Elastic Nonwoven Fabrics from Polyolefin Elastomers

by

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Abstract

Vistamaxx™ Specialty Elastomers are polyolefin elastomers with isotactic propylene crystallinity. These polymers contain a predominant (>80%) amount of propylene with isotactic propylene crystallinity, with the balance of the composition being ethylene and other α-olefins. This new family of thermoplastic elastomers are highly elastic and exhibit excellent recovery from deformation. These polymers share the processability of conventional polyolefins such as polyethylene and isotactic polypropylene and can, thus, be easily formed into spunbond and meltblown nonwoven fabrics using conventional plastic processing processes. The paper will discuss the processing and elastic properties of nonwoven fabrics made using these polymers, with an emphasis on the influence of polymer characteristics and processing conditions on the elastic behavior of the fabrics.

Introduction

The Vistamaxx™ Specialty Elastomers have a very unique property that fills the gap between the polypropylene crystallinity and polyethylene crystallinity as shown in Figure 1. As a result of the unique crystalline structure, the polymer has an elastic property that are normally obtainable with EPDM and other non-polyolefin polymers. The properties of these polymers can be tailored for specific applications by means of the control over molecular weight, molecular weight distribution, composition distribution, melting temperature, and degree of crystallinity[1]. All these molecular parameters affect the elastic behavior of the polymer, thereby offering the ability to "tune" elastic behavior for the specific application requirements. Table 1 lists the key polymer characteristics and property ranges for the specialty elastomers

Figure 2 shows the stress-strain plots of some of the specialty elastomers exhibiting a range of properties that are accessible by control over the molecular structure. It is clear from the figure that, as the degree of crystallinity increases, the mechanical behavior of the polymer transitions from elastomeric to plastic-like character, evidenced by a yield in the stress-strain plot. The polymers with the low degree of crystallinity show stress-strain behavior characteristic of typical elastomeric materials, i.e., lack of yield, a relatively flat stress across a range of strains, followed finally by strain hardening. The flat or unchanging stress across a strain range of ~ 300% for the polymer showing the lowest crystallinity is very advantageous for a number of applications.

Nonwoven fabric made of polyolefin, mostly polypropylene, is generally non-elastic unless an elastic component is incorporated or with complicated down stream treatment of the fabric. The Vistamaxx™ specialty elastomer can be processed directly into elastic nonwoven fabrics, such as spunbond, melt blown, or a composite fabric of spunbond and melt blown fabric[2].

Experimental

Spunbond nonwovens

Spunbond process is commonly used to produce polypropylene nonwoven fabric for hygiene and medical products. A spunbond process is shown schematically in Figure 3. The specialty elastomer of different elastic properties have been spun successfully on a 1-meter wide spunbond pilot line without modifications. The elasticity of the fabric is related to the molecular weight and composition of the specialty elastomer.

Processing characteristics

The fiber formation in a spunbond process is very similar to the partially oriented yarn process (POY). Unlike the POY process where the fiber is drawn mechanically by a godet, the high velocity air jet draws the fiber in a spunbond process. Based on the experiment in the POY fiber line, the specialty elastomer can be drawn at very high speed (> 3000 meter/min) to obtain fine fibers.

The main difference between the specialty elastomer and the homopolymer polypropylene is that the specialty elastomer has a slower crystallization rate. This can be overcome by a longer quenching distance, lower melt temperature, lower output per capillary (gram/hole/min), or lower quench air temperature. The polymer needs to "freeze", or crystallize, before the fibers come in contact with each other. This may occur as the fibers enter the narrow gap or the venturi area where the draw force is applied to the fiber. If the fibers are not quenched properly, some fibers may stick together and cause poor web uniformity because of uneven fiber distribution.

Fiber size has a significant effect on the uniformity of the spunbond fabric. Under the same spinning condition, the specialty polymer tends to have a larger fiber size than polypropylene homopolymer. Part of the reason may be due to the shrinkage of the fiber as fiber exits the draw unit and the extensional force is removed. A larger draw force may be required to achieve the same fiber diameter as the conventional polypropylene.

Bonding and annealing of the fabric

The bonding process also anneals the fabric. The fabric will shrink in the CD direction as it leaves the calender. A slower take-up speed downstream of the calender also allows some MD shrinkage, making the fabric more elastic in both CD and MD direction. A subsequent annealing may provide additional shrinkage and therefore more elasticity of the fabric.

Melt Blown Nonwovens

Melt blown process is a one-step process to convert directly from resin to very fine fibers. The fiber diameter of a melt blown product ranges from 2 microns to 8 microns. The fine fiber size makes the melt blown nonwovens an excellent barrier fabric for medical, hygiene and filtration applications. Figure 4 shows the key elements of a melt blown process. Basically, the fiber is formed by extruding a low viscosity (low MW) polymer through a capillary. A high velocity and high temperature air is blown almost parallel to the fiber axis to attenuate the fibers. The air temperature is generally the same as the melt temperature so that the melt continues to elongation by the high velocity air until a colder ambient air solidifies the fibers. The fibers are randomly laid down on a collection belt to form the nonwoven fabric.

Processing characteristics

Several samples of specialty elastomer have been spun on the 1", 6", and 20" wide melt blown lines. The resins used ranges from 35 MFR to 400 MFR with different compositions. If a lower MFR resin is used, a higher processing temperature will be required. A higher MFR is preferred in order to have a low melt viscosity at the die exit when processed at a low melt temperature. If the melt temperature is too low, the high elasticity of the melt may resist fiber drawing and make it impossible to form a melt blown web.

Because of the slow crystallization, the fiber may be partially fused together, and therefore the web has more integrity than the fabric made from polypropylene homopolymer.

Results and Discussion

Resin Properties

Although the specialty elastomer is basically a polyolefin resin, the crystallinity is substantially lower than the conventional fiber spinning polypropylene and polyethylene resins. Because of the lower crystallinity than the conventional polypropylene, the freeze point of the fiber is lower than that of polypropylene homopolymer when processed under the same conditions.

The specialty elastomer is produced from a proprietary metallocene catalyst system and therefore has an inherently narrow molecular weight distribution (MWD). The narrow MWD is an advantageous for spunbond and melt blown processes because the melt has a very low elasticity elongational viscosity. Figure 5 shows the melt viscosity of a specialty elastomer grade suitable for textile applications. Note that the viscosity at low shear rate is practically constant, illustrating the characteristic of narrow molecular weight distribution of the polymer. Another characteristic of metallocene based narrow MWD resin is the low melt elasticity. The melt elasticity can be characterized by the compliance of the melt[3]. Figure 6 compares the compliance of a controlled rheology grade (35 MFR polypropylene homopolymer from ExxonMobil, PP3155) against a 24 MFR special elastomer. The Vistamaxx™ has a lower compliance even with a lower MFR over the whole processing temperature range.

Fabric Properties

Spunbond fabric:

The spunbond fabric produced by the specialty elastomer has many positive attributes that are advantageous for many applications. The fabric is elastic and has good recovery. Figure 7 and 8 compares the recovery of the fabric made from polypropylene homopolymer and from specialty elastomer. Although the spunbond fabric made from specialty elastomer is twice as heavy in basis weight as PP spunbond fabric is, the stress is much lower. The fabric from the specialty elastomer has only a 15% permanent set vs. 45% for PP homopolymer.

Fabric softness is a key attributes for end use applications[4]. One of the tests is by the "handle-O-Meter". available commercially and is used for qualitative comparison of the fabrics. It measures the force necessary to push the fabric of a given size through a fixed opening. The lower the force, the softer the fabric because the fabric is more "drapable". Figure 9 compares the two Vistamaxx™ fabric of heavier basis weight against a PP sponbond fabric. Although the Vistamaxx™

fabric is much heavier (as measured by the basis weight), the force requires is substantially lower than the PP fabric is.

Melt blown fabric:

When polypropylene homopolymer and specialty elastomers of different crystallinity are processed under the same condition, the differences in elongation properties clearly illustrate the elastic properties of the Vistamaxx™. Figure 10 shows the ultimate elongation of these fabrics. The ultimate elongation of PP homopolymer is only 35% while the Vistamaxx™ fabric of high elasticity grade can elongate up to 360%.

Similar to the spunbond fabric, the elasticity of the melt blown web is related to the molecular weight and composition of the specialty elastomer. As expected, the lower the crystallinity and the higher the molecular weight, the higher the elasticity of the fabric.

The melt blown fabric has an excellent hysteresis and permanent set after a prestretch to 100%. Figure 11 shows the stress-strain behavior of a melt-blown fabric made from the specialty elastomer.

Conclusions

The Vistamaxx™ specialty elastomers are ideally suited for nonwoven applications. The high elasticity meets the industry needs of providing a better fit and body conforming hygiene and medical products using poliolefin based resin.

The resin can be converted elastic nonwoven fabric using the conventional spunbond and meltblown processes. Additionally, combining the specialty elastomer with other polymer in a bicomponent fiber structure can further extend the product attributes and broaden its applications. There are many potential applications where the unique processability and excellent elastic properties can be utilized.

Acknowledgments

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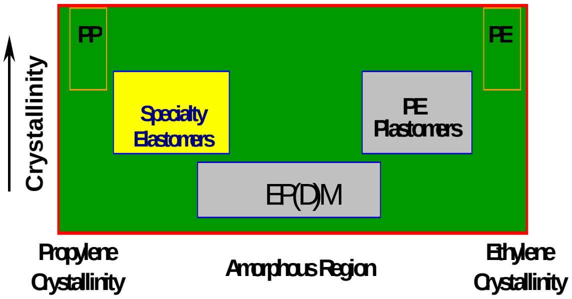


Figure 1. Polyolefin Product Family

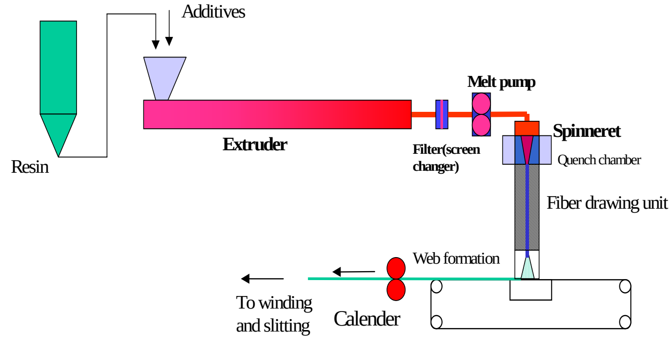


Figure 3, Spunbond process

Property	Specialty Elastomers
Density (gm/cm^3)	0.86 - 0.89
MI (gm/10 min)	0.5-12
MFR (gm/10 min)	1 - 25
Mooney Viscosity (ML)	10 - 30
Mw Mw/Mn	150 - 250 k ~ 2.0
T_g (°C)	-10 to -35
T_m (°C)	40 - 160
Hardness (Shore A)	50-90
Tensile Strength (psi)	1200-3500
Elongation (%)	100-1500
Elastic Recovery (%)	80-97%

Table 1, Polymer characteristics and property ranges for the specialty elastomer

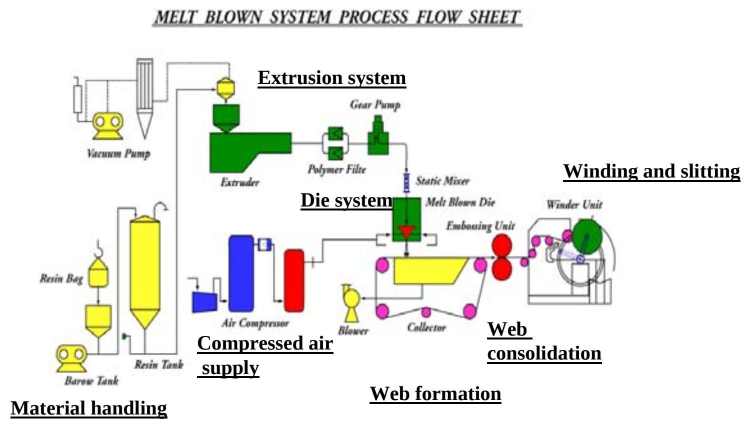


Figure 4, Melt blown process

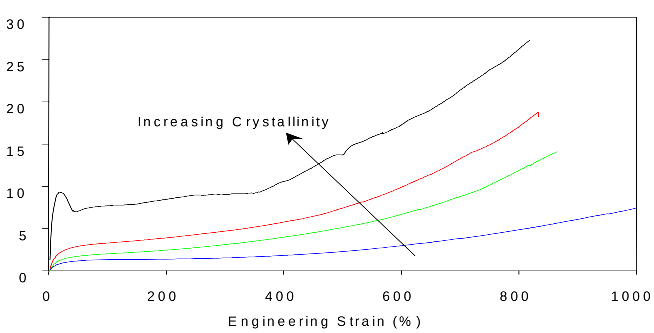
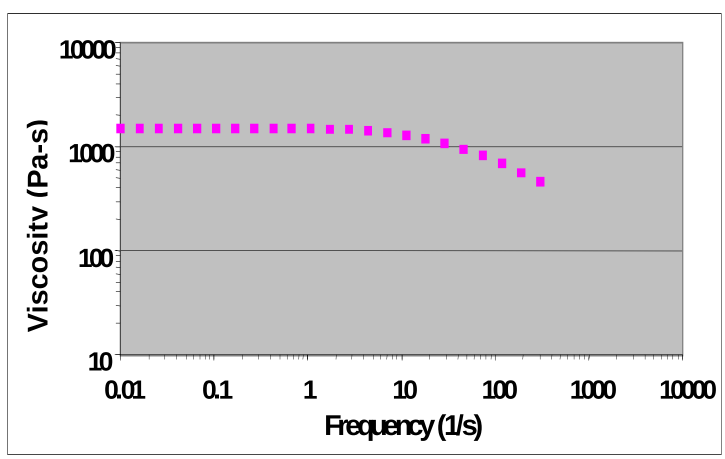


Figure 2. Stress-strain curve of specialty elastomer product family



Fibure 5. Melt viscosity of a 24 MFR Vistamaxx™ specialty elastomer at 190 °C

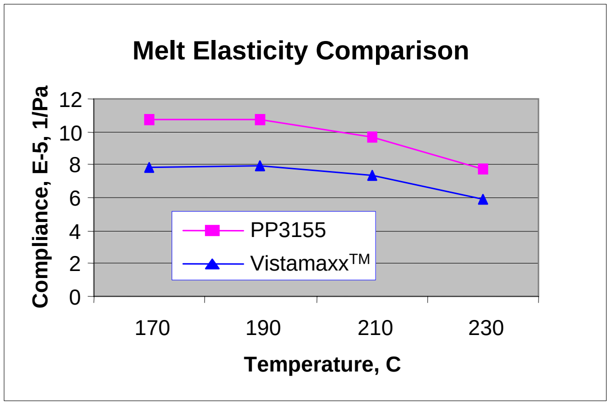


Figure 6, Compliance of Vistamaxx™ vs. PP homopolymer

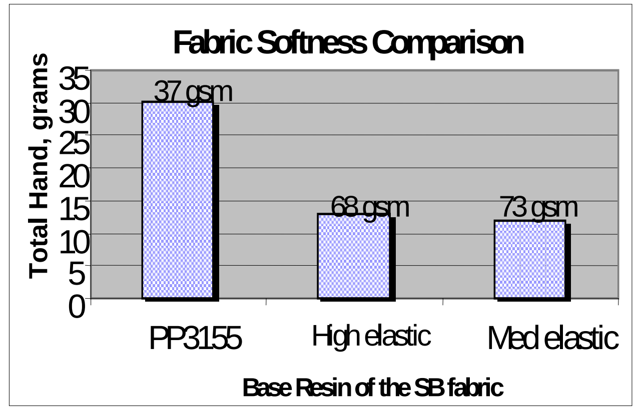


Figure 9. Comparison of fabric softness

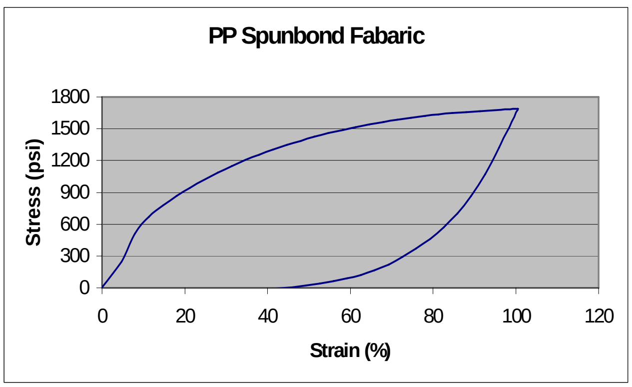


Figure 7. Hysteresis curve for PP homopolymer spunbond fabric

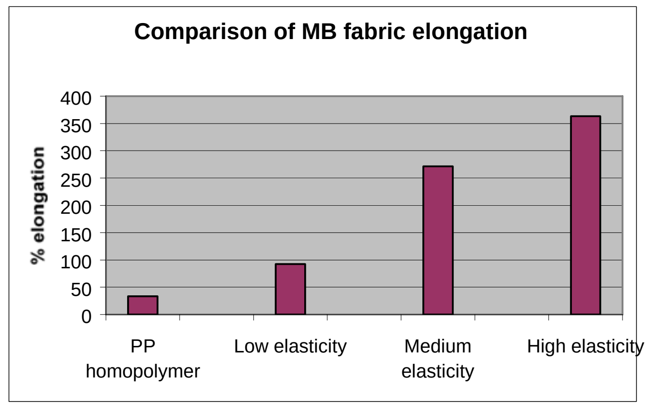


Figure 10. Comparison of fabric elongation

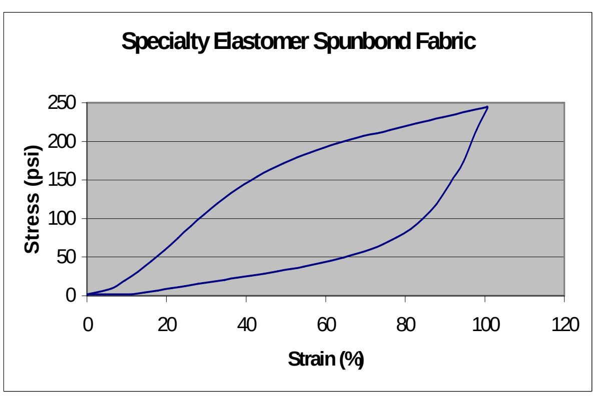


Figure 8, Hystersis curve of Vistamaxx™ fabric

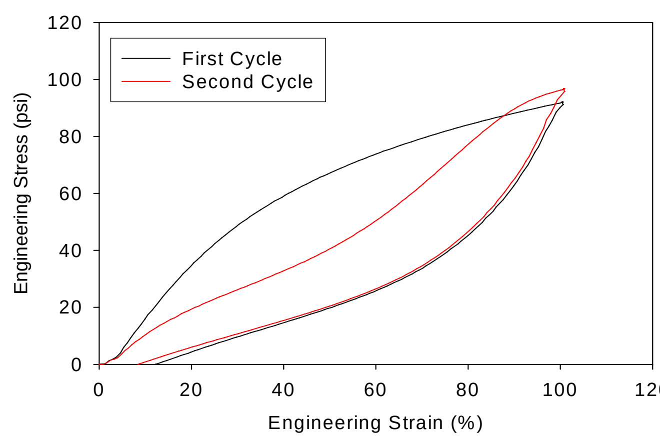


Figure 11. Stress-strain plots of a melt-blown fabric made from Specialty Elastomers