

Introduction into TPE

Thermoplastic elastomers (TPEs) are two-phase materials. They show basic physical properties similar to most rubbers. Instead they can be fabricated like conventional thermoplastics [1¹]. Commonly TPEs are built from two insoluble polymers: one builds the matrix polymer and the other forms droplets in the matrix polymer. TPEs are reinforced from the crystallinity of the thermoplastic polymer, while the elastomer is enclosed as droplets contributes the rubber elasticity. Due to the separate phases [2²] the physical properties are dependent from the average droplet diameter [3³]. Summarizing, they are defined as blends of various olefinic semicrystalline plastics and amorphous elastomers.

Among TPEs are thermoplastic vulcanizates (TPVs) and thermoplastic olefins (TPOs). TPVs contain a vulcanized elastomer phase, while TPOs composed with unvulcanized olefinic elastomers [4⁴]. Most common – specifically in automotive and other industries - are blends of polypropylene with ethylene propylene copolymers in a wide range of products, which are extruded, blow moulded or injection moulded. Lower processing costs are associated with TPEs relative to TSEs (Thermo Setting Elastomers). Process equipment for TPEs should be processed at a temperature at least 20 °C above the softening temperature of the matrix polymer [5⁵]. TPE molding cycles are often measured in seconds while those for TSE are typically measured in minutes still.

On the negative side, the nature of the thermoplastic polymer in the TPE limits its temperature range of usage to function under service conditions at higher temperatures compared to TSEs.

This is a common picture we have from TPEs and TPVs. But it neither covered the development steps towards TPE nor the invention of the TPEs as we see them today. The first composition of a thermoplast (PVC – Poly Vinyl Chloride) with a rubber (NBR – Nitril Butadien Rubber) was patented 1940 by Henderson of BF Goodrich and later marketed under the tradename GEON Polyblend®(6⁶). Starting with the invention of the PUR (Polyurethan) by Otto Bayer at IG Farben in 1937 (7⁷) it ended with the first glimpse on TPE like behavior by Schollenberger 1957, when he presented an article on a “virtually crosslinked elastomer, but without being in the position for a sound explanation (8⁸). In 1959 we had an article from Charch and Shivers in 1959 on elastomeric condensation block copolymers based on a morphology of hard crystalline segments embedded in amorphous soft low melting phase of copolymer blocks (9⁹). But then in 1966 came the scientific breakthrough, when Cooper and Tobolsky concluded that the origin of the TPE behaviour were the presence of segregation between hard and soft blocks by comparing properties of PUR and SBS (Styrene-Butadiene-Styrene) Triblock copolymer (10¹⁰). To make a personal remark: This was concluded in a publication given by Echte, Haaf and Hambrecht 1981 named: Five centennials Polystyrene (11¹¹), which marked the 100 birthday of Hermann Staudinger as well. All this understanding was necessary to industrialize TPEs. The announcement of the SBS Triblock TPE in 1965 and later publications on the domain structure triggered not only the interest of the scientific community but also the business community saw the advantages of TPEs (12¹², 13¹³).

From my point of view the applications commercialized was the impact modification of furniture made from thermoplastic and the usage in shoe industry, because of its cost advantage in processing as well as in material cost. Soon the rubber industry was the target of the TPE marketing, pointing out the processing advantage of the TPE with confusing approaches (14¹⁴). In the examples it was pointed out that neither mixing nor vulcanization was necessary anymore. This would be a tremendous cost advantage as long as the TPE could achieve similar properties as rubber materials. This approach left the rubber industry reluctant to evaluate TPEs, because in practice specifically in extrusion the cost advantages promised could not be verified. For example, TPE material cost were higher than rubber compound cost and neither extrusion lines could be made shorter (15¹⁵). The calibration and cooling devices had a similar length as the vulcanization tunnels. Another problem

was the anisotropic material properties depending of the flow direction and the differences of physical properties with confirmation measurements (16¹⁶). The mold construction and process engineers had to learn, how to overcome this behavior.

Further more resistance came from the impression, that the rubber manufacturer would turn into a converter of commodity raw material similar to the thermoplastic industry. While the TPEs made its way anyhow in the rubber as well as in the thermoplastic industry with a significant larger growth rate than rubber (17¹⁷), it was the medical and in North America the construction industry leading. Nowadays the chemist in the raw material departments develop an increase interest in the advatanges and limits of TPE starting to use their knowledge in chemistry and engineering. So far, to use standard equipment for mixing of rubber, failed to produce a competitive TPE in comparison with rubber (18¹⁸).

The compendium of thermoplastic elastomers give an overview of the research and development in this field from a material scientific point of view as well as processing. It gives the interested reader an insight view in this material, its behaviour and potential.

Hans-Joachim Graf
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