

# MODIFICATION OF NYLON 6, 6

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## Abstract

Nylon 6, 6 is regarded as tough and ductile materials since it exhibit high tensile elongation to break and high drop weight impact strengths. However, under conditions of stress concentration such as in the presence of sharp notches or cracks, polyamides exhibit brittle failure. This property, evaluated as notched Izod or Charpy impact tests, indicates that unmodified polyamides exhibit relatively low energies for crack propagation. Crystalline thermoplastic polymeric materials such as low carbon monomer nylons are very sensitive to craze and crack propagation and so their toughness and impact resistance properties are relatively low. Nylon 6 and 6,6 are relatively low cost engineering thermoplastics that have been found so many applications including automotive industry. However, relatively low impact and bending resistance of these materials especially at low temperatures and high deformation rates, restrict applications of these materials. Rubber toughening can be considered as an economical and effective method to toughen and extend applications of nylon without any important increase in its price or decrease in its engineering properties. Many rubbers such as EPR, EPDM (ethylene propylene- diene monomers), NR (nitrile rubber), SBR (styrene-butadiene rubber), and SEBS (styrene ethylene- butadiene-styrene tri-block copolymer) have been successfully used in toughening of thermoplastic materials. However, most rubbers are not compatible with nylon and cannot be finely dispersed in it. To overcome this deficiency, polyamides have been blended with several types of impact modifiers that are typically elastomeric or low modulus type olefinic polymers. However, the inherent immiscibility of polyamides with other polymers such as olefinic rubbers necessitated the development of proper compatibilization techniques to reduce the interfacial tension and improve the dispersability of the rubber for effective impact modification. This development in the area of nylon 6, 6/EPDM blend may give the more advantageous characteristics of the presently available nylon and may compensate the deficiencies of the same.

**KEYWORDS:** Nylon 6, 6, EPDM, impact strength, polymer blending, polyamides

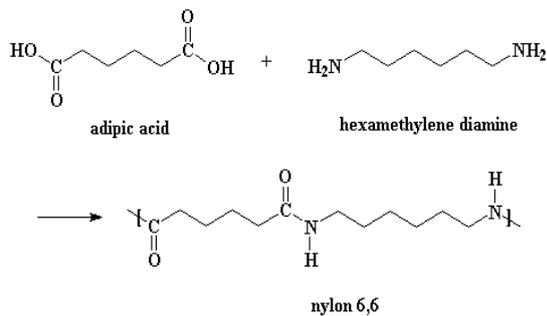
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## 1. Introduction

Polyamides referred to as nylons, are crystalline engineering thermoplastics exhibiting high performance characteristics such as high melting points, high mechanical strength, ductility, and excellent resistance to solvents, fatigue and abrasion. Nylon is a generic term used for all synthetic polyamides in which the recurring amide groups (-CONH-) are part of the main polymer chain.

These amide groups impart strong hydrogen bonding capability and crystallinity in the polyamides, PA, which account for their outstanding solvent resistance and mechanical properties. [4]

Commercial polyamides are generally of two types (a) those derived from diamines and dicarboxylic acids and (b) those derived from amino acids or lactams as monomers. The major characteristics of these two types of polyamides are similar since these are determined largely by the hydrogen bonding structure of the amide groups. However, within these two types, a wide variety of PA are known, varying in their melting points and moisture absorption characteristic, depending on their structure. Among these, PA-66, a polyamide made by polycondensation of hexamethylenediamine and adipic acid and PA-6, a polyamide made by the ring opening polymerization of caprolactam, are the two major nylon engineering thermoplastics produced commercially. Because of their widespread use in fiber, plastic and films, both PA-66 and PA-6 are produced on a large scale.



**Fig 1: Manufacturing of Nylon 6, 6**

Because of the high level of crystallinity and high melting points, PA's generally exhibit high heat distortion temperature at low loads even in unfilled form, and when reinforced with glass fibers, exhibit high heat distortion temperatures at high loads. Most of the commercial polyamides exhibit a common set of property advantages attributable to their crystalline nature and hydrogen bonding character. The advantages offered by the crystalline polyamides (PA-6, PA-66) in blends with other polymers, are: excellent solvent resistance (*e.g.*, gasoline, oils, paint solvents, etc.), heat resistance and melt flow characteristics. On the other hand, the primary motivation to blend other thermoplastic polymers with polyamides, is for reducing the moisture sensitivity of PA and improving its dimensional stability and

### 1.1 Polyamide & Elastomer blends

The technology for impact modification of polyamides has evolved significantly over a period of several years through improved methods of compatibilization and particularly through reactive blending techniques. Several commercially successful impact modified polyamides are based on blends of polyamides with (a) reactive elastomers such as maleic anhydride-grafted ("maleated") EPDM, EP and styrene-ethylene/butylene-styrene block copolymer rubbers, and (b) functional ethylene copolymers such as ethylene-ethyl acrylate, ethylene-acrylic acid, ethylene-ethylacrylate-maleic anhydride and ethylene-methacrylic acid ionomers.

Compatibilization of an olefinic rubber dispersion in a polyamide melt blend is achievable through a direct chemical coupling reaction between the polymers at the interface such as through the

toughness. Because of their highly polar and hydrogen bonded structure of the backbone, as a general rule polyamides are immiscible with most of the commercially known polymer systems. In addition, the high degree of interfacial tension between polyamides and other classes of polymers leads to highly phase separated blends with poor delamination resistance. Hence simple blends of PA with other commercial polymers generally do not have any practical value. Significant progress has been made in recent years. In developing techniques for compatibilizing polyamide blends, particularly utilizing the reactivity of polyamide end groups in forming ionic or covalently linked bonds with other polymers at the blend interface. Several commercial blends are based on such reactive compatibilization technology. The graft copolymer compatibilization technique requires the other polymer component to be already "functionalized", *i.e.*, modified with functionalities such as anhydride or epoxide groups, which are reactive towards the amine or carboxyl end groups of PA respectively. During the melt blending, the reaction between the functionalized polymers and polyamides leads to graft copolymer formation at the interface, which essentially compatibilizes and stabilizes the blend against delamination.

addition reaction between the amine end groups of polyamide and the anhydride functionality of a maleated EP rubber. The graft copolymer formed in situ via this reaction during the melt blending process effectively compatibilizes the blend by reducing the interfacial tension and increasing the adhesion at the phase boundary. Due to the graft copolymer's capability to act as an interfacial agent, the dispersability of the rubber in the polyamide matrix improves considerably, resulting in well stabilized, reduced particle size, rubber dispersions and thereby substantially increasing the toughness. [4, 7]

The toughening mechanism is believed to involve the internal cavitation and debonding of the rubber which induces localized shear yielding of the polyamide matrix as the primary energy dissipation processes. Commercial impact modified polyamides typically contain 10 to 25% of the reactive or compatible elastomer to maximize the toughening

efficiency. Commercial impact modified PA blends indeed offer a unique combination of high notched Izod impact and drop weight impact strengths, coupled with a good balance of modulus, tensile

strength, heat, solvent and abrasion resistance characteristics. These properties are suitable for many engineering and metal replacement applications.

maleic anhydride. But in this research EPDM is coupled with a coupling agent silane.

## 2 EXPERIMENTAL

### 2.1 Materials

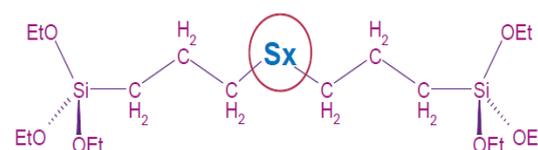
Nylon 6,6 (ZYTEL 101L NC010) supplied by Dupont and EPDM (Ethylene propylene diene monomer) commercialized as Vistalon supplied by Exxon mobil. An antioxidant SP was employed to diminish the effect of temperature and compounding conditions in polyamide 6, 6. This antioxidant was used to prepare batch which was added in 0.2% before blend preparation. A coupling agent Silane was also added in 0.2% in blend preparation. Before feeding the extruder (JSW TEX30α) granules of nylon 6, 6 & EPDM were put into the oven at 70 °C for 4 hours to remove moisture content. The compounds consists of various content of EPDM rubber (5%, 10%, 15%) twin screw extruder's temperature barrel adjusted at 260, 240, 240, 260 & 265 °C and the screw speed were adjusted at 150 rpm with co-rotating screws. The temperature of extruder's die was fixed at 270 °C. The average residence time of compound in the extruder was 3 minutes. The compositions of the studied blends are given in Table 1.

**Table 1 Blends composition in the extruder**

| Blend          | Composition (wt %) |
|----------------|--------------------|
| Nylon 6,6 EPDM | 95/5               |
| Nylon 6,6 EPDM | 90/10              |
| Nylon 6,6 EPDM | 85/15              |

### Results and Discussion

Nylon 6, 6 and EPDM rubber both are immiscible. To improve their miscibility EPDM is usually grafted with maleic anhydride. A number of researches are done using grafted EPDM with



**Fig 2: Structure of sulfidosilanes used in EPDM**

This group of organosilanes provides good bonding, good interfacial tension and imparts better adhesion to the compounds. However, adding silane at the earlier stage of blend preparation results in cross linking of chains affecting the melt flowability properties of the blend. It can be commented that the apparent viscosity of blends containing 5%, 10%, 15% of coupled EPDM increases & with increasing the shear rate apparent viscosity decreases. Increasing the viscosity of blend is due to the increase in chemical bonds between two phases that shifts the viscosity towards EPDM.

### Conclusion

The results of this research are useful for optimizing the mechanical, thermal & rheological properties of nylon 6, 6. In this study to increase toughness, impact strength of nylon 6, 6 EPDM rubber is used.

Compatibilized blends show better impact strength than non compatibilized blends. The research is still carried further to enhance the various blend combinations. This impact modified polyamides can be suitable for many engineering & metal replacement applications. Future scope of this blend can be widely used in automotive applications where high heat, high impact strength & chemical resistance are primary criteria for choice.

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