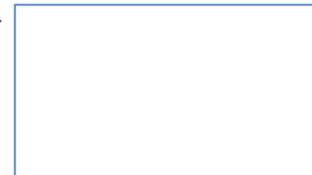
- Polyurethane resin is a commonly used material for encapsulating electronic components to protect them from external factors such as moisture, heat, and chemicals.
- The mechanism of polyurethane resin for encapsulation involves a chemical reaction between two main components, polyol and isocyanate, which forms a crosslinked polymer network.

Urethane linkage

So, the mechanism of polyurethane resin for encapsulation this involves a chemical reaction like here you see between the two resin component and a main component usually is referred as a polyol and isocyanate which forms the cross link polymer network and it provides the strong bonding. Now, this polyol is a long chain molecule with a reactive hydroxyl group at its end like here you see that reactive hydroxyl group. This isocyanate is a molecule with the reactive isocyanate group at its end. Now, when two components they are mixed a chemical reaction occurs in which isocyanate group reacts with the hydroxyl group to form the NCCO bonding that is called the urethane linkage. Now, the reaction between the polyol and isocyanate component is exothermic in nature which means it releases certain quantity of energy and typically initiated by adding a catalyst which speed ups the reaction.

## Polyurethanes: Encapsulation

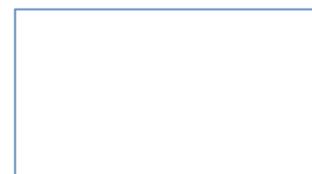
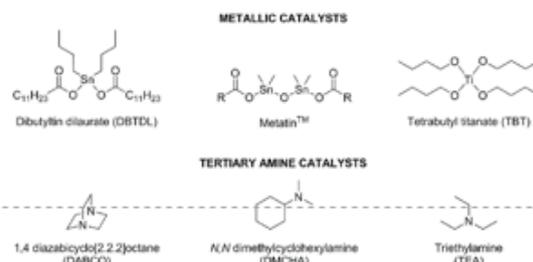
- The polyol is a long-chain molecule with reactive hydroxyl (-OH) groups at its ends. The isocyanate is a molecule with reactive isocyanate (-NCO) groups at its end.
- When the two components are mixed, a chemical reaction occurs in which the isocyanate groups react with the hydroxyl groups to form urethane (-NHCOO-) linkages.
- This reaction is called the urethane reaction or urethane linkage formation.



The resulting material is a cross link polymer network and that is insoluble and chemically stable. Now, these resins or polyurethane resins for encapsulation is typically applied as a liquid which then cures and harden over the period of time and it becomes solid. Now, this curing process involves the polymerization of the polyurethane resin to form a solid and they form the protective layer alongside of the component. The final properties of the polyurethane resin like hardness, flexibility, chemical resistance this can be controlled by adjusting the ratio of polyol to isocyanate and the type of catalyst used. Now, here you can see different type of polyurethanes like thermoplastic, flexible polyurethane, rigid polyurethane, polyurethane isocyanate, then water bound polyurethane like the example thermoplastic keyboard protector for the laptop, outer case of the mobile.

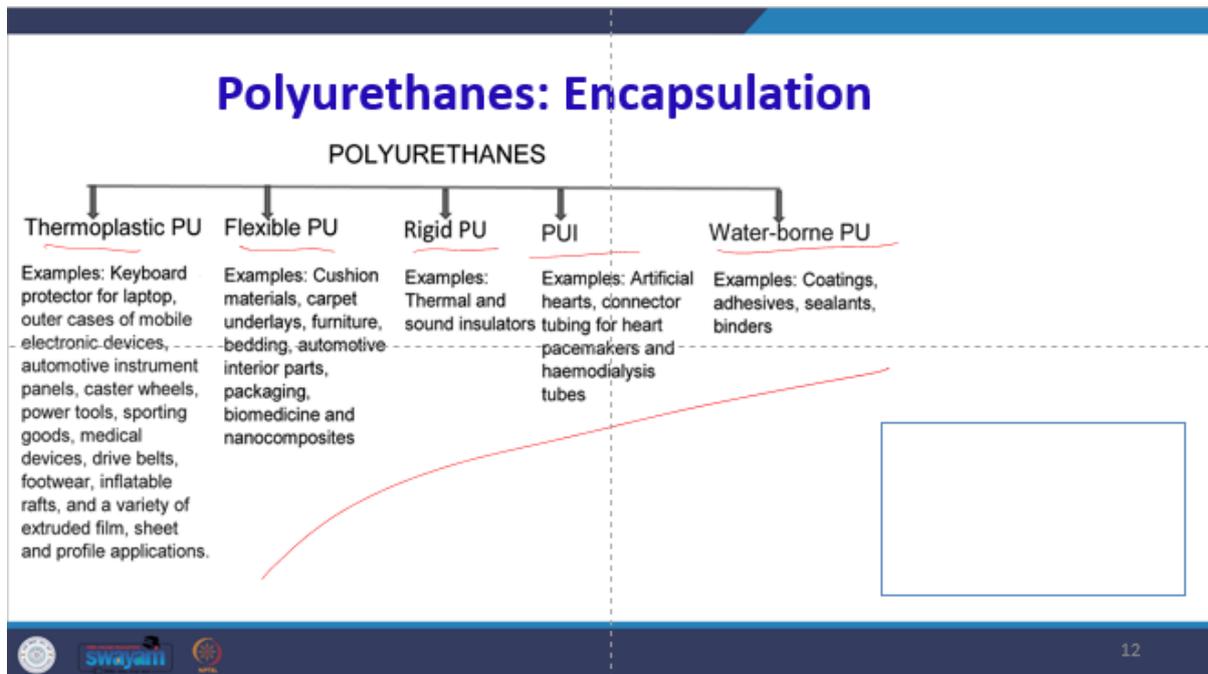
## Polyurethanes: Encapsulation

- The reaction between the polyol and isocyanate components is exothermic, meaning it releases heat, and it is typically initiated by adding a catalyst, which speeds up the reaction.
- The resulting material is a crosslinked polymer network that is insoluble and chemically stable.



You can see that all these finds a wide application in our day to day life in the flexible polyurethane, the cushion material, carpet, furniture bedding all those things you can find and rigid polyurethane

thermal and sound insulator. So, you see all these products they find a wide application in our day to day affairs. Now, there are various techniques associated with the encapsulation. Now, there are several type of polyurethane encapsulation. Now, each of this its own advantage and disadvantage.



The most common type of polyurethane encapsulation or potting these techniques involve the filling a cavity around the electronic component with the polyurethane resin. Now, this potting provides excellent protection against environment factor like moisture, heat, dirt, dust, chemicals whatever. It can be challenged to repair or replace component that that have been potted. Another is the encapsulation molding. Now, this technique involves the placing the electronic component into a mold and then injecting the polyurethane resin into the mold.

## Polyurethanes: Encapsulation Techniques

- There are several types of polyurethane encapsulation techniques, each with its own advantages and disadvantages.
- The most common types of polyurethane encapsulation are;
- Potting: This technique involves filling a cavity around electronic components with a polyurethane resin. Potting provides excellent protection against environmental factors such as moisture, heat, and chemicals. However, it can be challenging to repair or replace components that have been potted.

So, that this provides outer layer that particular thing and this excellent provides the excellent protection and it can be used as to produce the complex shapes, but it is costly and time consuming. Conformal coating, this technique involves applying a thin layer of polyurethane resin to the surface of electronic components and conformal coating provides excellent protection against moisture and other environmental factor. This can be easily repaired and removed and they do not provide as much protection as potting or encapsulation molding. Another thing is the transfer molding. Now, this technique involves the placing of electronic component and then pouring the pre-catalyzed polyurethane resin into the mold and transfer the molding molding provides good protection and a relatively fast and cost effective.

## Polyurethanes: Encapsulation Techniques

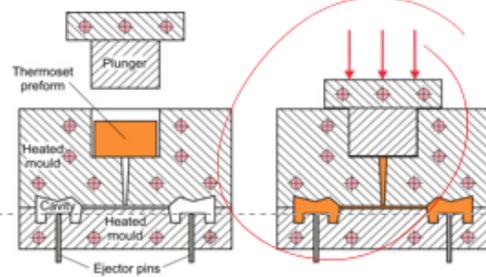
- **Conformal Coating:** This technique involves applying a thin layer of polyurethane resin to the surface of electronic components. Conformal coatings provide excellent protection against moisture and other environmental factors, and they can be easily repaired or removed. However, they do not provide as much protection as potting or encapsulation molding.



It is not suitable for producing the complex shape because the mold and other things they are very sensitive. So, the overall choice of the polyurethane encapsulation technique that depends on the specific requirement of the application like the level of protection you require, the complexity of the component, the shape of the component and how much production volume is needed. Let us talk about the isocyanates in polyurethane synthesis. So, isocyanates they are an important component in polyurethane coating formulation when we talk about the formulation they are very much important and when they react with the polyols to form a polyurethane film. Some of the typical isocyanate used in the polyurethane coating are toluene diisocyanate TDI this is referred as TDI this is widely used isocyanate in polyurethane coating and it is available in two form 2, 4 TDI and 2, 6 TDI and is used in both solvent based and water based formulations.

## Polyurethanes: Encapsulation Techniques

- **Transfer Molding:** This technique involves placing electronic components into a mold and then pouring a pre-catalyzed polyurethane resin into the mold. Transfer molding provides good protection and is relatively fast and cost-effective. However, it is not suitable for producing complex shapes.

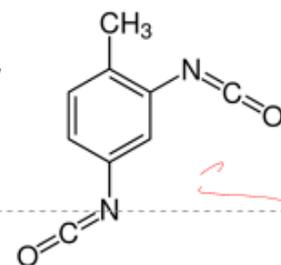


Then hexamethylene diisocyanate HDI this is another commonly used isocyanate in polyurethane coating it is the cyclophatic isocyanate and it is available in two form HDI isocyanate isocyanate and HDI biurethane isophorine diisocyanate IPDI this is another form and this is a low viscosity aliphatic isocyanate that is used in high performance coating and it is highly resistance to yellowing and weathering. Sometimes weathering effect is also play very vital role in that category this particular isocyanate is useful. Then MDI this is highly reactive isocyanate and that is used in polyurethane coating and it is available especially in two component system. Then dasmodu N 75 this in an aromatic poly isocyanate that is used in high solid coating and it is highly resistant to chemical and abrasion another property of this polyurethane is that abrasion resistance. Then dasmodu L 75 this is another aromatic poly isocyanate that is used in polyurethane coating and it is highly reactive and has a good weathering resistance.

## Isocyanates in polyurethane synthesis

- Isocyanates are an important component in polyurethane coating formulations, where they react with polyols to form a polyurethane film.
- Some of the typical isocyanates used in polyurethane coatings include:

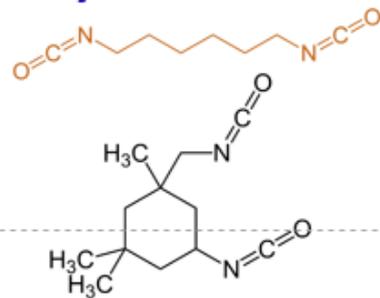
1. **Toluene diisocyanate (TDI):** This is a widely used isocyanate in polyurethane coatings. It is available in two forms, 2,4-TDI and 2,6-TDI, and is used in both solvent-based and water-based formulations.



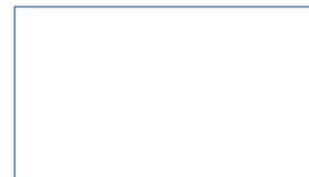
Another category is 4, 4 methyl methylene bisphenyl isocyanate MDI this is very common and very popular one. This is another highly reactive isocyanate that is used in polyurethane coating and it is often used in combination with other isocyanates to achieve the specific coating property. Sometimes you require some specific coating properties and these can be a case sensitive and this can be used in that particular aspect. Now, the when we are having a large chunk of the isocyanate availability then question arises how do we select this isocyanate? So, let us talk about isocyanate selection. So, when selecting an isocyanate for a polyurethane synthesis several criteria should be considered to ensure the desired properties and performance to the final polyurethane product.

## Isocyanates in polyurethane synthesis

2. **Hexamethylene diisocyanate (HDI):** This is another commonly used isocyanate in polyurethane coatings. It is a cycloaliphatic isocyanate and is available in two forms, HDI isocyanurate and HDI biuret.

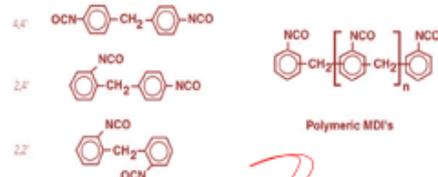


3. **Isophorone diisocyanate (IPDI):** This is a low-viscosity, aliphatic isocyanate that is used in high-performance coatings. It is highly resistant to yellowing and weathering.



## Isocyanates in polyurethane synthesis

4. **Methylenediphenyl diisocyanate (MDI):** This is a highly reactive isocyanate that is used in polyurethane coatings, especially in two-component systems.

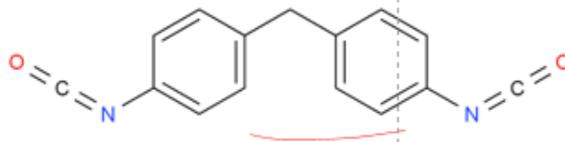


5. **Desmodur N-75:** This is an aromatic polyisocyanate that is used in high-solids coatings. It is highly resistant to chemicals and abrasion.



## Isocyanates in polyurethane synthesis

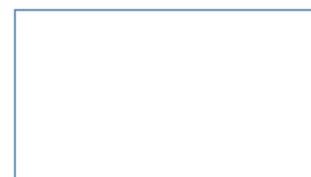
6. **Desmodur L-75**: This is another aromatic poly-isocyanate that is used in polyurethane coatings. It is highly reactive and has good weathering resistance.
7. **4,4'-methylenebis(phenyl isocyanate) (MDI)**: This is another highly reactive isocyanate that is used in polyurethane coatings. It is often used in combination with other isocyanates to achieve specific coating properties.



Now, there are some important selection criteria for isocyanate in polyurethane synthesis and we are also giving you some examples for the same. First one it is very common that is a reactivity the isocyanate should have an appropriate reactivity to achieve the desired curing or cross-linking rate and the reactivity affects the processing time, pot life, and the final properties of the polyurethane. The example of such isocyanates with different reactivity levels includes the tallow in diisocyanate TDI this is highly reactive isocyanate and is commonly used in flexible foam application. Then methylenediphenyl diisocyanate MDI this is moderately reactive isocyanate and suitable for wide range of polyurethane application including the rigid foam coating and adhesive. Another selection criterion is the compatibility.

## Isocyanate Selection

- When selecting an isocyanate for polyurethane synthesis, several criteria should be considered to ensure the desired properties and performance of the final polyurethane product.
- Here are some important selection criteria for isocyanates in polyurethane synthesis, along with examples.



Now, isocyanate should be compatible with the other components in the polyurethane formulation like polyols; additives compatibility ensures good mixing and uniform distribution of the component leading to improved mechanical properties and stability. Now, aliphatic isocyanates are

hexamethylene diisocyanate referred to as HDI or isophorone diisocyanate IPDI they are commonly used in coating and adhesive due to the excellent compatibility with various polyols and good UV resistance. Another criterion for isocyanate selection is performance requirement. The choice of isocyanate should align with the desired performance characteristics of the final polyurethane product like mechanical strength, chemical resistance, thermal stability and flexibility. Like polymeric isocyanate polymeric isocyanate such as MDI, PMDI they offer improved mechanical properties and enhanced durability and they are often utilized in application requiring high strength impact resistance like automotive parts and structural adhesives they are the best candidate to use these polymeric isocyanate.

## Isocyanate Selection

1. **Reactivity:** Isocyanates should have an appropriate reactivity to achieve the desired curing or crosslinking rate. The reactivity affects the processing time, pot life, and final properties of the polyurethane. Examples of isocyanates with different reactivity levels include:
  - a. **Toluene diisocyanate (TDI):** TDI is a highly reactive isocyanate commonly used in flexible foam applications.
  - b. **Methylenediphenyl diisocyanate (MDI):** MDI is a moderately reactive isocyanate suitable for a wide range of polyurethane applications, including rigid foams, coatings, and adhesives.

## Isocyanate Selection

2. **Compatibility:** Isocyanates should be compatible with other components in the polyurethane formulation, such as polyols and additives. Compatibility ensures good mixing and uniform distribution of the components, leading to improved mechanical properties and stability.
  - a. **Aliphatic isocyanates:** Aliphatic isocyanates, such as hexamethylene diisocyanate (HDI) or isophorone diisocyanate (IPDI), are commonly used in coatings and adhesives due to their excellent compatibility with various polyols and good UV resistance.

## Isocyanate Selection

- 3. Performance Requirements:** The choice of isocyanate should align with the desired performance characteristics of the final polyurethane product, such as mechanical strength, chemical resistance, thermal stability, and flexibility.

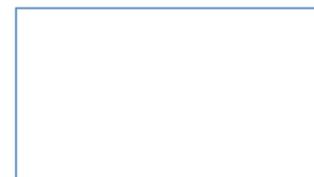
- a. Polymeric isocyanates:** Polymeric isocyanates, such as polymeric MDI (PMDI), offer improved mechanical properties and enhanced durability. They are often utilized in applications requiring high strength and impact resistance, such as automotive parts and structural adhesives.



## Isocyanate Selection

- 4. Health and Safety Considerations:** Isocyanates are known to have sensitizing properties and can cause health hazards. It is crucial to consider the health and safety aspects of the chosen isocyanate, including volatility, handling requirements, and exposure limits.

- a. Cycloaliphatic isocyanates:** Cycloaliphatic isocyanates, like isophorone diisocyanate (IPDI), are less volatile and have lower health and safety risks compared to aromatic isocyanates. They are often preferred in applications where reduced toxicity and lower odor are important, such as in medical devices and consumer products.



## Isocyanate Selection

- 5. Cost:** Cost considerations play a role in isocyanate selection, as different isocyanates vary in price. The cost should be balanced with the required performance and application needs.
- These criteria can guide the selection of an appropriate isocyanate for polyurethane synthesis, ensuring the desired properties, processing characteristics, and safety requirements of the final product.
  - It is recommended to consult technical data sheets, industry guidelines, and experts to make informed decisions based on specific application requirements.

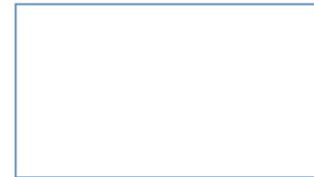


Another selection criteria is health and safety consideration. Now, this is a prime importance nowadays, and because of the various regulations, various regulatory bodies they are putting forward so many regulations and they are more concerned towards the health and safety operations. So, that is why the isocyanate selection again based on the health and safety consideration. So, they are known to have a sensitizing properties and they can cause the health hazard because of the presence of isocyanate embedded in it. Now, it is crucial to consider the health and safety aspect of the chosen isocyanate this include volatility, heating requirement and exposure limit and sometimes the if the component is there then VOCs and if it is there is a fire hazard then the limited limiting aspect should be there.

The cyclo aliphatic isocyanate they are the best candidate like isophorone diisocyanates they are less volatile and they have the lower health and safety risk compared to the other aromatic isocyanates and they are often preferred in application where reduced toxicity and lower order they are important like in medical devices and the consumer products. Another important factor which involves in the isocyanate selection is the cost. This is play a very vital role in the isocyanate selection as different isocyanate they vary in prices the cost should be balanced with the required performance and application needs. So, you must have some certain sort of an optimization and a balancing among all the desired properties and the cost in question. Now, these criteria whatever discussed those 5 criteria's in the previous slides we discussed these criteria can guide the selection of an appropriate isocyanate for polyurethane synthesis and they ensure the desired properties, processing characteristics and safety requirement of the final product.

## Classification of polyurethanes

- **Classification based on production method:**
  - ✓ **One-shot method:** all the reactants are mixed at once
  - ✓ **Prepolymer method:** the isocyanate and polyol are first reacted to form a prepolymer, which is then reacted with a chain extender to form the final product.
- **Classification based on chemical structure:**  
aliphatic, aromatic, or cycloaliphatic:
- **Classification based on application:**  
coatings, adhesives, foams, elastomers, and sealants



Now, it is recommended to consult the technical data sheets usually material safety data sheets are always available and readily available apart from the industry guideline and expert to make the informed decision based on the specific application requirement because the specific application requirement that the isocyanate selection may vary. Now, since we discussed about the isocyanate selection and the different isocyanates then it is a time to have a classification stream of polyurethanes. Now, usually the classification based on the production method one is that one shot method the all reactants they are mixed at once then prepolymer methods the isocyanate and polyol they are first reacted to form a pre-polymer which is then reacted with the chain extender to form the final product. Now, the classification again the based on the chemical structure like we may have the aliphatic we may have the aromatic and then we may have the cyclo aliphatic. Another class of polyurethane based on the classification based on application the polyurethane can be used for the coating they can be used for the adhesive they can be used as an air foam they can be used as an elastomer and they can be used as a sealant.

## ASTM testing methods for polyurethanes

The American Society for Testing and Materials (ASTM) has developed several standards for polyurethane materials used in various applications. Some of the ASTM standards for polyurethane are summarized below:

- **ASTM D1621:** Standard Test Method for Compressive Properties of Rigid Cellular Plastics - This test method is used to determine the compressive properties of rigid cellular polyurethane foam.



Another class of the classification is the classification based on hardness this may be a flexible or rigid foam. Then the classification based on the functionality like di isocyanate based or tri isocyanate based. So, you can based on these functionality you can classify them. Then another classification is based on the molecular weight may be high medium or low molecular weight. Now, let us talk about the ASTM testing methods for polyurethane.

Usually the ASTM American Society for Testing and Materials ASTM they developed several standards for polyurethane materials they are used in the various applications and some of the most popular standards used for the polyurethane characterization they are like ASTM D1621. This standard test method for compressive properties of rigid cellular plastic and this test method is used to determine the compressive properties of a rigid cellular polyurethane foam. Another testing method is that ASTM D3575 the standard test method for flexible cellular materials polyurethane latex and rubber. This standard covers various test method for evaluating the physical properties of the flexible cellular polyurethane foam. This may include the density, this may include the compression force deflection, this may include the tear strength and inside strength.

Another test method that is ASTM D395 this is the standard test method for rubber property or rubbery properties the compression set. Now this standard covers the determination of the compression set properties of elastomeric materials this including the polyurethane. Another test protocol is ASTM D412 this is the standard test method for vulcanized rubber and thermoplastic elastomer tension. This standard covers the measurement of tensile properties of vulcanized rubber and thermoplastic elastomers and this includes the polyurethane. Then ASTM D2240 this is the standard test method for rubber properties durometer hardness and this standard covers the measurement of the hardness of rubber and plastic materials this includes the polyurethane.

Again, one of the most popular test methods is ASTM D648 this is the method for deflection temperature of plastic. So, under the flexural load this standard covers the determination of the deflection temperature of plastic this includes the polyurethane under flexural load. So, these ASTM standards they provide a consistent and a reliable way to evaluate the properties and performance of polyurethane material used in various application. So, depending upon the properties of these material the ASTM also classify them like one is the one component blocked polyurethane that is ASTM type 3. The one component system with the blocked isocyanate groups see the mostly used in the electrical application and particularly in wire coating.

## One-component Blocked Polyurethanes (ASTM Type-3)

- The one-component systems with blocked isocyanate groups see the most use in electrical applications, particularly for wire coatings. ←
- The active isocyanate groups are made latent by interacting with other organic compounds that contain active hydrogen atoms in order to prolong pot life and produce more aesthetically pleasing one-component systems.
- The prepolymer is nonreactive and has an infinite shelf life in this state, known as a blocked isocyanate.

The active isocyanate groups are made latent by interacting with other organic compound that contains active hydrogen atom or in order to prolong pot life and produce more and more aesthetic pleasing one component system. So, the pre polymer is non reactive and has an infinite shelf life and in this case state known as blocked isocyanate. The blocking ingredient separates when it is heated and released isocyanate group this may be the polymerize and appropriate hardener components and the most used blocking agent is phenol although there are also additional agents including chrysol, methyl ethyl ketoxime butanol and caprolactam. The temperature requirement or temperature required to unblock the phenol is about 160 degree Celsius. Now such high processing temperature usually limit the use of type 3 polyurethane and they cannot be used for temperature sensitive electronic components and hardware because the segment may get deformed and then whatever product you are requiring in that case you may not have the desired properties.

## Two-component Prepolymer: Polyol (ASTM Type-5)

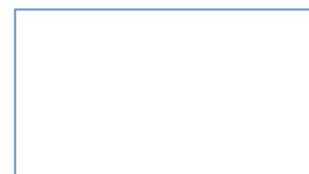
- These are widely used for corrosion-protective and high-reliability electrical insulating coatings.
- Component **A** is usually a toluene di-isocyanate or a poly-isocyanate prepolymer, also known as an adduct. Component **B** is a hydroxyl containing resin.
- The most commonly used **B** components, are hydroxyl-terminated polyesters, polyethers, polyols, castor oil, and some epoxy resins.



So, however they are very ideal for wire and a coil insulation and for coating other materials or metal or ceramic. Now objects prior to the attachment of temperature sensitive part like other adducts with the lower unblocking temperatures they are available like the melonic ester adduct which unblocks at 130 degree Celsius. Another class based on ASTM that is two component pre polymer polyol ASTM type 5 these are widely used for corrosion protective and high reliability electrical insulating coating. Now component A is usually a toluene diisocyanate or poly isocyanate pre polymer they are also known as adduct and component B is hydroxyl containing resin. The most commonly used B component are hydroxyl terminated polyesters, polyethers, polyol, castor oil and some sort of epoxy resins.

## Two-component Catalyst-cured Systems (ASTM Type-4)

- Type-4 systems consist of an isocyanate resin as one component and a catalyst as the second component. The urethane reaction is base-catalyzed, and hence small amounts (0.5 to 4 percent) of basic (alkaline) materials may be used to initiate polymerization.
- Among the commonly used catalysts are the tertiary amines.



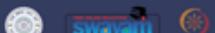
The polyethers they are based on polypropylene oxide and are termed as polypropylene glycols a large variety of these glycols differing in molecular weight and viscosities are available. So, both the

polyethers and polyesters range from long linear structure as in generalized formula for a hydroxyl terminated polyether or highly branched structure. Now a proper selection the properties of the coating may be varied from highly flexible to very hard orbital. So, as a rule most linear structure the more flexible the resulting film and the more branched structure the harder and more chemically resistant the coating will be. Another type of classification is based on two component catalyst cured system and referred as ASTM type 4.

So, the type 4 system consist of an isocyanate resin as one component and a catalyst as a second component. The urethane reaction is base catalyzed hence a small amount say 0.5 to 4 percent of basic alkaline material may be used to initiate the polymerization. And the commonly used catalysts are tertiary amines. The combination of two different catalysts have been found in more active than either catalyst used alone.

## One-component Oil-modified Systems: Uralkyds (ASTM Type 1)

- One component polyurethane systems are commercially available. They are based on urethanes containing as part of their structure modified drying oils such as linseed oil, and are referred to as uralkyds, urethane oils, or oil-modified urethanes.
- In their manufacture the oil is first partially de-esterified to give a mixed hydroxy ester. The free hydroxyl group of this ester can then react with an diisocyanate to give the prepolymer resin:

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This enhancement is achieved by combining two catalyst which are called the synergistic action. An example of is the combination of tin catalyst and tertiary amines. Another type of classification is one component oil-modified system elides that is ASTM type 1. Now, one component polyurethane systems they are commonly available are based on urethanes containing as part of their structure-modified drying oils such as linseed oil and they are referred to as eualkides urethane oil or oil-modified urethanes. In their manufacturing, the oil is first partially deesterified to give a mixed hydroxy ester, and the free hydroxy ester group of these esters can then react with a di isocyanate to give the pre polymer resin.

Now, here you see that this represents the fatty acid portion or double bond like this and it should be noted that this particular resin cannot polymerize further through the free isocyanate group because none are available. Here, you find no one is available. The polymer does, however, contain many double-bond ethylene groups in the fatty acid portion of the oil and, therefore, cures by air oxidation. The free radicals are formed from the active methylene group adjacent to the double bond and several units may then combine to form a high molecular weight polymer. The addition of drying catalysts

such as cobalt or manganese, naphthalate will then accelerate the air curing and take free take free time to 2 to 5 minutes at room temperature.

This may be achieved by the addition of such dryers. The main feature of your eulkides resin coatings is their lower cost in comparison to the polyurethane types. This is a result of the lower cost of the naturally occurring oil used in their elides like alkyd. They exhibit very good water and alkali resistance, but they are marginal in color and gloss retention, which is very important. Now, they are not as extensively employed for electrical applications as blocked polymers or two-component systems. Since they do not have the high overall performance characteristics of a rapid air-drying formulation, which becomes stack-free in 2 to 5 minutes.

## One-component Moisture-cured Systems (ASTM Type 2)

- The moisture cured prepolymers are obtained by reacting hydroxyl-containing materials such as castor oil, hydroxyl-terminated polyesters, or hydroxyl-terminated polyether with an excess of tolylene diisocyanate. Prepolymer adducts having free isocyanate groups are thus obtained.

Tolylene diisocyanate

Prepolymer adduct

Source: Licari 1991, Handbook of polymer coatings...

Another type of system is the component moisture-cured system ASTM type 2. The moisture-cured pre-polymers are obtained by the reacting hydroxyl-containing material such as castor oil, hydroxyl-terminated polyester or hydroxyl-terminated poly ether, which an excess of toluene diisocyanate pre-polymer ducts having the free isocyanide groups which is then obtained. You can see in this particular formula. Now, a thin film of these pre-polymer will then cure on exposure to the air moisture. The atmospheric air contains a sizable amount of moisture, and then the curing mechanism involves the cross-linking of molecules through the formulation of the urea link agents it may be represented like this.

Now, moisture-cured polyurethane coating they are among the toughest and the most abrasion resistant coating available. They command the widest use as a floor wood and appliance coating, which is again very important, and their use in electronics is very limited because the time required for a complete cure depends on the relative humidity and may, therefore, vary considerably from day to day and place to place. Apart from this it would be difficult to adhere strictly to production specifications film 1 to say 3 else thick might require 45 minutes to 12 hours to harden depending on the formulation and relative humidity. It is also difficult to prepare good coating by baking and again because the humidity in the curing oven is very low because of the high temperature and the coating

may remain in an uncured or semi cured condition. Now, another type of classification is one component non reactive that is ASTM type 6.

## One-component Nonreactive (ASTM Type-6)

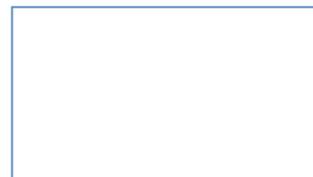
- These polymers are pre-reacted and thinned with solvents such as alcohols, N-methyl-2-pyrrolidone, toluene, or methyl ethyl ketone.
- They may also be purchased as anionic colloidal urethane elastomer dispersions in a water/solvent mixture.
- These systems are primarily used as impregnates for fabrics, leather and paper and as primers and topcoats for other plastics.
- Type-6 urethanes are not generally used for coating electronics.



Now, these polymers are pre-reacted and thinned with solvents like alcohol and methyl 2 pyrrolidine toluene or methyl thio ketone. Now, these may also be purchased as anionic colloidal urethane elastomer dispersion in a water solvent mixture. Now, these systems are primarily used as impregnates for fabrics, leather, and paper and as a primer and top coats for other plastics. So, type 6 urethanes are not generally used for coating the electronics. So, dear friends, in this particular segment, we discussed about the various aspects of polyurethane.

## References

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We discussed about how these polyurethanes are classified and how their standard and test methods are being classified. For your convenience we have enlisted so many references you can use all these references as per your convenience. Thank you very much.