High Performance Polypropylene for the packaging market

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A new generation of polypropylene resins offers improved water vapor transmission rate and stiffness.

A new type of polypropylene resin, which will be referred to in this paper as High Performance Polypropylene (HPPP), will support the evolution of packaging structures available in today's packaging market. HPPP will produce an oriented film that has the water vapor transmission rate (WVTR) of polyvinylidene chloride (PVdC), secant modulus 50% better than conventional oriented polypropylene (OPP), and increased recyclability, while maintaining the excellent gloss and haze of conventional OPP film.

HPPP has properties that allow for new package design in the OPP packaging film market. Applications needing improved WVTR barrier without the cost of coating or laminating, such as the packaging of snack foods, candy, bakery products, etc., are a natural fit for HPPP. The improved stiffness will allow downgauging of OPP films and still provide excellent machinability on high speed packaging equipment.

HPPP will support the ongoing drive toward source reduction in the packaging market. By providing a polymer with an improved WVTR barrier and stiffness, an end user can design more simplified packaging, reducing the need for PVdC coating and/or extrusion laminating in some applications. In other applications, HPPP resin will produce a base sheet that adds higher value to the overall lamination. Unlike many traditional barrier polymers, HPPP is easily recyclable in a customer's extruder, thus reducing the amount of plastics that have to go to landfills.

From a marketing perspective, HPPP fills an unmet need in the OPP packaging marketplace. It will produce a totally recyclable film that has the optics of conventional oriented polypropylene with a 40% improved WVTR barrier and a 50% increased secant modulus. The HPPP resin provides the market with improved performance and thus added value before the coating or laminating step in a film converting operation.

Test methods

All water vapor permeation rate values were measured in duplicate on a Mocon Permatran-W6 at 38°C and 90% relative humidity.

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I. Moisture barrier performance ranking

Film	*WVTR @ 1.0 MIL (g/mil/100 in.²/24 h)*
Extrudable high barrier PVdC	0.22
High performance polypropylene*	0.22
Blown HDPE	0.35
Oriented polypropylene	0.40
Cast HDPE	0.50
Unoriented polypropylene	0.70
Cast MDPE	0.75
LDPE	1.0
Oriented polyester	1.2
EVOH	1.4

*Oriented via tenter frame process.

Units for WVTR = g/mil/100 in.²/24 h (1)

The 1% secant modulus was measured on a United Six Station Testing Machine according to ASTM D-882 Method A.

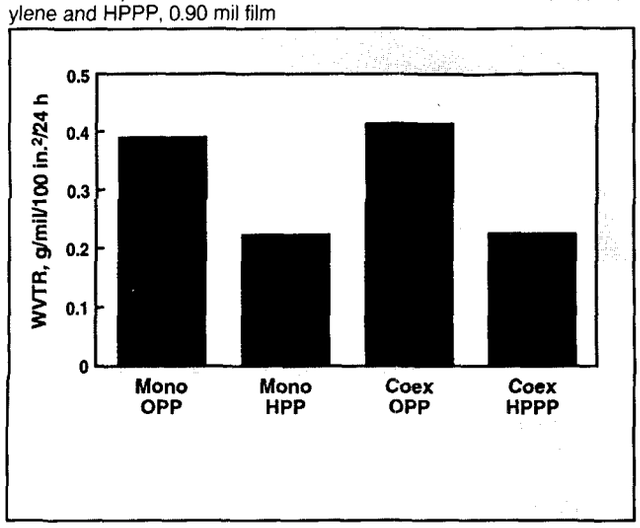
Barrier improvements

HPPP brings to the OPP packaging film market several important attributes: water vapor barrier, stiffness, and recyclability, to name a few. However, an investigation of the benefits for the end user are the focus of this paper.

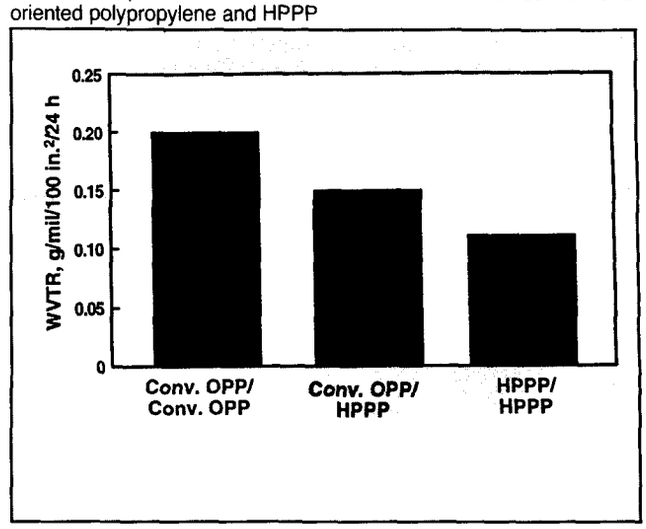
In the food segment of the OPP packaging film market, salty snack foods, candy, and bakery products all use package structures that have certain drawbacks. These include the need for increased moisture protection, source reduction, and, ultimately, recyclability.

If we look specifically at the salty snack segment of OPP packaging, we find that these structures consist of an oriented polypropylene film which is then coated and/or laminated to achieve a certain level of product protection. Since the importance of any individual characteristic in the product protection category is determined by the shelf life expected by the end user, these characteristics are divided into three different categories: "short" shelf life (less than two months; required moisture permeability of packaging no greater than 0.30 g/mil/100 in.²/24 h), "medium" shelf life (two to four months; required moisture

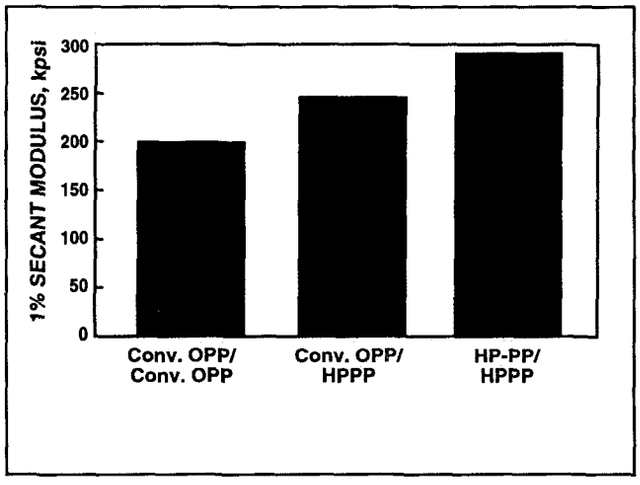
1. Water vapor transmission rate for conventional oriented polypropylene and HPPP, 0.90 mil film



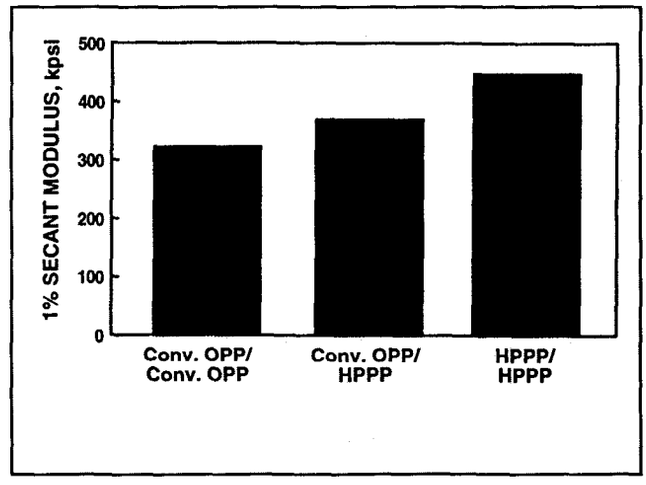
2. Water vapor transmission rate for laminations of conventional oriented polypropylene and HPPP



3. 1% secant modulus in machine direction for laminations of conventional OPP and HPPP



4. 1% secant modulus in transverse direction for laminations of conventional OPP and HPPP

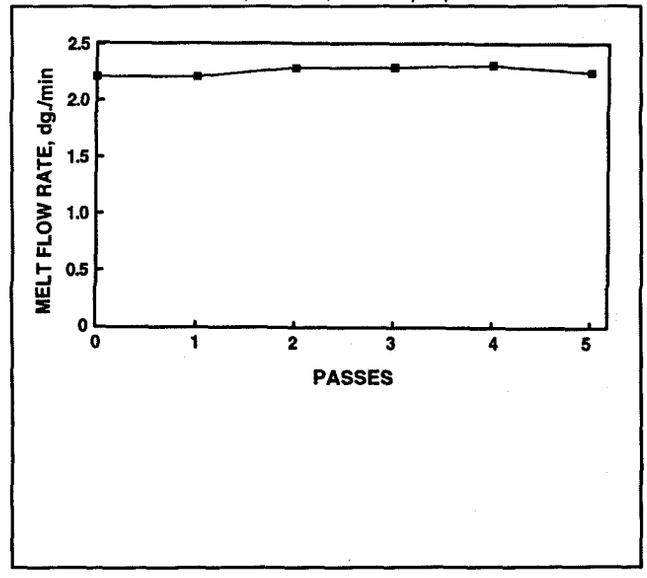


permeability of packaging no greater than 0.20 g/mil/100 in.²/24 h), and "long" shelf life (greater than four months; required moisture permeability of packaging no greater than 0.10 g/mil/100 in.²/24 h) (*1*).

The water vapor barrier is by far the most critical product protection characteristic of salty snack products because the great majority are essentially dehydrated vegetables. Consequently, one finds three quarters of all salty snack package structures have two common components—oriented polypropylene film and polyvinylidene chloride coating—which exhibit water vapor permeation rates of less than 0.4 and 0.2 g/mil/100 in.²/24 h, respectively. As described above, each shelf life has WVTR requirements. By overlaying WVTR performance with shelf life expectations, we found the barrier performance of HPPP to be equivalent to the performance of PVdC (*2*). With the development of HPPP, one could expect to see water vapor permeation rates of 0.2 g/mil/100 in.²/24 h. **Table I** compares the permeation rates of several barrier materials.

The average shelf life of a salty snack product in the

5. Melt flow rate of HPPP, series 1, vs. multiple pass extrusion



grocery store today is 40-60 days (short shelf life). After that time, approximately 5% of the product is stale, which results in lost revenue for the snack food producer. Development of a polypropylene resin that would extend shelf life expectancy offers a significant cost savings to the snack food producer. The snack food producer also benefits by reducing the likelihood of a dissatisfied consumer due to the deterioration of product flavor.

By introducing a base sheet of HPPP into a lamination designed for snack packaging, we have a package that can be extrusion or adhesively laminated with 40% less water vapor permeation of conventional OPP laminations, as shown in **Figs. 1 and 2.**

Source reduction

Both monolayer and laminated film structures produced with HPPP exhibited the increased stiffness over conventional OPP film at equal gauges, as shown in **Figs. 3 and 4.** With the combination of improved stiffness and water vapor barrier, an OPP film producer could offer film structures to the converter and end user at a thinner gauge with the performance of conventional films and laminations.

OPP packaging film produced with HPPP provides 50% greater stiffness over conventional OPP films when measured by 1% secant modulus, as Figs. 3 and 4 indicate. Stiffness in OPP film is critical for machinability on high-speed packaging equipment, and downgauging of conventional OPP films has reached its limit due to lack of stiffness. The long history of salty snacks being in cellulose-base structures, such as sulfite paper, cellophane, and glassine, set a precedent of relatively stiff films that has been well established. In addition, some snack food consumers feel that stiff films connote "crispy, fresh product" better than softer films. It is also a fact that the packaging material must be stiff enough to maintain the product and package integrity during shipping and handling, especially in larger supermarket size bags.

Today's large snack bags are anywhere from 2.2 mils to 2.6 mils in gauge. A typical laminated structure would consist of 1.0 mil OPP/1.0 mil of polyethylene laminant/ 0.75 mil PVdC (*3*). The stiffness improvements of HPPP would allow the packaging engineer to design a snack package with 0.55 mil of HPPP/1.0 mil of polyethylene laminant/ 0.55 mil of HPPP. This structure would provide adequate water vapor barrier and stiffness while reducing the amount of plastic in the overall package.

Utilization of HPPP in monolayer and laminated structures permits source reduction in an industry that is conscientious about the amount of plastic in landfills or the recycling pool.

Recyclability

In addition to improved barrier and increased stiffness, HPPP is recyclable. HPPP can be re-extruded through an OPP regrind system or through a recycling center plant instead of going to landfill.

HPPP resin was tested after multiple pass extrusion on an instrumented Haake extruder to simulate what the polymer would experience in a film producer's regrind system. As shown in **Fig. 5,** melt flow rate and color stability testing showed no changes in molecular weight or color, indicating HPPP to be a very stable polymer even after multiple pass extrusion.

Conclusion

HPPP provides the OPP film packaging industry with the performance attributes of 40% improved water vapor barrier, 50% increased stiffness, and recyclability, while maintaining the optical properties of conventional polypropylene when oriented on extrusion blown or tenter equipment.

While the data here consider only snack food market applications, the benefits of HPPP can have uses in many markets needing improved water vapor barrier for shelf-life extension, increased stiffness for downgauging, or source reduction and recyclability to reduce the amount of plastics going to landfill. All these performance improvements, together with the gloss and haze of conventional polypropylene, is the reason we call this next generation resin "High Performance Polypropylene."□

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