Impact & Temperature-Resistant Oligomers

Effect of Newly Developed (Meth)acrylate Resins on Impact Strength in 3D Printing

The Challenge

Dymax is creating solutions that allow photopolymer-based 3D printing resins to meet or exceed the capabilities of thermoplastic materials such as polycarbonate or ABS, targeting superior impact and temperature resistance properties. The goal is improvements in impact strength while maintaining a high Heat Deflection Temperature (HDT).

The Trade-Off

Stronger UV-curable materials with high HDTs are generally low in impact resistance, being more inflexible or brittle due to a high degree of cross-linking in their molecular composition. On the other hand, high molecular weight materials with low crosslink density typically have a low HDT or are too high in viscosity to properly 3D print. To solve this persistent problem and achieve advancement in balancing these properties, chemists need to determine the best formulation approach to attain this balance of properties within a UV-cured polymer network.

The Materials

To identify the best options for 3D printing oligomer development, Dymax explored one concept for improving impact resistance by modifying hard, highly crosslinked networks with flexible impact-modifying resins. Dymax tested three experimental Hard Resins (HR) both alone and together with several Impact Modifying (IM) materials in a model formula. These materials were categorized by functionality and molecular weight and included a range of backbone chemistries.

Model 3D Printing Formulas

		No IM	Modified
Oligomers	HR	52.00 %	37.00 %
	IM	-	15.00 %
Monomers	IBOA*	42.00 %	
	DCPDA	5.00 %	
Photoinitiator	TPO	0.99 %	
Light Absorber	BBOT	0.01 %	

* For resins that include IBOA as a reactive diluent, the added IBOA content was adjusted to normalize IBOA content to 42.00% across all formulations

White Paper Results

Hard Resin	Impact Modifying Resin	HDT (°C)	Impact Resistance (J/m)	Formulated Viscosity (cP)	Tensile at Break (MPa)	Elongation (%)
BR-952	None	130	12	155	53	4.9
	BR-5541M	97	27	1,190	53	8.1
	BR-543	104	33	520	56	6.9
	BR-7432GB	112	30	700	61	7.7

Printability

As Bomar researches and develops materials that balance HDT and impact resistance, we also must consider the limitations of the 3D printing process, including low formulation viscosities, limited light–source intensities, and cure dynamics of the 3D printing process. Formulators must also balance the need to achieve fast cure speed with the desire to minimize part shrinkage in order to achieve excellent print resolution and dimensional stability.

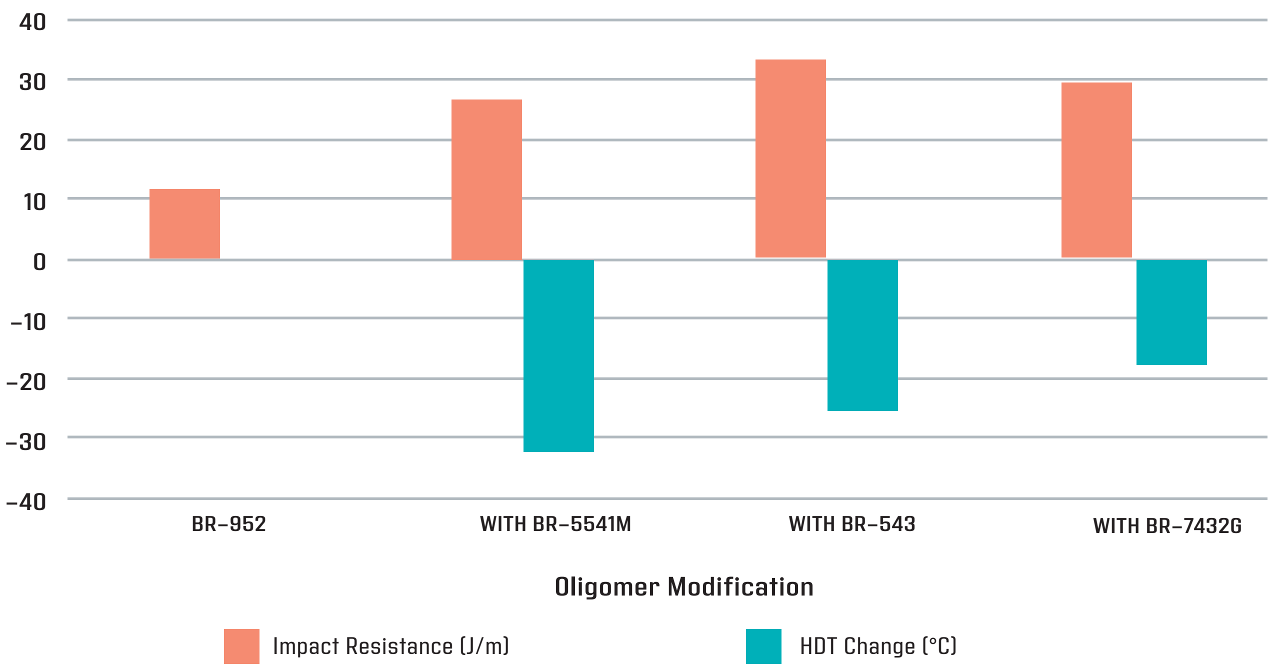
Tensile Properties

The formulations of HR/IM combinations with the best balance of impact resistance and HDT properties were subjected to additional testing to identify potential relationships to tensile strength and elongation. Materials with lower functionalities and molecular weight showed higher tensile strengths and somewhat reduced elongation. In some cases, the HR materials are able to be toughened through the IM modification with an increase in elongation as well as a constant or increased tensile strength.

The Results

The data gathered in testing several urethane (meth)acrylate resins has allowed Bomar to expand the reach of light–curing 3D printing processes and gain powerful insight into improving both HDT and IM simultaneously, rather than simply sacrificing one for the other. As industry leaders in the chemistry, mechanical systems, and formulation expertise needed to provide total solutions to our 3D printing clients, Bomar will apply these learnings to continue to push our understanding and development even further.

Impact Resistance and HDT Trade-Off



Other Suggested Bomar Oligomers for 3D-Printing Applications

Property	Bomar Oligomer	Neat Viscosity	Viscosity in 30% IBOA (25˚C)	Tensile Strength (psi, 30% IBOA)	Elongation (%, 30% IBOA)	Elastic Modulus (ksi, 30% IBOA)
Rigid	BR-952	7,200 @ 25˚C	500	10,800	5.4	380
	BR-371B	67,000 @ 60˚C	42,000	6,000	4.3	250
	BR-741	74,000 @ 60˚C	34,000	9,200	10.0	390
Tough	BR-541MB	6,400 @ 60˚C	7,400	4,100	85	85
	BR-571MB	28,000 @ 60˚C	27,000	4,500	110	140
	BRC-4421	6,600 @ 60˚C	6,800	3,000	120	90
	BR-970BT	13,000 @ 25˚C	1,000	3,400	50	40
	BR-970H	24,000 @ 25˚C	1,400	4,600	6.5	210
Flexible	BR-345	46,000 @ 25˚C	5,200	130	260	0.1
	BR-543	13,000 @ 60˚C	14,000	900	200	0.9
	BR-5541M	24,000 @ 60˚C	23,000	440	270	0.4
	BR-744BT	46,000 @ 60˚C	23,000	1,000	160	2.4
	BR-7432GB	88,000 @ 60˚C	65,000	1,400	190	3.2
	BRS-14320S	16,000 @ 60˚C	1,800	600	400	1.0