BOMAR® OLIGOMERS FOR LIGHT-CURABLE NAIL COATINGS

Technology Bulletin

UV– AND LED–CURABLE NAIL COATINGS

Nail gel coatings have revolutionized the salon experience in the past decade, providing important benefits like extended wear, high gloss, excellent adhesion, and toughness. While initially broad–spectrum UV lights were used to cure the nail gels, the industry has rapidly shifted over to LED systems as the preferred cure source. LED–curable systems provide significant advantages over broad spectrum UV systems, including faster cure times, reduced energy and maintenance costs associated with LED–curing equipment, and safer UV–A curing without harmful UV–B and UV–C waves.

However, the cosmetic industry continues to look for raw materials to help overcome the many challenges to formulating UV– and LED–curing nail coatings, including low gloss, color drift/yellowing, premature chipping, and increasing regulatory requirements. Many formulas also have issues with high exotherms being generated in the curing process, which causes a burning sensation for the consumer.

Several Bomar® oligomers are ideal backbone options to consider when working to solve these challenges in UV–cured and LED–cured nail coatings. Newly developed bio–based oligomers with low MeHQ content to meet the latest cosmetic guidelines for inhibitor concentration and formulated with a tin–free catalyst are also suitable alternatives for applications with low irritancy requirements.

A range of Bomar oligomers were evaluated in a model formula to provide comparable data on their suitability for these applications. The oligomers offer a range of properties depending on the needs within the formula, including non–yellowing characteristics, high gloss, easy removability with acetone, low MeHQ, and low heat generation [see Table 1]. Formulas that contain oligomers with low heat generation can reduce or eliminate the burning sensation which may occur. By using these oligomers, companies will have the capability to formulate nail gel coatings with desirable mechanical properties and appear salon–fresh for an extended period.

Table 1. Summarized List of Oligomers

Formula Type	Requirements	Suggested Oligomers
Hard Gels	High viscosity, high hardness, low exotherm, high gloss, low color	BR-371B, BR-371MS, XR-741MS
Soak-Off Gels	Medium viscosity, acetone removability, toughness, low exotherm, low color	BR-541MB, BR-571MB, BR-742M, BR-742MS, BR-744BT
Gel Polish – Top Coat	High gloss, low color, hydrophobic, abrasion resistant, adhesion to base/color coat	BRC-843D, BRC-443D, BR-551ME, BR-541MB, BR-541S, BR-571MB, BR-952, BR-1041MB
Gel Polish – Color Coat	Good dispersibility with pigment systems, toughness, adhesion to base coat, low exotherm	BR-742M, BR-742MS, BR-551ME, BR-7432GB, BR-744BT, BR-543MB, BR-952, BR-1042MB , BR-1043MB
Gel Polish – Base Coat	Adhesion to nail, flexibility and toughness	BR-7432GB, BR-744BT, BR-742M, BR-742MS, BR-543MB, BR-1043MB

TESTING & RESULTS

A selection of Bomar oligomers were tested in a model formula [Table 2] using a 405 nm LED light source at 75 mW/cm^2 of intensity to cure the formula.

Viscosity and Hardness

Although there are innovative nail product categories that defy categorization, in general there are three main types of UV/LED–curable nail coating formulations: hard gels, soak–off gels, and gel polish. Each type of formula has a different set of target requirements, particularly the viscosity and hardness. Hard gel oligomers will have the highest viscosity and durometer hardness because they are used as an extension of the nail. The major challenge with hard gels is obtaining the combination of very high viscosity, high hardness, and a low heat generation. Soak–off gel oligomers require a lower viscosity and lower durometer hardness relative to hard gel oligomers in order to make the coating more flexible and easier to remove. Obtaining a medium viscosity oligomer with good adhesion to the nail as well as the ability to soak off easily from the nail is the primary challenge with these types of nail coatings. The classic gel polish oligomers usually make up a base, color, or top coat and remain at the lowest viscosity in the spectrum of nail coating oligomers because they are used primarily for color and long–lasting shine on natural or pre–extended nails. Challenges appear in each layer of this type of nail coating.

The selected range of oligomers provides a range of viscosities and durometer hardnesses for formulators. In general, the products with the highest durometer usually appear in the hard gel category, and materials with lower durometer hardness typically are better suited for the more flexible soak–off gels and gel polish. Oligomers given in Table 3 can be blended in formulations to create chip–resistant, long–lasting gel nail coatings that last up to two weeks.

Glass Transition Temperatures of Cured Oligomers

Several different Bomar oligomers were selected with varying degrees of flexibility to allow formulators to balance properties as desired. The selection process was based on many factors, one being the published glass transition (Tg) of the cured oligomer which is available on the oligomer's product data sheet. Each formula consisted of 2% photo initiator. According to the Tg values shown in Table 4, hard gels tend to be more rigid and have higher Tg's while soak–off and gel polish tend to have more flexible properties at lower Tg's.

Table 2. Nail Gel Coating Model Formula

Material	Amount
Oligomer	50%
DEGDMA	48%
TPO	2%

Table 3. Viscosity and Hardness of LED–Curable Formulations

Oligomer	Formulation Viscosity, cP at 25°C	Durometer Hardness
BR-952	60	D85
BR-371MS	560	D80
XR-741MS	390	D82
BR-371B	130	D75
BR-742M	680	D75
BR-541MB	480	D76
BR-742MS	720	D73
BR-551ME	150	D74
BR-571MB	1500	D83
BRC-843D	650	D80
BRC-443D	970	D80
BR-744BT	1500	D72
BR-7432GB	4600	D73
BR-543MB	1800	D71
BR-1041MB	345	D87
BR-1042MB	413	D80
BR-1043MB	668	D75

Table 4. Glass Transition Temperatures of the Cured Neat Oligomers

Oligomer	Glass Transition Temperature, Tg
BR-952	153°C
BR-371MS	110°C
XR-741MS	107°C
BR-371B	86°C
BR-742M	61°C
BR-541MB	60°C
BR-742MS	58°C
BR-551ME	53°C
BR-571MB	50°C
BRC-843D	45°C
BRC-443D	41°C
BR-744BT	8°C
BR-7432GB	-4°C
BR-543MB	-56°C
BR-1041MB	89°C
BR-1042MB	45°C
BR-1043MB	19°C

Acetone Removability

A highly desired characteristic of cured nail coatings is easy removal by acetone because it prevents skin irritation. To evaluate the coating's removability by acetone, a 10mil layer of each nail coating formula was applied to glass. The coating was cured using a 405 nm wavelength LED light at 75 mW/cm^2 intensity for 1 minute. The cured formulas are left out for 24 hours to ensure a full cure and then exposed to acetone double rubs (ASTM D4752). It is important to note that while a nail coating should be easy to remove to prevent irritation, it should also be long– lasting. Replacing the difunctional monomer, DEGDMA, with a monofunctional monomer such as IBOMA will reduce the acetone double rub resistance for the formula and lower the temperature during cure. Relatively easy to remove coatings were BR–742M, BR–551ME, BRC–843D, BRC–443D and BR–543MB (see Figure 1).

Non–Yellowing Oligomers

In many nail coating formulations, post–cure yellowing can be an issue. This happens because photooxidation during curing generates chromophores that result in yellowness in the final coating. Therefore, it is important to minimize or eliminate yellowing in nail coating formulas. In this study, each formula is rolled out onto a Leneta card in a thin layer and cured under a 405 nm wavelength LED light at 75 mW/cm^2 intensity for 1 minute. Each formulation was evaluated for yellowness post–cure according to ASTM E313, using a photo–spectrometer. The standard white background is set before testing the cured formulas on a Leneta card. Formulas containing the oligomers BR–371MS and BR–543MB show the least amount of yellowing post–cure (as shown in Figure 2). When compared to traditional polyether–based oligomers, the bio–based products BR–1042MB and BR–1043MB indicate very low yellowing and reveal good post–cure results as well.

Figure 1. Acetone Double Resistance Provided by the Oligomers

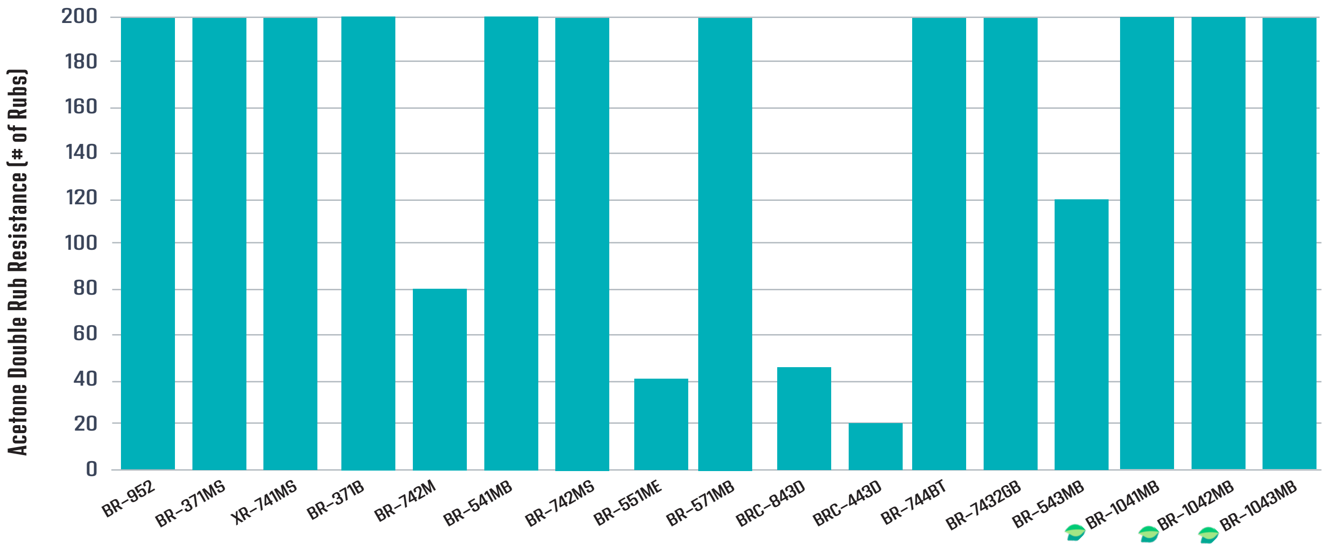
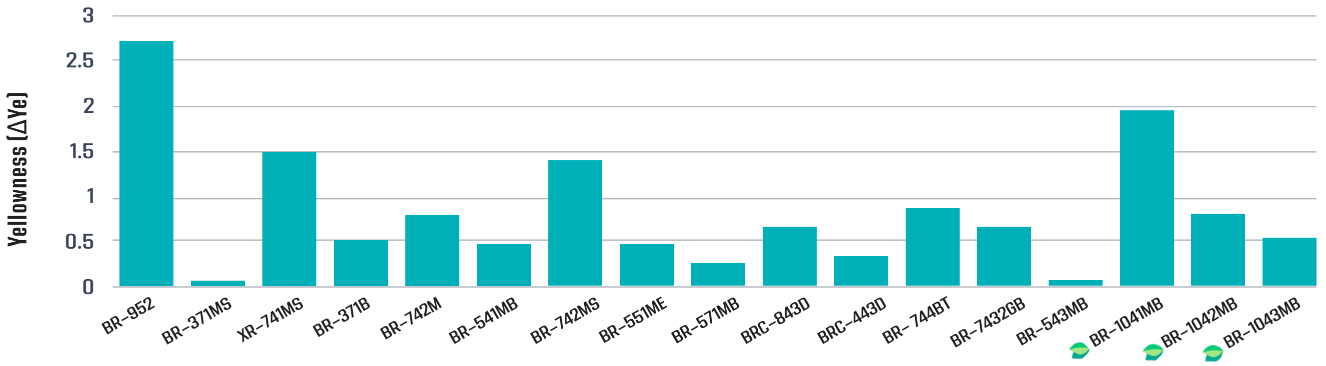


Figure 2. Yellowness Values of the LED–Cured Coatings



Gloss of Coatings after IPA Wipe

Coatings need to be wiped with IPA in order to obtain a hard and non-tacky surface. In this study, each formula is rolled out onto a Leneta card in a 10mil layer and cured under a 405 nm wavelength LED light at 75 mW/cm^2 intensity for 1 minute. After being wiped with IPA, coatings should still look glossy. To measure the gloss of coatings (ASTM D2457) after the IPA wipe, a gloss meter is used to measure a value for gloss at 20, 60, and 85 degrees. Coatings with a gloss level value of over 70 at 60 degrees are considered high gloss. Gloss levels over 80 are desired for a long-lasting gloss coating. Formulas containing BR-742M, BR-541MB and bio-based BR-1041MB exhibit the highest gloss values in this study (see Figure 3). BR-1041MB cures to a hard coating and should be used with a flexible monomer.

At this times it is important to note that monomer selection plays a key role in the gloss level of oligomers. Since DEGDMA is a relatively hydrophilic monomer, the gloss levels of hydrophobic Bomar oligomers such as BRC-443D and BRC-843D will be reduced due to incompatibility. When properly formulated, these oligomers in a more hydrophobic monomer such as IBOMA are likely to exhibit higher gloss.

Heat Generation

Cure profiles of all formulations were analyzed by a Differential Scanning Calorimeter (DSC) equipped with a Dymax BlueWave® LED Flood VisiCure®. After 30 seconds of isothermal stabilization at 25°C, samples were exposed to 405 nm wavelength light at 75 mW/cm^2 intensity for 15 seconds. The maximum exotherm temperature for each sample was recorded. Neat oligomers are represented by orange data and nail coating formulas are represented by the blue color. The data presented here is for reference purposes only and may be found in Figure 4. The heat generation in the formulations are above body temperature and are not recommended for use as nail gels. Tested oligomers in the neat state however have exotherm temperatures in most cases at or below 30°C.

Figure 3. Gloss Coatings after IPA Wipe

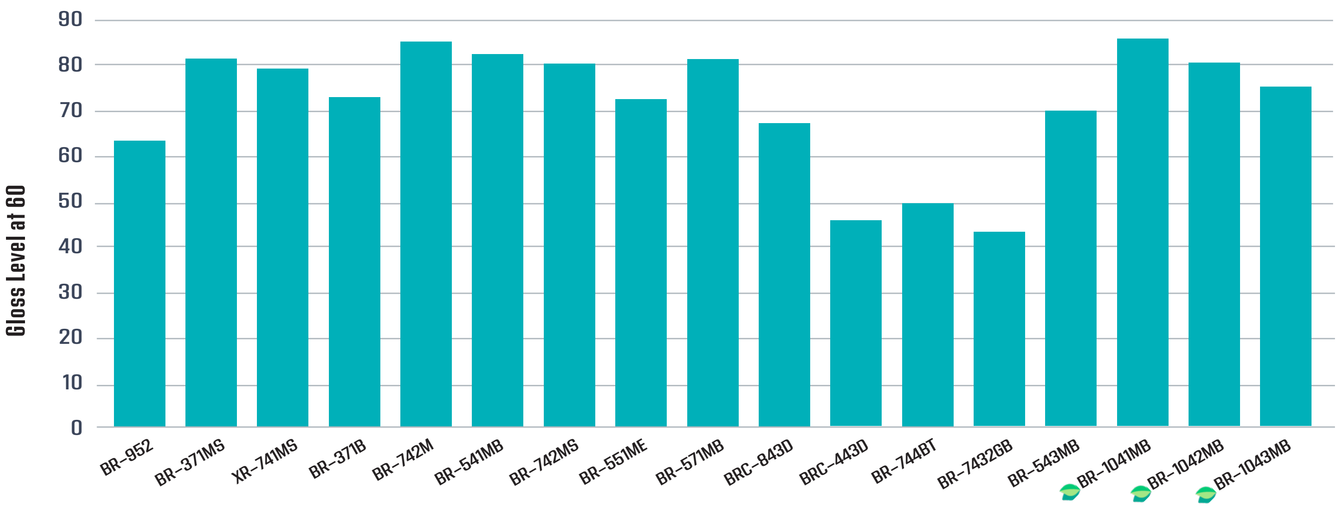
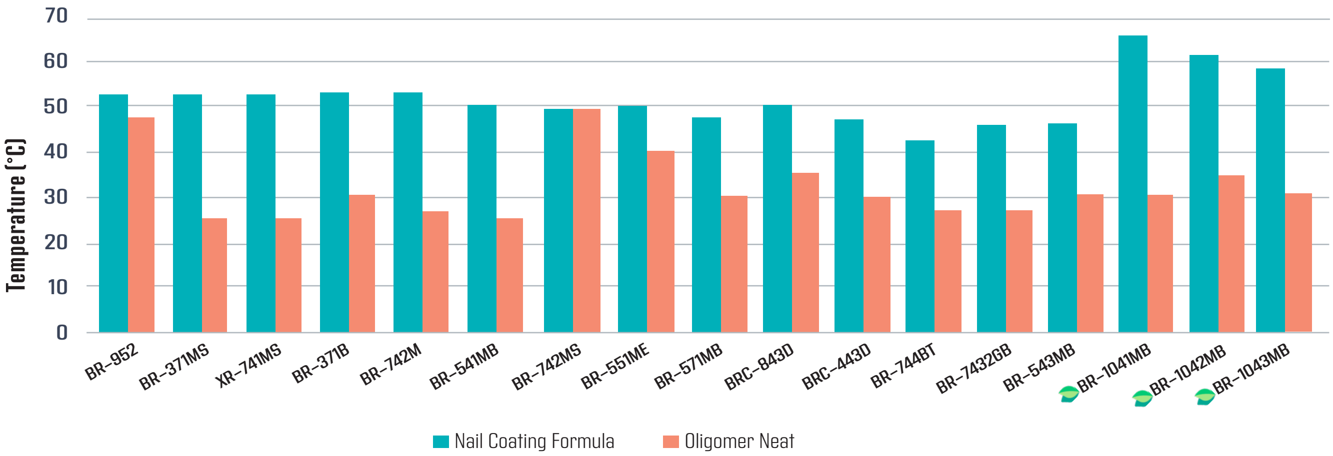


Figure 4. Maximum Temperature Observed During LED Curing



CONCLUSION

Various Bomar oligomers – petro–based as well as bio–based – that underwent testing in this study offer advantages to UV– and LED–curable nail coatings. They were tested in a model formula to establish a comparative data base. Oligomers can add desired properties to different types of nail coatings: hard gels, soak off gels, and gel polishes. Therefore, in this study, they are organized into these groups so that customers can choose the product that is most appropriate for their application. It is important for all curable nail gel coatings to be non–yellowing, high gloss, and have low MeHQ content for low skin irritation and to meet the latest cosmetic guidelines for inhibitor concentration. Bomar oligomers can assist in the optimization of these properties to best suit a customer application.

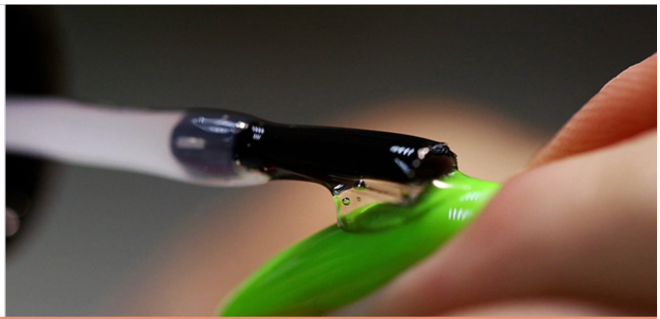
OTHER SUGGESTED NAIL COATING PRODUCTS

LumiSet™ Film Formers for Long–Wear Nail Coatings

LumiSet™ resins are a range of film forming materials that can be utilized in hybrid or long–wear nail polishes for a long–lasting nail coating. Curable with natural light these polyurethane methacrylate resins offer excellent adhesion, easy removal, inherent toughness, and fast drying times. Their superior compatibility with organic solvents and common film formers as well as their flexibility over cellulose resins easily allows to create 5–free formulations without any suspect materials.

Table 6. Summarized List of LumiSet™ Film–Forming Resins

Bomar Oligomer	Applications	Comments
LSR-141	Hybrid nail polish base/color or gel polish base/color coats	Sunlight-curable, film-forming base/color coat resin with good toughness; excellent adhesion
LSR-241	Hybrid nail polish top coat	Sunlight-curable, film-forming base/color coat resin with good toughness; excellent hydrophobicity
LSR-241P	Hybrid nail polish top coat	Sunlight-curable, film-forming top coat with good toughness; excellent hydrophobicity



BR–581MT: Tack–Free Top Coat Oligomer

Tack free gel polish top coats provide a durable, high–gloss finish to a manicure without an IPA wipe step to save time and allow the coating to exhibit its natural gloss. A model formula containing BR–581MT, a monofunctional and a difunctional methacrylate monomer, and a photo initiator performs exceptionally well when compared to competitor top coats for yellowness, viscosity, and hardness.

See the Bomar Specialties Sell Sheet for more information on BR–581MT.