BOMAR® OLIGOMER STUDY

Dendritic Oligomers for UV Flexographic Systems

bomar-chem.com

BOMAR

Emerging reports indicate that dipentaerythritol hexaacrylate (DPHA) may soon be subject to regulatory restrictions in UV-curable food packaging applications. Several regulatory bodies are actively introducing or expanding limitations on UV-reactive chemicals that come into direct or indirect contact with food. DPHA is commonly used in UV flexographic systems for food packaging, so the potential for new restrictions has prompted the need to explore alternative materials that can deliver similar performance without regulatory concerns. In this study, Bomar dendritic oligomers were evaluated as potential alternatives to DPHA in UV flexographic systems.

Dendritic Oligomers for UV Flexographic Systems

Dendritic oligomers are polymeric, hyper-branched thioether urethane acrylates, offering acrylate functionalities of 6 or greater. Their highly branched structure and high functional density provide broad formulation flexibility and the potential for enhanced performance. In this study, Bomar dendritic oligomers with acrylate functionalities from 6 to 32 were assessed for key physical and performance properties to determine their suitability as a replacement for DPHA in UV flexographic systems.

TESTING & RESULTS

Fifteen formulations were prepared for this study, as shown in Table 1. All samples were cured using a Dymax UVCS V2.0 Conveyor outfitted with a Fusion H bulb, with a lamp height of 2.1 inches and a conveyor speed of 10 feet per minute. Film thickness on all samples were drawn down using a 1-mil drawdown square, unless otherwise noted.

Samples underwent a series of physical and performance tests, including evaluations for abrasion resistance, humidity resistance, cure speed, surface hardness, and more. The test methods used are outlined as follows:

MEK Double Rubs: (ASTM D4752) All films coated at 2 mils; a cheesecloth covered ball-pinned hammer was used.

Steel Wool Scratch: (Internal Method) – testing using steel wool #1, 20 double rubs per sample using a ball-pinned hammer

Yellow Index: all measurements made on the coated white portion of a white Leneta card using BYK Spectro-guide sphere gloss instrument

Taber Abrasion: (ASTM D4060) CS-10 wheels, 500 cycles measure at 100 cycle intervals (Modified Method)

Pendulum Hardness: (ASTM D4366) measurements on glass panels using the Koenig method

Pencil Hardness: (ASTM D3363) measurements on glass panels after 24-hour ambient equilibration

Humidity Resistance: (ASTM D2247) measurements on steel panels for 7 days at 38°C/95% Relative Humidity

Crosshatch Adhesion: (ASTM D3359) measurements on PVC, polystyrene, polycarbonate, polymethylmethacrylate, and glass

180° Peel Test: (ASTM D903) measurements using a Thwing-Albert Peel tester using biaxial oriented polypropylene

Photo-Rheology: testing performed using TA Instruments Discovery HR-20 Hybrid Rheometer w/405 nm LED lamp at 30 mW/cm^2

Mandrel Bend: (ASTM D522) measurements made on steel panels after 24-hour ambient equilibration

Viscosity: (ASTM D D4287) all measurements were using a BYK CAP+2000 Viscometer

BOPP: samples of PST-2 substrate graciously supplied by Taghleef Industries

Table 1. Prepared Formulations

Resin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CN-2262	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
DPHA*	25.0	15.0	5.0												
XDT-1018				25.0	15.0	5.0									
BDT-1006							25.0	15.0	5.0						
BDT-1015										25.0	15.0	5.0			
BDT-4330													25.0	15.0	5.0
DPGDA*	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
GPTA	15.0	25.0	35.0	15.0	25.0	35.0	15.0	25.0	35.0	15.0	25.0	35.0	15.0	25.0	35.0
Irgacure 184	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Darocur 1173	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total (wt%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

* DPHA is under global regulatory review

Viscosity

As shown in Figure 1, the viscosity of formulations containing BDT–1006 closely matched that of the DPHA containing formula. This low viscosity attribute makes BDT–1006 an excellent candidate for ink–jet printing. The viscosity of BDT–1015, XDT–1018, and BDT–4330 formulations were higher in viscosity than DPHA containing formulations at the same concentration.

Scratch Resistance

Figure 2 presents the results of steel wool scratch resistance testing. Among the tested formulations, the formulation containing BDT–4330 exhibited the highest scratch resistance, consistently maintaining high gloss across all concentrations. In contrast, the formulation incorporating XDT–1018 demonstrated the poorest performance, showing more gloss reduction under abrasive stress. These findings suggest that BDT–4330 is a strong candidate for applications where haze resistance is needed.

Surface Hardness

The following is the order of surface hardness as tested by Koenig Pendulum:

DPHA > BDT–4330 > BDT–1006 > BDT–1015 > XDT–1018

This order is formulation and concentration dependent. The number of swings at 15 wt.% dendritic oligomers were almost identical. At this 15% concentration, dendritic oligomers had little influence over the formulation hardness.

Figure 1. Viscosity at 25°C (cPs)

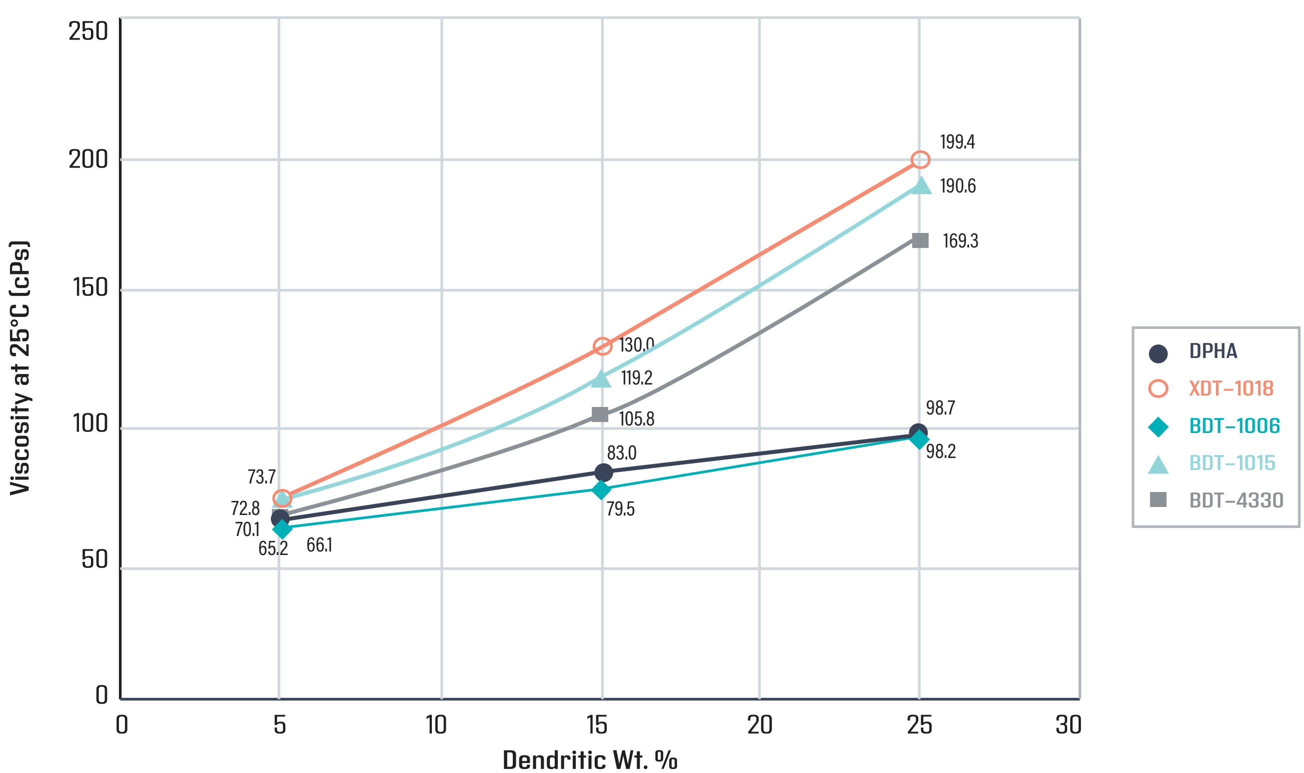


Figure 2. Scratch Resistance Testing Results

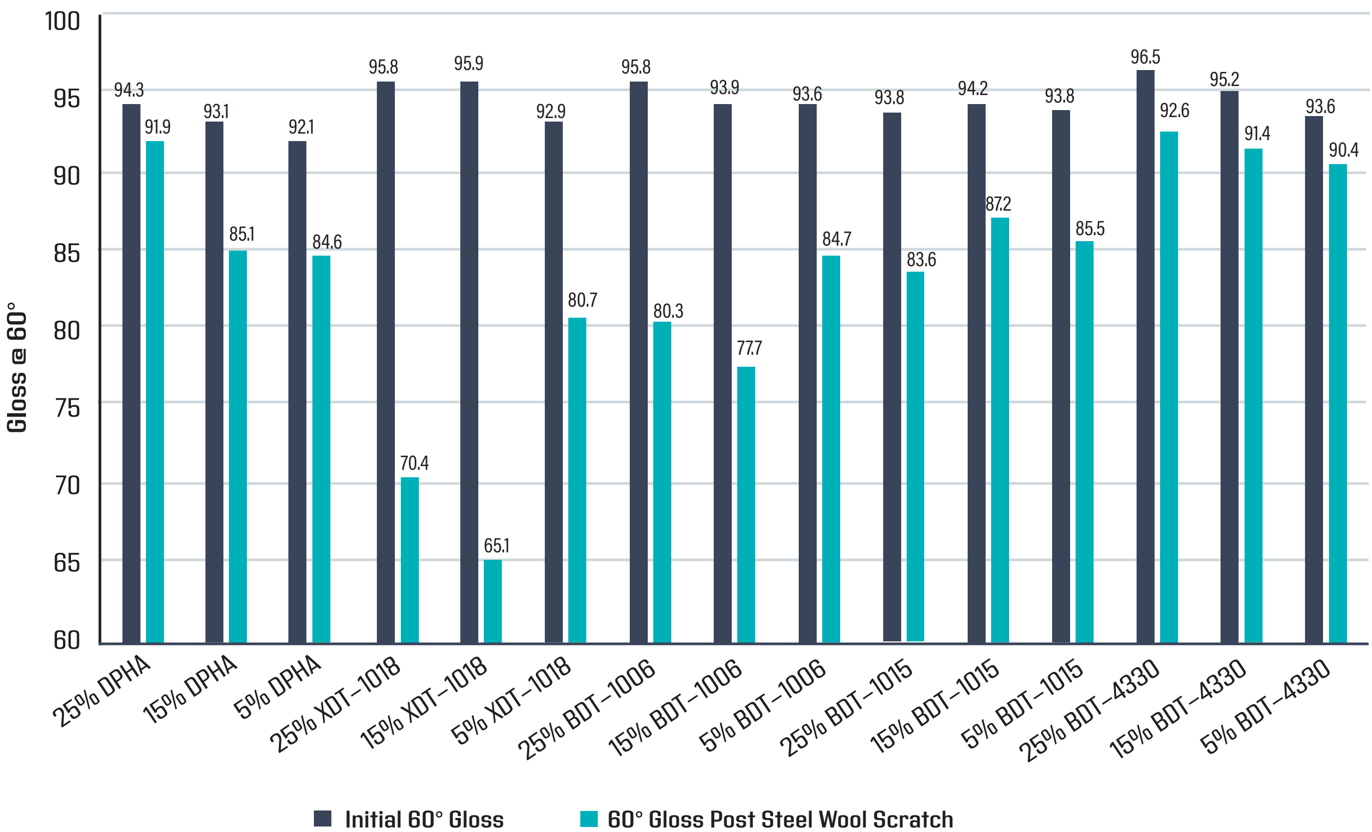
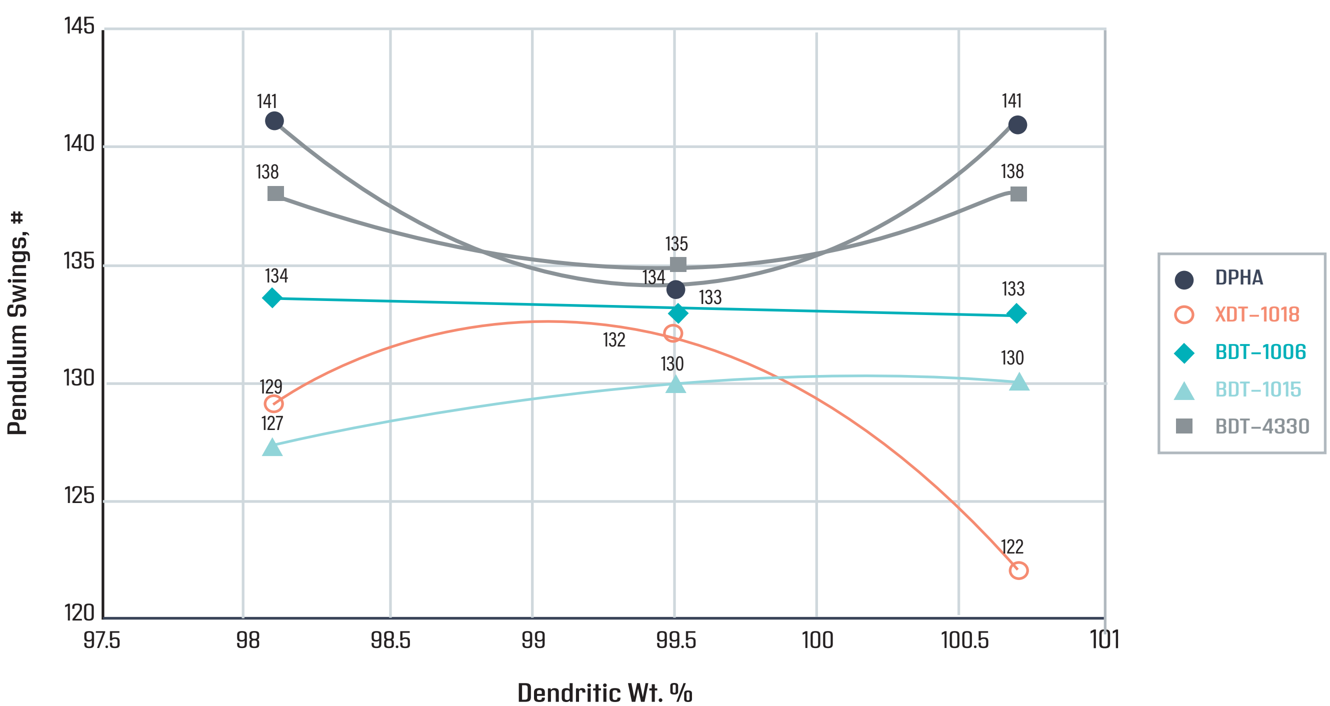


Figure 3. Pendulum Hardness (Koenig) Testing Resuls



Abrasion Resistance

Taber abrasion testing was conducted on the samples at 100-cycle intervals, up to a total of 500 cycles. The results are presented in Figure 4 below. Among the formulations containing dendritic oligomers, the one with 25% XDT-1018 exhibited the best abrasion resistance. This aligns with the fact that XDT-1018 is the most flexible of the dendritic oligomers tested. In contrast, the formulation with 25% BDT-1015 showed the poorest abrasion resistance. Notably, the formulation containing 25% BDT-4330 outperformed the DPHA-containing formulation in abrasion resistance.

Humidity Resistance

Humidity resistance was evaluated according to ASTM D2247, using coated steel panels exposed to 38°C and 95% relative humidity for 7 days. Results are presented in Figure 5. Formulations containing 25% BDT-4330 and 25% BDT-1015 showed excellent resistance to moisture. This performance is likely due to the fact that both oligomers have high cross-linking density to innate structural flexibility. In contrast, the DPHA-containing formulation exhibited poor humidity resistance.

Figure 4. Taber Abrasion Testing Results

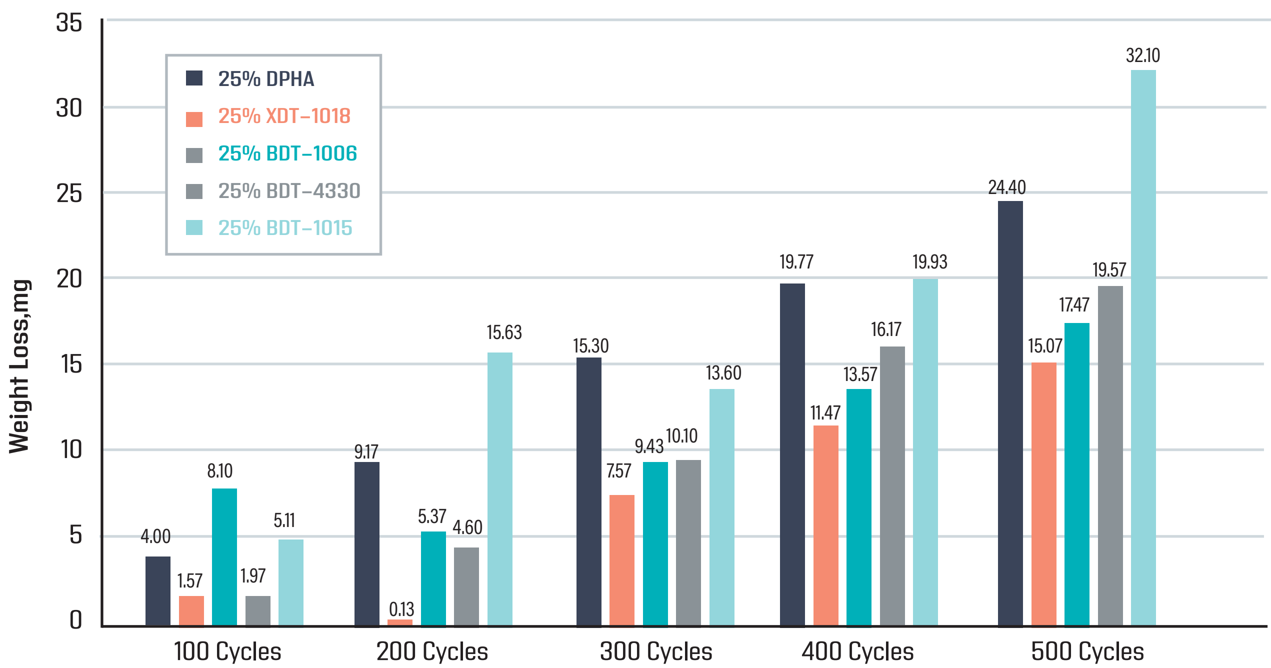
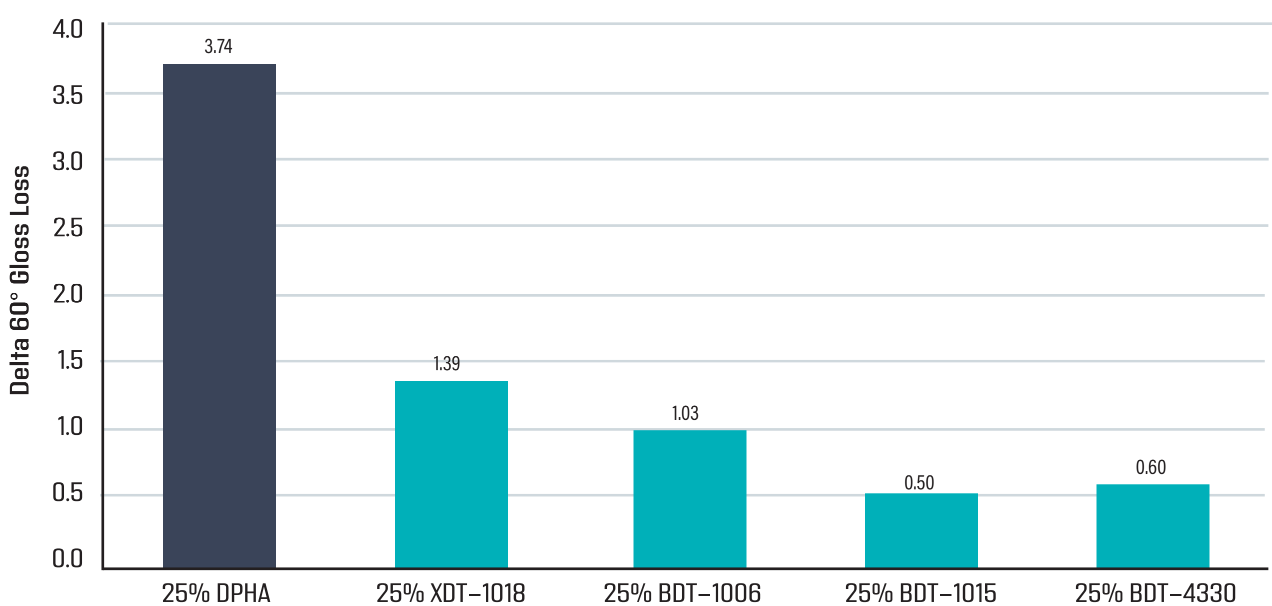


Figure 5. Humidity Resistance, Delta Gloss Loss Testing Results (7 Days)



Photo–Rheology: Storage Modulus

The photo–rheology of these dendritric oligomers revealed several aspects which influence the performance of dendritic oligomers in flexo formulations. IN regards to storage modulus (Figure 6), the formulation containing BDT–4330 had the greatest storage modulus. Theoretically, this property is related to a material's ability to store energy and demonstrates the elastic properties of the coating.

Photo–Rheology: Loss Modulus

The loss modulus, shown in Figure 7, reflects a polymer's ability to dissipate mechanical energy and is sometimes associated with the viscous component of a polymer. In this evaluation, the formulation containing BDT–4330 exhibited the highest loss modulus among all materials tested. This performance further highlights BDT–4330's unique balance of flexibility and structural integrity.

Figure 6. Photo–Rheology, Storage Modulus Testing Results at 100 Seconds

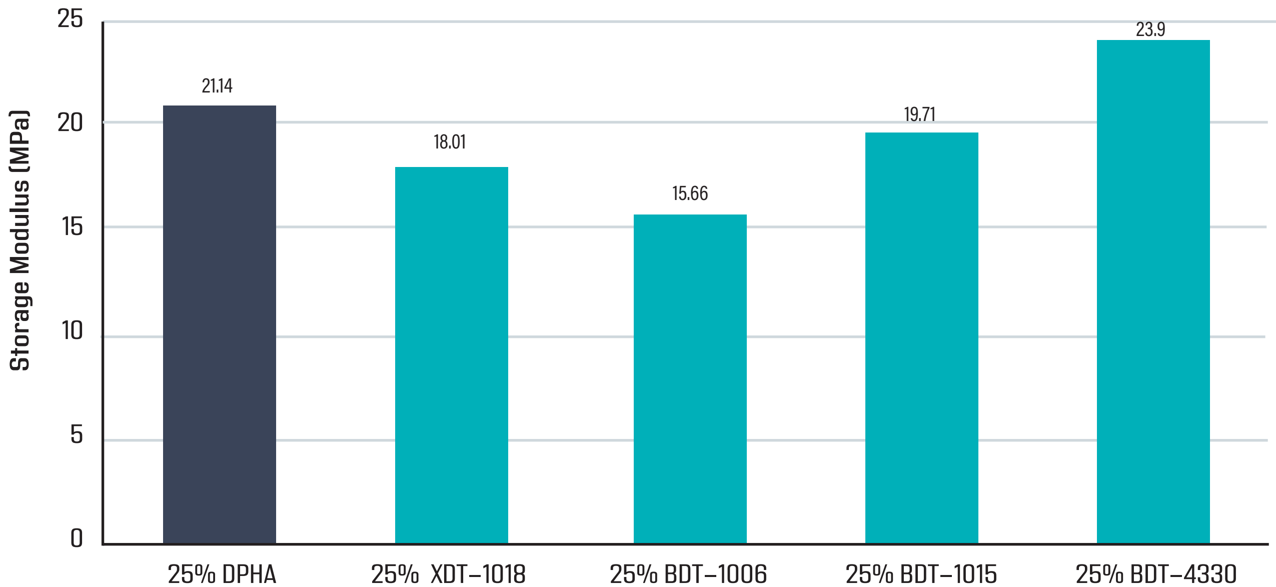
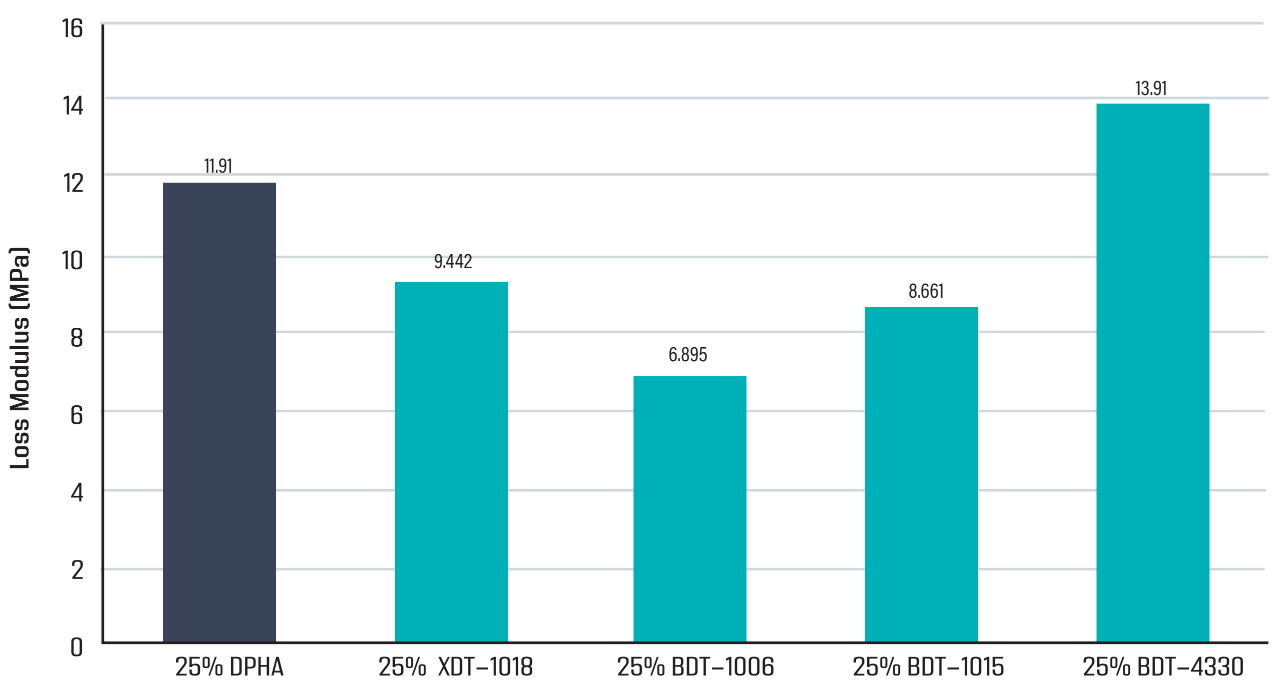


Figure 7. Photo–Rheology, Loss Modulus Testing Results at 100 Seconds



Photo–Rheology: Complex Modulus

The complex modulus, presented in Figure 8, provides insight into the degree of cross–linking within each formulation. Higher complex modulus values typically indicate a more densely cross–linked network. Among the materials tested, formulations containing BDT–4330 and BDT–1015 exhibited the highest complex modulus..

Photo–Rheology: Cure Speed

The relative cure speed of each formulation was evaluated by measuring the time required to reach 1 MPa following UV exposure. As shown in Figure 9, formulations containing BDT–4330 and BDT–1015 achieved this threshold in the shortest time, indicating a rapid cure response. In contrast, formulations with XDT–1018 exhibited the slowest cure response according to this photo–rheological method.

Figure 8. Photo–Rheology, Complex Modulus Test Resutls at 100 Seconds

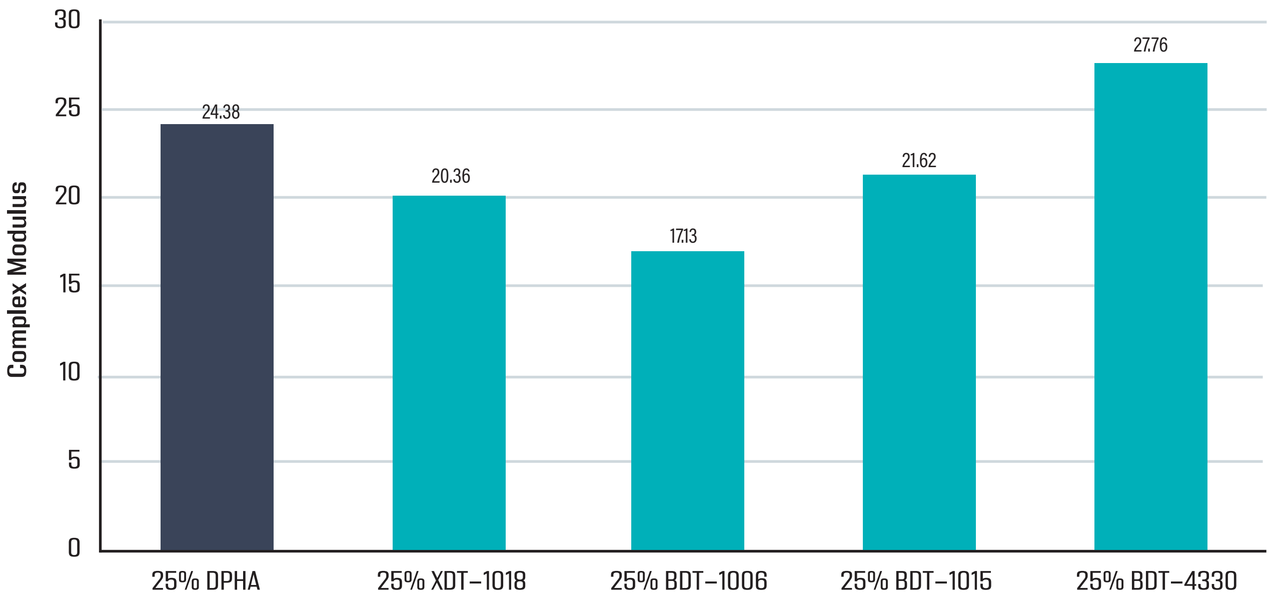
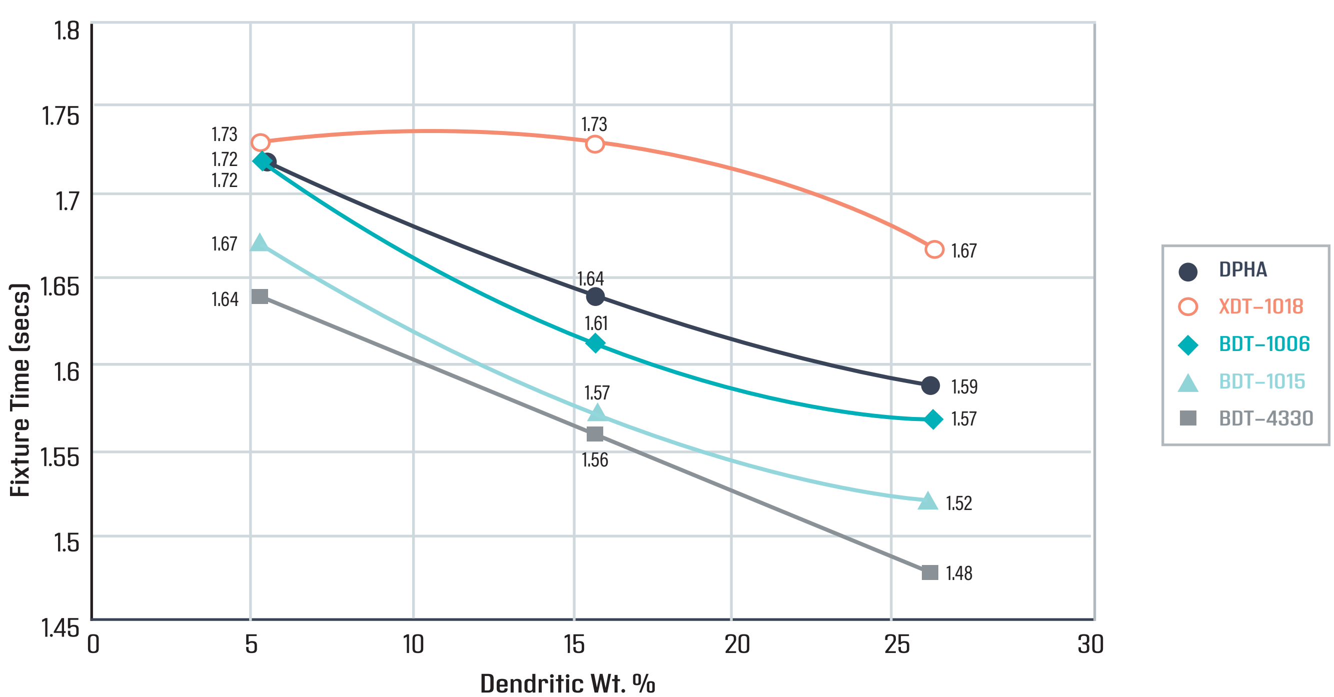


Figure 8. Photo–Rheology, Cure Speed Comparison at 1MPa



Peel Strength

As shown in Figure 10, formulations containing BDT–4330 demonstrated peel strength matching those with DPHA. In contrast, formulations with BDT–1006 and BDT–1015 exhibited limited adhesion to BOPP. None of the tested formulations showed adhesion to PET.

Crosshatch Adhesion

There was little segregation of the dendritic oligomers in formulations on rigid substrates. All the formulations gave adhesion to polyvinyl chloride (PVC), polymethyl methacrylate (PMMA), and polycarbonate (PC). Meanwhile, no adhesion was shown by the any of the tested formulations to glass or polystyrene (PS). These results are found in Table 2.

Figure 10. BOPP Peel Strength Testing Results

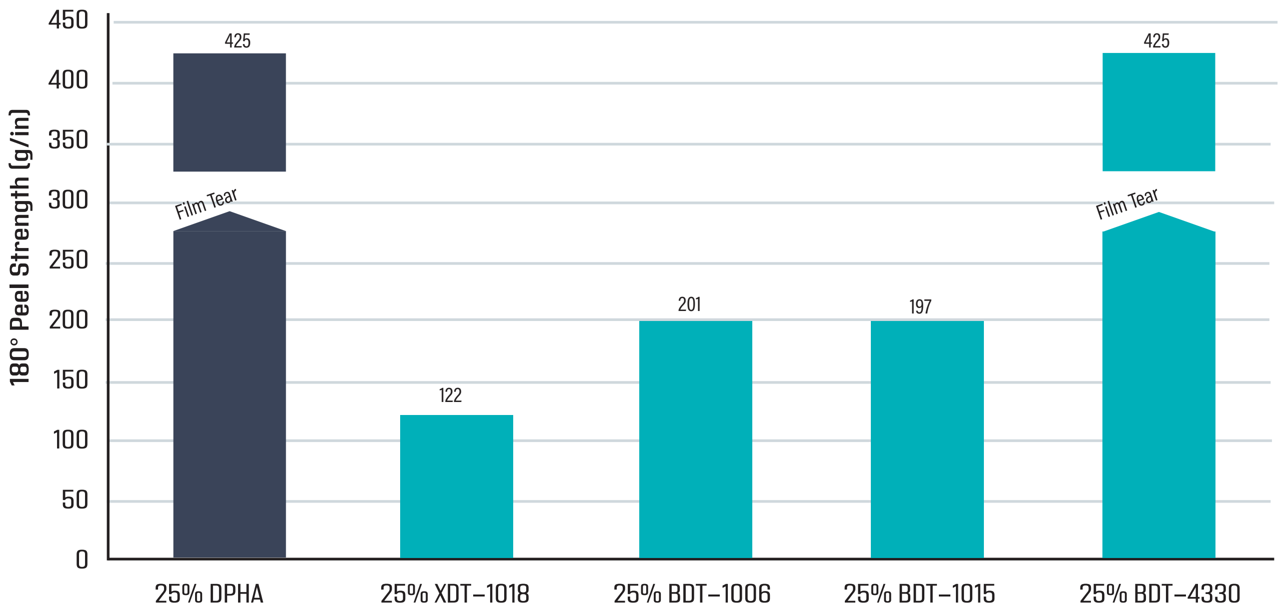


Table 2. Cross Hatch Adhesion Testing Results

	PVC	PS	PC	PMMA	Glass
25% DPHA*	5B	0B	5B	5B	0B
25% XDT-1018	5B	0B	5B	5B	0B
25% BDT-1006	5B	0B	5B	5B	0B
25% BDT-1015	5B	0B	5B	5B	0B
25% BDT-4330	5B	0B	5B	5B	0B

CONCLUSIONS

This study provides strong evidence that Bomar dendritic oligomers are potential alternatives to DPHA in UV flexographic systems. Across a comprehensive series of mechanical, chemical, and rheological tests, at least one dendritic formulation matched or surpassed the performance of the DPHA benchmark.

Key Findings:

- BDT-4330 exhibited excellent adhesion, scratch resistance, and outstanding humidity resistance.
- XDT-1018 was the most flexible oligomer, delivering superior abrasion resistance.
- BDT-1006 had the lowest viscosity, making it particularly well-suited for inkjet printing applications.
- BDT-1015 offered the best humidity resistance, along with fast cure speed and strong overall photo-rheological performance.
- DPHA performed poorly in both humidity resistance and abrasion resistance, ranking among the lowest in these categories.

With increasing pressure surrounding DPHA, Bomar R&D is working toward developing a food grade version of these dendritic oligomers Bomar's dendritic oligomers offer a timely and effective solution – combining performance, formulation flexibility, and potential compliance advantages.

Let's Partner on Your Next Project

To support your formulation development, we offer samples of our oligomers along with expert guidance from our application engineering team. Contact us today to request materials or start a conversation about your formulation goals.