INNOVATIVE, HIGH STRENGTH GLASS MICROSPHERES FOR LIGHTWEIGHT INJECTION MOLDED PLASTICS AND COMPOSITES

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Abstract

High strength, low density glass microspheres have been developed and commercialized for use in injection molded plastic parts and pressed composite structures. This new and innovative 3M™ Performance Additives iM30K product is low in density, but has very high compressive strength survivability, providing OEM designers and Tier 1 molders new application opportunities. This paper will detail potential application benefits for injection molded plastic parts containing iM30K including lower weight, improved thermal expansion properties, improved processing and improved dimensional stability (less warpage and sink marks). Addition of these materials will also result in the maintenance of important thermoplastic physical properties.

Background and Requirements

The ability to develop lightweight automotive and aerospace materials has been keenly desired by engineers and designers for improved fuel economy and range (distance on a tank of fuel). In 2004, 4.8 billion lbs of plastics were consumed in approximately 16 million automobiles and light trucks produced in North America - or about 300 lbs of plastic per vehicle[1]. Assuming a 0.6 g/cc microsphere was used in all plastic materials in a vehicle, providing nominally a 33% weight reduction; this would result in a 100 lb weight reduction per vehicle. The US EPA and DOE estimate a 100 lb reduction of vehicle weight would result in a 2% increase in MPG[2]. Automotive News has reported that 25% of overall potential fuel savings, from existing applicable technologies, can come from light weight materials or switching to lighter materials such as aluminum and low density plastics[3].

Though low density microspheres have been available for use in these markets, the applications have been limited to those where little or no shear or compressive force is used to form or apply the materials; most notably plastisols, potting compounds and SMC[4]. Many have tried to incorporate these same products into injection molded thermoplastics and pressed composites with limited success. At issue has been the strength of the microsphere and its ability to survive the forces present during processing.

The optimum balance of strength properties with low density has been difficult to achieve due to trade-offs that occur between producing a consistent, controlled microsphere wall thickness and manufacturing efficiencies. Through innovative process and composition developments, 3M Company has produced the first 30,000 PSI compressive strength microsphere, with a density of 0.6 g/cc and a particle size of 18 microns. Their spherical shape allows higher filler loading and reduced resin demand, while greatly reducing friction and helping improve the viscosity of highly filled polymer systems. Accompanying data in this paper shows how the new product can be extruded and injection molded to provide significant weight reduction. Also demonstrated are improvements in LCTE and dimensional stability while maintaining important material physical properties.

Experimental

Figure 1 shows the particle size distribution, size and compressive strength of three grades of 3M's hollow glass microspheres. Historically, S60HS has been 3M's high strength extrusion and injection molding grade microsphere with a density of 0.6g/cc and a compressive strength of 18,000 PSI and a particle size of 30 microns. Two new grades of hollow glass microspheres from 3M, iM30K and S80HP, are substantially smaller than S60HS and have a much higher compressive strength - close to 30,000 PSI.

Table 1 shows examples of formulations and typical physical properties, achieved in a commercial grade of Nylon 66 (Zytel® 101LNC010) compounded with S60HS, iM30K and S80HP. A Leistritz ZSE-40 twin-screw extruder was used for compounding the glass microspheres into Nylon 66. The glass microspheres were added downstream using a side stuffer. A general-purpose injection molding machine (Boy 50M) with a three-zone screw (feed, compression and metering) was used to injection mold ASTM test specimens for physical property measurements.

Physical property testing was done in accordance with the following ASTM methodologies;

Physical Property	**ASTM Method**
Flexular Strength and Modulus	D790
Notched Izod Impact	D252
Tensile Properties	D638
Elongation at Break and Yield	D638

Figure 1: Particle Size Distribution, Density and Hydrostatic Strength of 3M Extrusion Grade Hollow Glass Microspheres

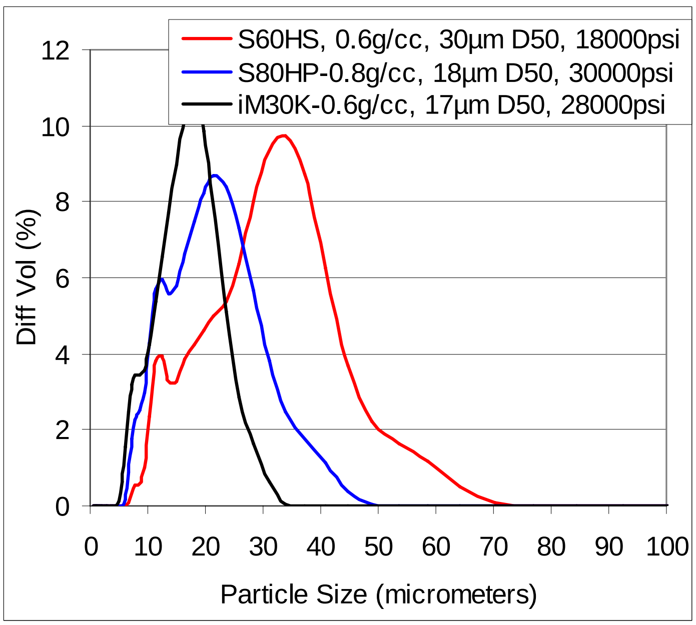

Table 1. Mechanical Properties of Hollow Glass Microspheres Compounded into Nylon 66

Sample #	Glass Microsphere Grade	V% Glass Microspheres	Density (g/cc)	% Wt. Reduction	Tensile Strength (MPa)	Tensile Modulus (Mpa)	Flex Strength (Mpa)	Flex Modulus (Mpa)	Notched Izod (ft lb/inch)
1	-	0	1.14	0	75	3200	76	2581	0.72
2	S60HS	20	1.04	8.8	57	3496	103	3103	0.26
3	S60HS	30	0.99	13.2	52	3875	83	3447	0.23
4	S80HP	20	1.07	6.0	59	3792	112	3737	0.42
5	S80HP	30	1.04	8.9	57	4226	85	4123	0.34
6	iM30K	20	1.03	9.5	60	3585	110	3730	0.5
7	iM30K	30	0.98	14.2	59	3930	83	4109	0.37

Results and Discussion

In Figure 1, the size distributions, density and hydrostatic compressive strengths of S60HS, S80HP and iM30K grades of glass microspheres are compared. It can be seen that the iM30K and S80HP glass microsphere are significantly stronger and smaller than the S60HS glass microsphere. There are several advantages to using a stronger microsphere for thermoplastic applications. The stronger microspheres will be able to withstand more stringent processing conditions such as the use of higher rpm screws, use of higher shear rate mixers etc. The advantages of the smaller particle size are evident in the improved mechanical properties of the final composite properties as discussed in more detail below.

It can be seen in Table 1 that the part density decreases from 1.14g/cc for regular Nylon 66 to 1.03g/cc at a 20% volume loading of iM30K and 0.98g/cc at a 30V% loading of iM30K. This corresponds to a density reduction of ~10% and 14% respectively over standard Nylon 66. The formulations containing S60HS and S80HP also show significant density reductions over Nylon 66.

All the glass microsphere formulations also provide a significant increase in tensile and flex modulus as well as flex strength as compared to Nylon 66. Although there is slight decrease in tensile strength with glass microsphere loading levels, this property reduction can be minimized by using the high strength, small microspheres iM30K and S80HP.

A significant negative effect of adding hollow glass microspheres to Nylon 66 is the reduced notched Izod impact strength of the composite. This is not unexpected as glass microspheres are essentially non-reinforcing fillers dispersed into a plastic material. However, as can be seen in Table 1, over a 50% improvement in the Izod impact strength is realized by using iM30K or S80HP in the formulations instead of S60HS. This is most likely due to the smaller size of these microspheres compared to S60HS.

Summary and Next Steps

Hollow Glass Microspheres can be used in thermoplastics to reduce weight, mold shrinkage, warpage and CLTE. Other attributes unique to hollow glass microspheres are their low thermal conductivity and low dielectric constant. The use of the new high strength microspheres such as the iM30K can also offer the additional benefits of improved survivability during stringent thermoplastic processing conditions as well as improved properties of the final composite in many applications.

References

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2. http://www.fueleconomy.gov/feg/driveHabits.shtml, Section Entitled "Remove Excess Weight".
3. Automotive News, "Engineers Comment: Focus on the Basics", March 8, 2004.
4. 3M™ Microspheres Application Guide, Revision 7/04.