POSS keeps high temperature plastics flowing

High performance plastics often require high processing temperatures. However, at such temperatures organic molecules start to degrade. Additives to keep the polymer flowing in moulding applications are required to aid processing while preventing degradation. Dr. Chris DeArmitt and Dr. Paul Wheeler of Hybrid Plastics describe the advantages of the hybrid ceramic-organic structure of POSS additives that can provide thermal stability and the retention of mechanical properties.

POSS® Nanostructured® Chemicals are a family of hybrid materials that span the gap between organic and inorganic properties. Composed of an inorganic silica-like core surrounded by adjustable organic functionalities, these molecules are not only revolutionary and exciting but also highly useful. POSS was commercialized by Hybrid Plastics'™ around ten years ago and there has since been much activity, in academia and industry alike, to realize the potential of these novel molecules. With over 2300 articles and 800 patents to date, POSS is finding uses in many areas, ranging from dentistry to packaging and from aviation parts to optical devices. At present there are over 80 POSS types available and many more under development. Some are chemically inert and others are designed to react. For example, there are POSS acrylates, methacrylates, epoxies, amines, sulphonates, carboxylic acids, thiols, alcohols, phenyl, alkyl and fluoroalkyl. In fact, just about any organic functionality can be incorporated and custom synthesis is available.

Some examples of the benefits attainable from POSS include: reduced friction; POSS as dispersants for particles and nanoparticles; POSS monomers to improve high temperature performance of polymers; and POSS as flow aids for thermoplastics. This article will highlight the use of POSS as a flow aid for high temperature polymers.

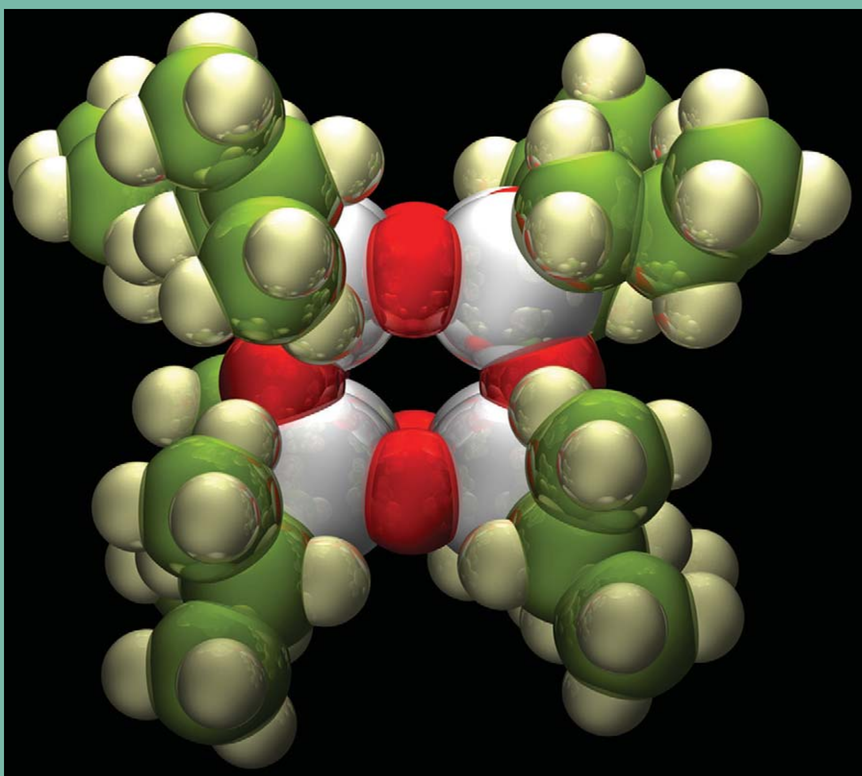

Figure 1: Octa i-butyl POSS: Silicon-Silver; Oxygen-Red; Carbon-Green; Hydrogen-Khaki.

What is POSS?

POSS stands for polyhedral oligomeric silsesquioxane, a class of molecule comprised of a rigid inorganic core, most often made of 8, 10 or 12 silicon atoms linked by oxygen atoms (see Figure 1). Each corner is attached to an organic group and the entire molecule is only 1-3 nm in size. The central core is ceramic in nature, lending thermal stability and rigidity whereas

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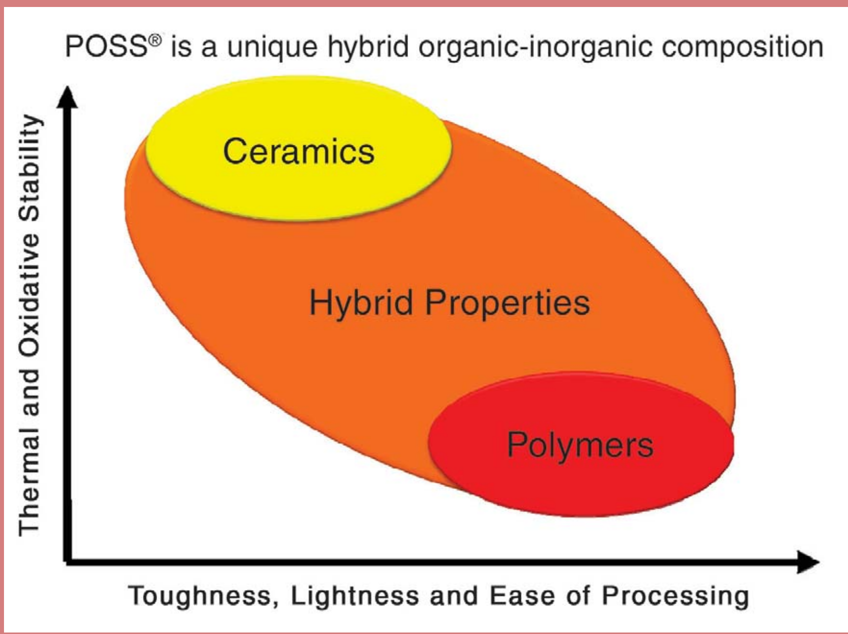

Figure 2: POSS is a unique hybrid organic-inorganic composition.

the surrounding organic groups compatibilize the POSS so that it can dissolve in polymers, solvents or coatings (see Figure 2). Particulate additives need to be properly dispersed or they will negatively affect the mechanical properties of the polymer, in particular impact resistance and elongation to break. The molecular nature of the POSS circumvents those issues.

POSS Flow for PEEK

PEEK (polyetheretherketone) is a widely-used high temperature polymer that combines good tensile modulus and strength with chemical resistance. However, as PEEK does not melt until 350°C, it must be processed at high temperatures - in the 400°C range. At such high temperatures, all organic molecules begin to degrade and so the challenge is to make the PEEK flow well enough to be processable while preventing degradation. Thin-walled parts in particular require excellent flow so that the part can be moulded properly.

POSS Flow masterbatches are provided in pellet form and can be added to PEEK in order to improve flow. Normal addition levels are 10-20 weight % but even higher levels can be used with no appreciable decrease in mechanical properties.

The melt flow index (MFI 380°C, 5kg) is raised for even low addition levels and nearly doubled at 20 % POSS Flow (see Figure 3). As would be expected the improved flow also results in a reduced extruder torque,

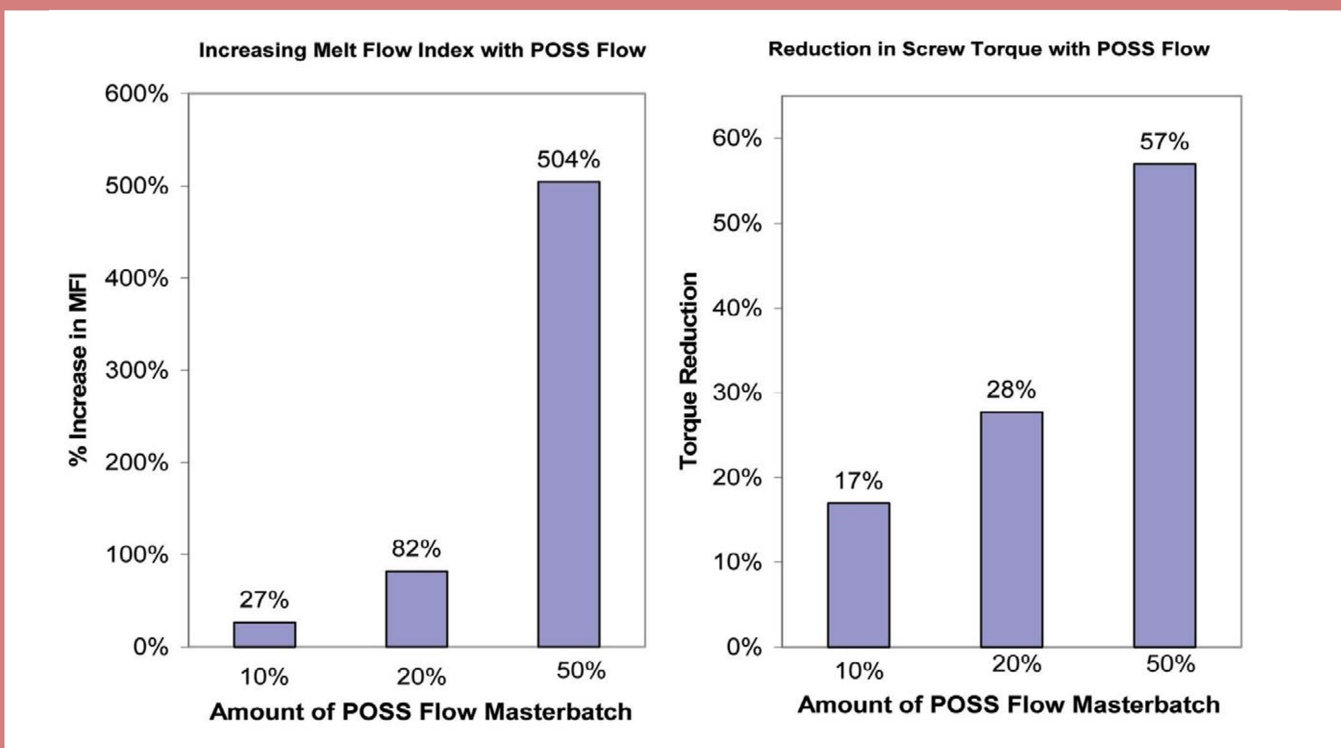

Figure 3: POSS Flow in PEEK to increase MFI and lower extruder torque.

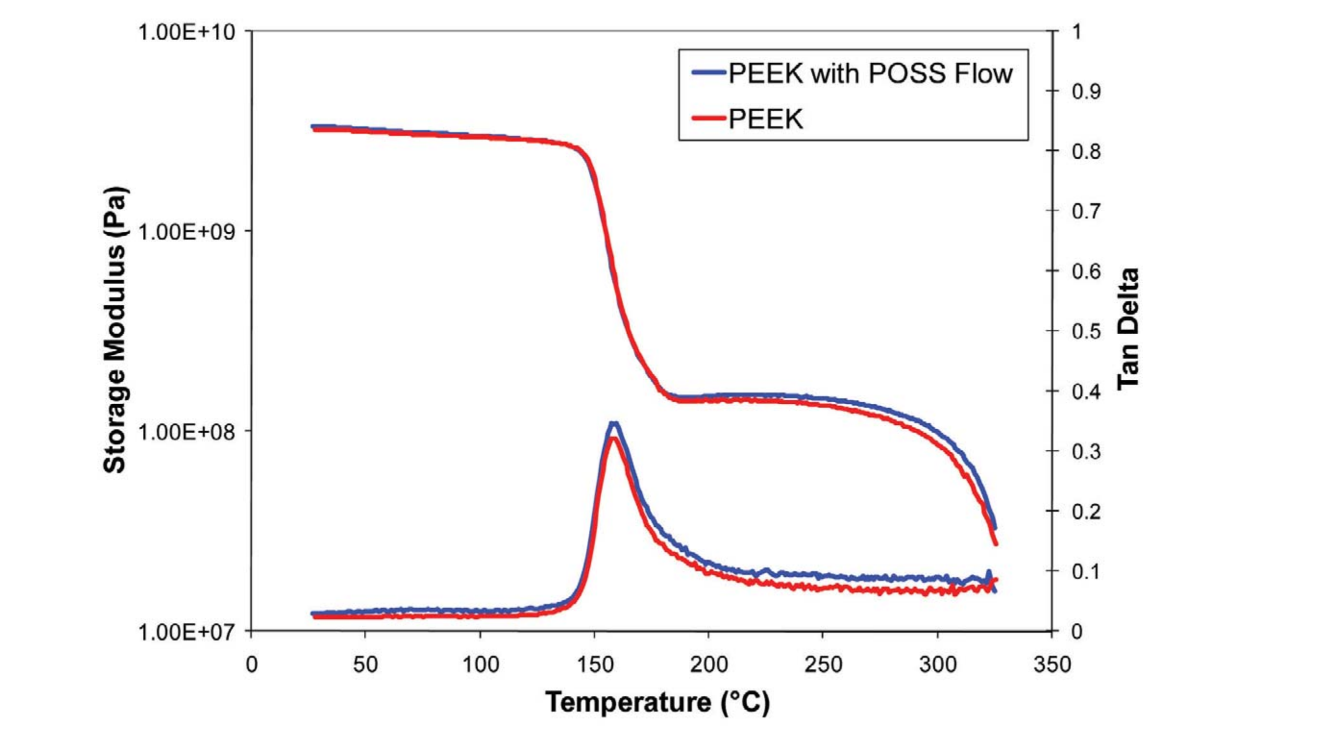

Figure 4: DMA showing POSS Flow retains modulus and T_g.

giving the potential for improved extruder throughput.

Many flow aids have drawbacks. They can either plasticize the polymer, lowering the glass transition temperature (T_g) so that the HDT is affected, or they degrade the polymer by reducing molecular weight. POSS does not plasticize the polymer and mechanical properties are retained (see Figure 4). Dynamic mechanical analysis (DMA) shows that T_g is unaltered and the modulus is unaffected even at high temperatures.

As well as the flow enhancement, improvements in mould release, a reduction in friction and better dispersion of common minerals and pigments are additional benefits.

POSS Flow for polyphenylene ether (PPO/PPE)

Polyphenylene ether is a polymer with exceptionally good mechanical properties and high heat distortion temperature (HDT) and therefore it would be expected to compete with other high temperature thermoplastics. Unfortunately, PPO in its pure form is not commercially available because it flows so poorly that injection moulded parts are not possible. Consequently, commercial PPO is always blended with other polymers such as polystyrene, polypropylene or nylon in order to improve flow. The drawback to this is that these polymeric flow aids must be used in large amounts and they dramatically lower the HDT/Vicat of the PPO. Until now this trade-off has been unavoidable.

The introduction of Nanoreinforced® polyphenylene ether marks a new era for PPO. The addition of low levels of POSS provides for good flow so that injection moulding and extrusion are possible while retaining the exceptional heat distortion temperature that is characteristic of the polymer (see Table 1).

It is immediately apparent that the Nanoreinforced PPE retains good tensile properties while raising the HDT from 113°C up to 185°C. In fact, most of the modulus is retained all the way up to 175°C. The MFI of the new material is 12.5g/10 min and as a bonus the material is transparent whereas traditional PPE blends are always opaque due to the light scattering created by adding two immiscible polymers together.

Table1: Nanoreinforced polyphenylene ether compared to blended PPE.

	Typical PPE	Nanoreinforced® PPE
Modulus	2.4 GPa	2.4GPa
HDT	113°C	185°C
Transparent	No	Yes

Key properties of Nanoreinforced polyphenylene ether

Product name	Nanoreinforced® polyphenylene ether
Product number	PO6C81.01
Colour	Transparent, light amber colour
Density	1.09 g/cm^3
Melt flow index	12.5 g/10 min (300°C/5 kg)
Modulus @ 40°C	2.4 GPa
Modulus @ 175°C	1.85 GPa
Stress @ yield	75 MPa
Elongation @ yield	6%
Elongation @ break	14%
Glass transition temperature	210°C
Flammability @ 3.2mm	V-0

Conclusions

Flow aids are an essential part of polymer processing. The hybrid ceramic-organic structure of POSS provides thermal stability and retention of mechanical properties while the organic groups allow the POSS to dissolve molecularly in the polymer. Normal low molecular weight additives falter under the high processing temperatures needed for PEEK and other performance plastics. Unlike such additives, POSS has very low volatility and good thermal stability. Moreover, where low molecular weight additives plasticize polymers and degrade properties, the exceptional rigidity of the POSS molecule provides for retention of good modulus and strength. So far POSS Flow has proven effective in PEEK, PPE, COC, polyphenylene and FEP. Work with several other polymers is underway.

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