Modifying TPE properties with organomodified siloxanes (OMS)

Tegomer OMS grades help compounders to optimize mechanical and surface properties of their products

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Organomodified siloxanes (OMS) provide multiple functions in thermoplastics, e. g., improved melt flow, enhancement of haptic performance, low COF, and improved scratch resistance. OMS additives can be effectively used in the manufacturing of thermoplastic elastomers (TPE) and they have become an integral part in TPE compound development and formulation. Automotive applications, appliances as well as medical applications take advantage of these additives. Furthermore, there are novel flame retardant applications in consideration for usage. The present article will focus on benefits of organomodified siloxanes in thermoplastic elastomers (TPE) in general; future articles will highlight special features such as low odor and flame retardancy.

1 Introduction

Thermoplastic elastomers (TPE) can deliver both properties and performance required for many applications in industrial or consumer goods. The pleasant touch and the luxurious feeling because of the smooth and soft yet scratch resistant surface, the elasticity, the ease of processing and recyclability, the heat, chemical, UV or compression resistance or flame retardancy are properties that make TPEs attractive for product designers to give their final product the differentiation and the functionality making it look more appealing at the point of sale **(fig. 1).**

2 Market outlook

According to latest market studies the markets for thermoplastic elastomers are expected to grow continuously worldwide. In 2014 the global TPE market accounted for approx. 4.0 million t; and is expected to grow until 2018 at a rate of 6.3 % to be approx. 5.1 million t [1]. **Table 1** shows how this growth is distributed among the different TPE groups [2].

Revenues generated with TPEs amounted to USD 16.7 billion in 2014. Analysts forecast annual revenues generated with TPE to increase by 4.7 % p.a. until 2022 [3]. In 2014 Asia-Pacific was the largest regional market; it accounted for more than 40 % of total consumption. China and India are major TPE consumers; these countries accounted for approx. 66 % of the regional demand in 2014, while North America was the leading TPO consumer and accounted for 35.5 % of the product volume in 2014. [1].

Advances will be driven by continued product innovation and differentiation on the part of TPO/TPV manufacturers allowing these materials to substitute thermoset elastomers and other thermoplastics in a variety of applications. Positive growth will be noticed in an improved economic outlook in developed regions such as North America and Europe, while gains in emerging markets will benefit from further adoption of TPOs/TPVs over other materials. The total global consumption of olefinic thermoplastic elastomers is forecasted to reach 1,545 thousand t by 2018 (includes TPOs, TPVs and reactor-made TPOs). **Figure 2** shows world consumption of olefinic thermoplastic elastomers, as a whole, by major country/region in 2013.

Fig. 1: TPEs in packaging increase product visibility on the shelf.

Tab. 1: Estimated global market for TPE, by compound (1,000 tonnes)

Product	2011	2012	2013	2014	2018
TPE-S	1,144.4	1,197.2	1,245.4	1,306.8	1,597.1
TPE-O	887.1	937.5	997.5	1070.5	1,389.2
TPE-V	564.4	599.0	636.2	686.6	908.0
TPE-U	469.2	497.4	534.6	568.8	740.7
TPE-E	131.7	142.1	150.1	163.1	218.0
TPE-A	70.9	71.1	75.0	78.8	95.3
Others	108.0	108.4	112.5	103.4	121.7
Total	**3,375.7**	**3,552.6**	**3,751.3**	**3,978.0**	**5,070.0**
Source: Smithers Rapra					

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3 Use of OMS for the modification of mechanical and surface properties

The Interface & Performance business line under the Evonik Nutrition & Care GmbH offers specialty additives which help TPE manufacturers and compounders to develop innovative compounds with enhanced properties. Depending on the desired property there are several organomodified siloxanes available under the brand names Tegomer and Tegopren.

Fig. 2: World consumption of olefinic TPEs by major region – 2013 [1]

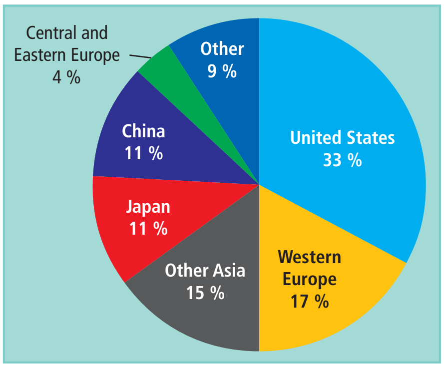


Fig. 3: General structure of organomodified siloxanes (OMS)

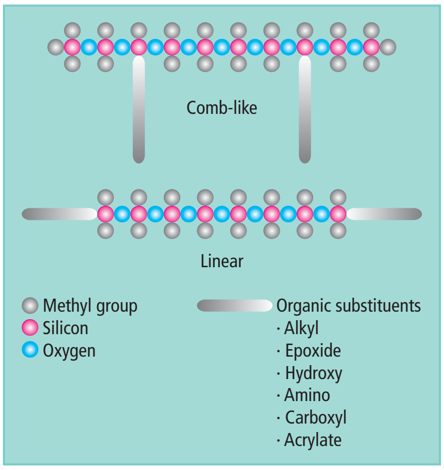
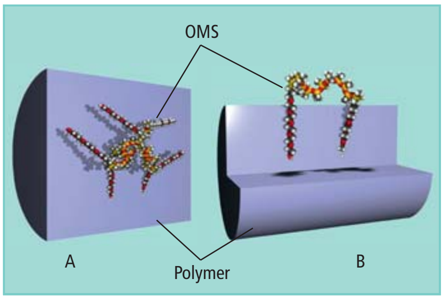


Fig. 4: Functionalization of a polymer matrix with OMS: (A = bulk modification, B = surface modification)



These additives allow to modify TPE properties by

- improving melt flow for easy flow of the compound while molding complicated parts and reducing cycle time,
- enabling loading of flame retardants for achieving UL 94 V0,
- reducing coefficient of friction (COF),
- improving abrasion and wear resistance,
- improving scratch and mar resistance,
- protecting against degradation.

The OMS consist of a siloxane backbone with attached organic groups **(fig. 3).** The functional groups could be alkyl, amino, acrylate, carboxyl, epoxide or hydroxyl groups. Different molecular architectures of OMS derivatives are available, linear and comb-like types as depicted in **figure 3.** These can be tailored to the final application by varying the density and nature of the attached organic groups to achieve the necessary compatibility level. **Figure 4** shows the functionalization of a polymer matrix with OMS. The additives can either work for bulk modification (A) or for surface modification (B).

OMS additives are suitable for polymerisation processes and for compounding as well. Reactive siloxanes can be used in the polymerisation process (for instance the hydroxyl or amino functional siloxanes in TPUs); non-reactive types are used in compounding.

In addition to OMS-based performance additives, the specialty additive Tego Sorb could be used for effectively controlling and preventing undesired odors evolving from ingredients such as sulphur, hydrogen sulfide, mercaptane, thioether, isovaleric acid, amines, and ammonia.

Fig. 5: VDA 270 test

4 Test methods

4.1 Odor

A standard method to determine odor in plastics is VDA 270. It is used to analyze interior parts of cars in Germany. For this test method 30 g of compound is filled into a 100 ml glass bottle **(fig. 5).** The compounds are first tempered at 80 °C for 2 h. After cooling down to 60 °C the odor is determined by three independent test persons. The odor intensity is rated on a scale from 1 – 6. Lowest determined odor is rated by 1 and heavy malodor is rated by 6. Especially thermoplastic vulcanizates can have a malodor due to the vulcanizing step. Here a significant improvement can be achieved by the use of Tego Sorb.

4.2 Melt flow index (MFI)

The melt flow index (MFI) and the spiral test are significant tests to obtain reliable information regarding flowability and processability. MFI is measured according to ISO 1133 or DIN 53735. Improvements in processability can best be detected by the use of the melt flow spiral equipment; Evonik Industries uses the elliptic form **(fig. 6).**

Fig. 6: Spiral tool for the measurement of melt flow index (MFI)

4.3 Flame retardancy

The UL 94 method **(fig. 7)** can be used for the evaluation of the flame retardancy of OMS containing compounds. The siloxane base of the materials gives a good charring behavior and allows the use of high amounts of inorganic flame retardants without significant loss in the mechanical properties.

4.4 Surface appearance

Beside good mechanical properties and excellent scratch resistance compounds for automotive interior applications also require non-tacky surfaces. Tackiness might either be caused by the migration of additives such as amides or waxes, e. g. in a TPO, or because of the migration of oil from a TPE-S. If so, blooming will appear at the surface of the part and especially when the material is exposed to heat and/or UV light as in the PV 1306, the change is even more obvious **(fig. 8).**

OMS-based additives are non-migrating when used at recommended level due to their high molecular weight and balanced compatibility **(fig. 9).**

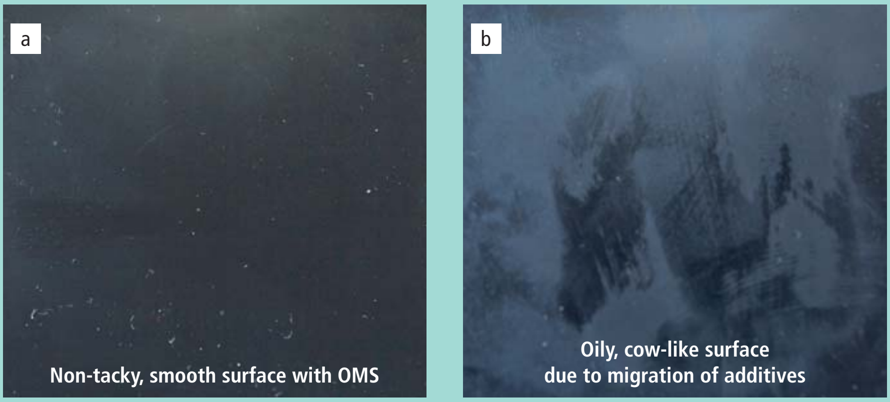
Table 2 gives an overview about OMS products and their use in a variety of TPE applications.

Future articles will describe in more detail the use of OMS and special bifunctional polyether blocks in thermoplastic polyurethanes (TPU) and how to achieve flame retardant TPE materials.

Fig. 7: UL 94 test equipment

Fig. 8: Xenon test chamber

Fig. 9: Surfaces with (a) and without (b) OMS additives



Tab. 2: Improvement of TPE properties with Tegomer organomodified siloxanes

	POE	TPE-V	TPU	TPE-S, SEBS/SBS	TPO
Melt flow					
Tegomer H-Si 6441P	+	+	+	+	+
Tegomer M-Si 2650		+		+	
Tego Sorb PY 88 TQ (odor absorber)		+			
Flame resistance					
Tegomer V-Si 4042	+	+		+	+
Tegomer FR 100	+	+		+	+
COF reduction, abrasion					
Tegomer M-Si 2650		+	+	+	
Tegomer H-Si 6440 P	+	+	+	+	+
Scratch resistance					
Tegomer AntiScratch 100	+	+			+
Tegomer AntiScratch L	+	+		+	
Tegomer H-Si 6440 P	+	+	+	+	+
Tegomer 6264				+	

5 References

[1] Global TPE Report, Grand View Research, San Francisco, CA, USA, August 2015.
[2] P. Ellis, Global TPE markets – forecasts to 2018, TPE Magazine, vol. 5, October 2013, 238–239.
[3] Thermoplastic Elastomers (TPE), Ceresana, Konstanz, Germany, January 2015.
[4] E. Ormonde, U. Löchner, Y. Yamaguchi, W. Chen, Chemical Olefinic Thermoplastic Elastomers (525.8800) Economics Handbook, IHS Chemical 12/2013, 5–6.