RHOBARR™ 320 Barrier Dispersion

Description

RHOBARR™ 320 Barrier Dispersion has been designed for use in formulations targeted for paper barrier coating applications. This base dispersion can be formulated with rheology modifiers, waxes and other components as required, forming a resistant coating upon proper thermal curing.

Typical properties

Property	Typical values
Appearance	White milky liquid
Solids, by weight, %	43 ± 2.0%
Density (g/ml), wet	0.97 ± 0.2
Acid Number (mg KOH/g of POD solids)	44 ± 4
pH	9.0-10.5
As manufactured viscosity[a] (Brookfield RV spindle #3, 50 rpm, 25°C), cps	<1000
Storage precautions	Protect from freezing

Formulation guidelines

RHOBARR™ 320 Barrier Dispersion can be formulated with a wide range of additives in order to tune application and final coating properties.

Components such as surfactants, antifoaming reagents, lubricants, rheology modifiers, pigments, and other additives should be added under agitation. Care should be taken to always keep the formulation at a pH >8 during preparation to reduce formation of precipitates. Use of basic water (pH > 7.5) for dilution and stirring before use is recommended.

Sodium hydroxide 10% at 0.3 wt. % is recommended for adjustment of de-ionized water to the appropriate pH.

Polyolefin description

Polyolefins are a stable class of polymers produced from simple alkene monomers. At high molecular weight and with suitable levels of crystallinity, films of polyolefins provide superior chemical and liquid resistance while maintaining thermoplastic characteristics (e.g. heat sealability) and low temperature flexibility.

Often, polyolefins are applied to substrates using extrusion technology which involves heating solid polymer pellets to a molten state followed by coating the thermoplastic material onto a substrate and rapidly cooling. Although commercially successful, for paper applications this approach yields film thicknesses greater than necessary for barrier performance, primarily to impart improved mechanical bonding to the cellulosic substrate [1]. These thick polymer coatings negatively impact fiber recovery during repulping, complicate recycling, and make finished articles heavier than needed for performance.

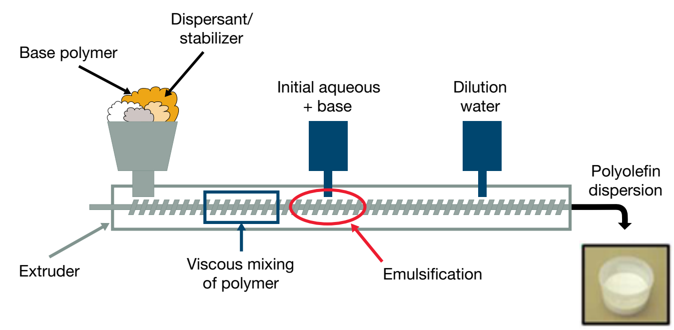
An alternative coating process is to apply polymeric barrier material as a waterborne emulsion using traditional wet application methods (e.g. air knife, rod, blade, gravure, dipping, frothing, spraying, etc.). Aqueous coatings are already used in the paper coating industry to reduce paper topography, however typical dispersions do not possess the same performance characteristics of polyolefins and are therefore not suitable as a single barrier solution.

Polyolefin dispersions (PODs) produced by a proprietary mechanical dispersion process [2], bridge the gap between extrusion coatings and conventional aqueous dispersions. The technology generates a colloidal suspension of high molecular weight non-self-dispersing polymers (e.g. polyolefins) in water. This unique class of material provides broad chemical and liquid resistance, heat sealability, and low temperature flexibility commonly associated with polyolefin films, but with the application advantages of a low viscosity water-based dispersion.

Experimental materials and methods

PODs are produced using mechanical dispersion technology (see Figure 1). This process was designed to enable dispersion of polymers which are not self-dispersing, such as high molecular weight (> 75,000 g/mol) polyolefins. The process begins by melting and blending polymer material into a viscous molten state using high temperature and shear. Addition of a dispersant, water, and a neutralizing agent produces a high internal phase emulsion or HIPE which controls particle size. Processing conditions and water addition allows particles to be generated with diameters of less than 1 micron at high solids (up to 60 wt. %) and relatively low viscosity (typically less than 1000 cps).

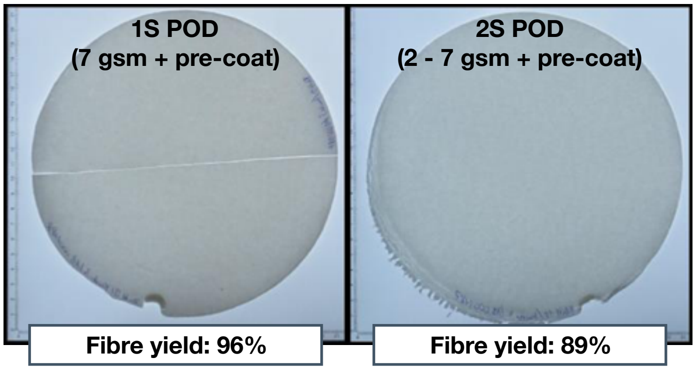
Figure 1. Drawing of BLUEWAVE™ production of a typical polyolefin dispersion.



For performance tests described here, PODs were applied to 200 g/m^2 solid bleach board (SBS) using a rod coater with coat weights ranging from 6-10 g/m^2. Test samples were dried in a forced air oven using a range of temperatures (100°C to 150°C). Liquid barrier testing was performed in accordance with TAPPI Method T441. Repulpability was assessed at Western Michigan University using SBS-E protocol and by PTS (Germany) following PTS-RH 021/97 – Category II: Paper and board for recycling (PfR). For comparative extrusion coated sample analysis, commercial samples of cupstock were used. Atomic force microscopy data were collected using a Bruker Dimension FastScan (Billerica, MA). Scanning electron microscopy data were collected using FEI Nova NanoSEM 630 (Hillsboro, OR).

Case study: Recyclability

PTS-RH 021/97 – Category II: Paper and board for recycling (PfR)



POD: > 99% of total fiber present recovered
POD: Enhanced recyclability over incumbent (65-80%)*

*Factors: coat weight, pre-coat, composition, repulping conditions, and others

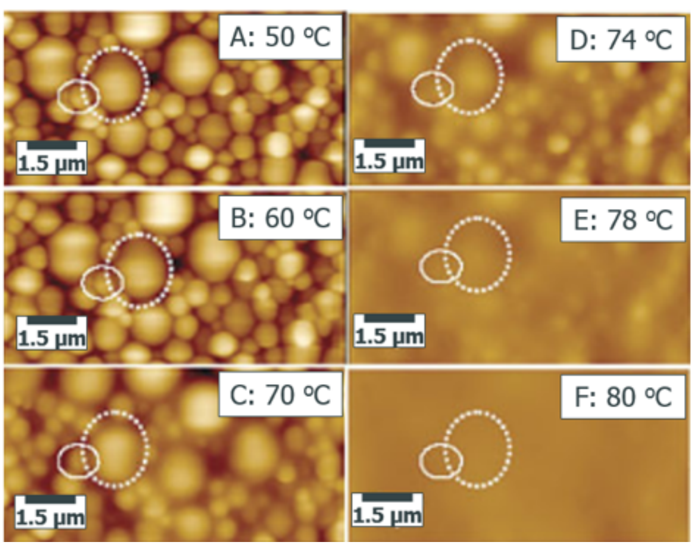
POD development for paper cupstock and food service products

To meet barrier and performance requirements for cupstock and food service products, a novel POD composition was developed. Food service metrics vary based on application, but generally require: multiple hot and cold liquid barrier performance (e.g. water, coffee, acidic juice, alcohol), oil/grease resistance, heat sealability, block/stain resistance, and foldablity.

To meet these demands, a dispersion based on a unique combination of functional and non-functional polymers were developed as generally described elsewhere [2].

Critically, POD compositions need to be compatible with typical paper drying requirements. Generally, paper products (including cupstock) need to maintain a moisture level of > 5 wt. % otherwise fibers become brittle and lose flexibility. To address this issue, polymers utilized in the development of paper PODs were selected to have melting points below 100°C as demonstrated by atomic force microscopy (AFM) shown Figure 2. For that experiment, a height map of air-dried POD was examined at increasing temperatures. Initially at 50ºC, POD particle boundaries are clearly defined indicating little or no film formation. As the temperature begins to increase above 70ºC, particle boundaries become less defined and by 80ºC the material melts into a defect-free continuous film coating.

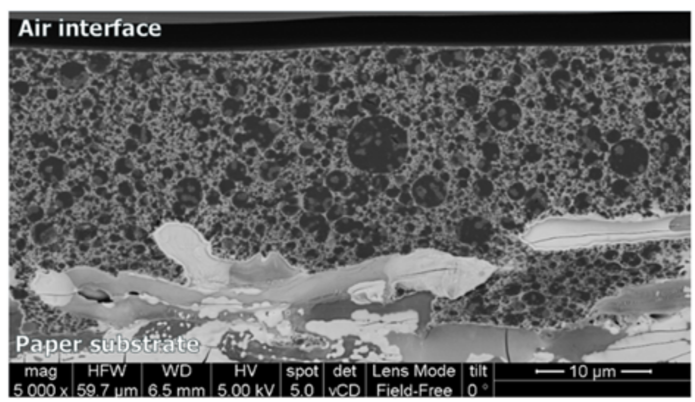
Figure 2. Atomic force microscopy (AFM) height map for a polyolefin dispersion coating at elevated temperature. At low temperature (50ºC) discrete particle boundaries are observed. When temperature is increased, particle boundaries begin to blur together, highlighting melt flow into a monolithic coating. By 80ºC, particle boundaries are no longer visible suggesting complete film formation. Film formation below 100ºC is critical to paper applications to prevent over-drying paper fibers.



Another important consideration for the development of PODs for paper coatings is adhesion. In paper applications, generally there are two types of bonding mechanisms: chemical and mechanical. For polyolefin extrusion films, chemical adhesion is achieved by heating polymer to high temperatures in air promoting oxidization. The oxidized polyolefins contain polar groups which are attracted to cellulose fibers by hydrogen bonding, helping to maintain contact between the polymer and the substrate. By comparison, paper PODs were designed to contain similar polar functionality with comparable attractive forces, but without the need for high temperature oxidation.

A second type of adhesion to paper is mechanical bonding. Mechanical bonding for extrusion coatings is achieved by heating the polymer to a molten state and compressing the flowable material into the paper surface. Importantly, this process is severely limited by polymer cooling [1]. When extruded polymer cools too quickly, which is common in thin films, it does not have sufficient time to penetrate into the paper, thereby reducing mechanical bonding. For PODs, mechanical adhesion is dictated by surface coverage. During wet application, POD particles distribute across the paper surface contouring to topography and filling gaps or voids prior to drying. During oven drying particles melt/flow into a uniform coating, anchoring around paper fibers. This is best visualized by cross-section examination of a POD film on paper as shown in Figure 3. The scanning electron micrograph (SEM) showcases coating distribution on and around various paper fibers and highlights good substrate adhesion.

Figure 3. Scanning electron micrograph of a polyolefin dispersion coating on paper. The air interface (top) of the coating is relatively uniform demonstrating self-leveling. At the paper interface, the coating has adhered efficiently to the paper surface, contouring to the paper fibers.



POD application to paper

PODs can be applied to paper substrates using traditional aqueous application methods such as curtain, blade, or rod coaters. In comparison to extrusion coating, this process may offer enhanced mill speed production. Once applied to paper, drying can take place in existing equipment such as forced air ovens or using IR dryers at between 100 to 180ºC for short periods of time. This provides enough thermal energy to drive off moisture from the coating and allow for film formation without over-drying paper fibers. After drying, POD coated paper requires cooling prior to roll up the reel, which can be achieved by either using a chill roll or having ample linear distance between drying and winding.

As mentioned earlier in the article, a key property of paper PODs is that the quality of adhesion is decoupled from coating thickness. Therefore coatings can be applied either directly to paper or on top of pre-coats (polymer or pigmented) at weights as low as 6-8 gsm. Despite a coat weight reduction of over 50% relative to extrusion coatings, performance in typical cupstock application is not compromised, as discussed in more detail in the next section. Since low coat weights are achievable, the percentage weight that a barrier film represents in a finished article can be greatly reduced. For example, an 8 g/m^2 coating direct to paper on 200 g/m^2 SBS represents a barrier coat weight of just 3.8 wt. % of the total article.

POD performance case study: Cupstock

Liquid barrier performance for a POD designed for paper is shown in Figure 4. For barrier testing, an 8-10 gsm coating of the POD was hand applied to SBS using a wire wound drawdown rod. For comparison, a commercial extrusion coated disposable paper cup (20-25 gsm) was also examined. Overall, the POD coated paper provides about the same level of barrier performance as an extrusion coated cup for hot and room temperature water, hot coffee with and without cream, and room temperature orange juice or Diet Coke, at less than half the coat weight. Further, the coating also provides good oil and grease resistance, stain resistance, block, and heat seal as described in Table 1.

Figure 4. Liquid barrier performance for a typical extrusion coated cup (20-25 gsm) compared with a POD coated paper (6-10 g/m^2).

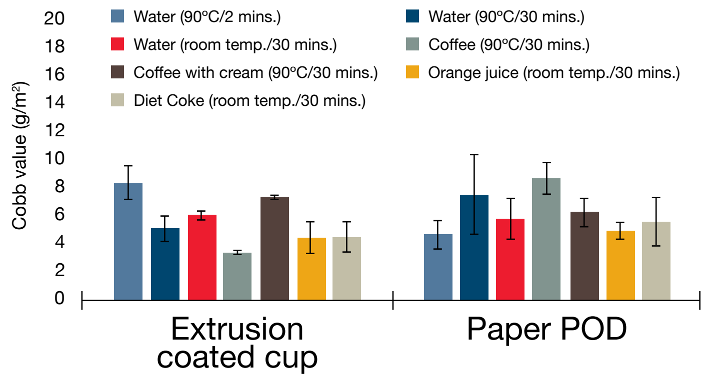


Table 1. Performance attributes of a paper coated with a POD designed for paper applications.

Cupstock attribute	Paper POD performance
Oil and grease	Kit 12 (flat/folded); no leak
Stain resistance	No stain visible at all angles
Block	Pass (no fiber tear)
Heat seal	Pass (with fiber tear)
Mechanical integrity	Foldable

In addition to barrier performance, the level of repulpability and recyclability was also assessed. Conceptually, reduced coat weight should have a direct influence on repulping of disposable paper cups since there will be a higher percentage of reusable fibers compared to the amount of barrier present.

To determine if repulpability is improved for POD coatings, samples were submitted to PTS and Western Michigan University for analysis. For the tests, POD coatings of 7-10 g/m^2 on 200 g/m^2 pre-coated (7 g/m^2) and untreated SBS were evaluated. Overall, POD coated paper returned > 99% of the available fiber present for one-sided and two-sided articles, demonstrating excellent coating/fiber separation and fiber recovery. Screened fiber recovered from the repulping process was successfully made into handsheets using either 100% recovered fiber or mixed with untreated paper at 15/85. In both tests, POD coated paper was certified as recyclable.

References

[1] B. Morris, "Understanding Why Adhesion in Extrusion Coating Decreases with Diminishing Coating Thickness," Journal of Plastic Film & Sheeting, vol. 24, no. 1, pp. 53-88, 2008.

[2] J. E. Pate, "Process for preparing high internal phase ratio emulsions and latexes derived thereof". United States Patent US5539021A, 23 07 1996.

[3] J. Katzenstein, "Paper Coated with a Functional Polyolefin Film". United States Patent 20180363248, 12 June 2018.

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