Enhanced Polymers using POSS®

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Chief Scientist

Hybrid Plastics™
Overview

- What is POSS®?
- POSS® Flow enhancers
- Friction & hydrophobicity control
- Dispersants for pigments & fillers
- Copper passivation
- POSS® thermosets
- Safety and production of POSS®
- Conclusions
POSS® is a unique hybrid organic-inorganic composition.
<table>
<thead>
<tr>
<th>Material Type</th>
<th>Density (g cm(^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>2.60</td>
</tr>
<tr>
<td>Amorphous silica</td>
<td>2.18</td>
</tr>
<tr>
<td>Octa hydrido POSS</td>
<td>1.82</td>
</tr>
<tr>
<td>Octa methyl POSS</td>
<td>1.50</td>
</tr>
<tr>
<td>Octa ethyl POSS</td>
<td>1.33</td>
</tr>
<tr>
<td>Octa i-butyl POSS</td>
<td>1.13</td>
</tr>
<tr>
<td>Octa i-octyl POSS</td>
<td>1.01</td>
</tr>
<tr>
<td>Iso-octane</td>
<td>0.69</td>
</tr>
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</table>
What does POSS® look like?

Crystalline Solids
Wide melting range 24°C to 400°C

Liquids/Oils
Wide viscosity range 1000cP to 100000cP

Waxes
POSS® Actually Dissolves in Polymer

Each “black dot” represents a 1.5nm POSS®

*scale of bar = 50nm

Viers - US Air Force Research Laboratory
What can POSS® do for you?

- Increased $T_g$
- Increased $T_{decomp}$
- Extended temperature range
- Reduced flammability
- Radiation Resistance
- Oxidation resistance
- Reduce friction
- Change permeability
- Solvent resistance
- Low volatility
- Catalytic activity
- Improved Flow
- Surface passivation
- As a dispersant
- Beat Competitor Patents
Flow Enhancement in COC (5% POSS®)

MFI Increase

- **SO1450**: 65%
- **MS0825**: 148%

POSS Type

260°C 2.16kg
Flow Enhancement in PPO/PPE

5% POSS in PPO/PPE

MFI Increase

POSS Type

AM0265  AM0270  AM0275  MS0805  MS0825  OL1118  SO1450

170%  196%  348%  183%  83%  75%  59%

US 6, 759,460 & US 2004/0138355 Asahi Chemical
POSS® Flow Masterbatches

- Polysulfone
- PEEK
- Polyetherimide
- Polyamideimide

Melt flow increase (%) vs. Amount of POSS Flow (arbitrary units)
Hydrophobization

Teflon
Contact angle: 110° ± 2°

Nylon 6
Contact angle: 49° ± 2°

Nylon 6 + 5% Octaisobutyl POSS
Contact angle: 88° ± 3°

Nylon 6 + 10% Octaisobutyl POSS
Contact angle: 108° ± 2°
Reduction of Friction in PP

Coefficient of Friction ($\mu$) vs. Octaisobutyl POSS in PP (wt.%) for different relative humidity (RH) conditions: 15%, 60%, and 90% RH.
POSS® Trisilanol
TiO$_2$ Masterbatch with POSS® Dispersant

PP with 1wt% TiO$_2$

PP with 1wt% TiO$_2$ + 5 wt% POSS
POSS® Passivating Agent for Copper

In hydrocarbon oil (squalane) 190°C, oxygen atmosphere
POSS® Epoxy Retains Modulus above Tg

Ambient cure for 3 days; DMA 2°C/min, 1Hz

Hybrid Plastics™
POSS® Ultra-High Temperature Epoxy

Young's Modulus (Pa)

Temperature (°C)

$E'$

$tan\delta$

$NH_2$

$NH_2$
<table>
<thead>
<tr>
<th>Material Type</th>
<th>Weight increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone + 0% POSS</td>
<td>25</td>
</tr>
<tr>
<td>Silicone + 20% POSS</td>
<td>19</td>
</tr>
<tr>
<td>Silicone + 40% POSS</td>
<td>14</td>
</tr>
<tr>
<td>Silicone + 60% POSS</td>
<td>10</td>
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</tbody>
</table>

- High cross-link density
- The cage cannot swell

1 week in acetone
POSS® Colorless Polyimide Spray

Tg 250°C; tensile strength 74MPa; elongation 8%; CTE 68 μm/m/°C

With ManTech Corp.
Several of the larger production volume POSS® types are TSCA listed

Octaisobutyl POSS® MS0825
US Category IV Oral LD50 > 5000 mg/kg

Octamethyl POSS® MS0830
EU Oral LD50 > 2000 mg/kg

Dodecaphenyl POSS® MS0802
EU Oral LD50 > 2000 mg/kg

Does not require the risk phrase R22 "Harmful if Swallowed."

Tested on rats by independent accredited laboratory
Tooth Restoration Products

Nano-Bond® Nano-Particulate Reinforced Adhesive System

Artiste™ Nano-Hybrid Flowable Composite

TempSpan GLAZE Eliminates Polishing Step

NIH sponsored products
POSS® in Food Packaging

- POSS® incorporation provides longer shelf life
- Film blowers like it because it is cheaper to use
- Improves color printing
POSS® Pricing

Order Quantity

Pricing

Hybrid Plastics™
Summary

• POSS® additives available neat or in masterbatch concentrate

• The hybrid structure provides unique property combinations

• Hybrid Plastics works closely with customers to develop new products

• Custom synthesis of new actives available