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Ceramization of elastomeric composites

Ceramizable elastomeric composites under the influence of fire change their structure (morphology) from elastic rubber to porous ceramics. Resembling pumice, newly formed, ceramic phase protects the interior of the material from further degradation and materials coated with it protects against direct exposure to fire and high temperature. This process is mainly based on physical changes (also termed as passive), which has an advantage over classic methods of flame retarding of polymer composites, because dangerous fumes are not formed during thermal decomposition of polymer matrix and used chemical flame retardant. In order to be able to ceramization this type of composites, it is necessary to add a special filler, the fluxing agent. It is most often a mixture of metal oxides characterized by a low value of softening temperature. This filler is designed to combine particles of other heat-resistant fillers that are also part of the ceramizable composite together before the polymer matrix decomposes under the influence of temperature. In this way, the thermally activated transformation of a ceramizable composite with a polymer matrix into a continuous, porous ceramic structure with high mechanical resistance and barrier properties takes place.

Because polymeric composites capable of ceramization are materials with a high degree of filling, the literature part begins with describing the properties of selected polymer composites wherein the amount of fillers used exceeds 100 parts by weight per 100 parts by weight of polymer. Next, phenomena occurring during thermal degradation of selected polymers are described: silicone rubbers, poly(vinyl chloride), ethylene and vinyl acetate copolymer, and styrene-butadiene rubber. The following subchapters contain descriptions of the method of testing the flammability of polymeric materials and methods of reducing their flammability, including the division of flame retardants into the mechanism of their operation, it is chemical, physical and hybrid. The first part ends with the description of individual ceramization mechanisms and focuses on the description of the properties of ceramizable composites already known in the literature with a matrix of silicone rubbers and other organic polymers.

The research in this work focuses on the subject of flammability of polymeric materials, focusing on elastomeric composites capable of ceramization. The synergistic effect of flame retardant and ceramization process was also confirmed to improve the thermal properties and fire resistance of elastomeric composites.

The second part presents the research methodology and results describing the properties of ceramizable composites with a styrene-butadiene rubber matrix. The properties of these composites have been determined by studying the effect:

- mineral fillers;
- a co-milling of the mineral filler and fluxing agent before being added into the rubber mix and the different ratios of these fillers relative to each other;
- ethylene and vinyl acetate copolymers differing in the content of vinyl acetate;
- standard plasticizers and graphite;
- graphene;
- silicone oil and cross-linking by dicumyl peroxide;
- common operation of a system capable of ceramization and melamine cyanurate.

In order to determine the properties of the produced ceramizable composites, the following tests were carried out:

- kinetics of the vulcanization processes using a vulcanometer;
- tensile strength, tear resistance, hardness using a standard testing machine;
- electrical resistance using an apparatus constructed at the Institute of Polymers and Dyes Technology;
- fire resistance and thermal properties using a cone calorimetry, thermogravimetric analysis, differential scanning colorimetry;
- compressive strength of the scale formed during the ceramization process using a standard testing machine;
- morphology using an optical microscopy, scanning electron microscopy.

The results of the research have shown that the optimal filler for the production of elastomer composites based on styrene-butadiene rubber is mica, which should be added to the composite with the fluxing agent in a 2:1 ratio (mica : fluxing agent). Addition of plasticizers to improve miscibility negatively affects the mechanical properties and fire resistance, however, when as plasticizers was used a graphite, it worsens these properties slightly and additionally reinforced mechanical properties of the scale formed during the ceramization process. Graphene due to the effective reflection of infrared radiation may delay the ignition and the ceramization system together with the standard flame retardant, in this case melamine cyanurate, can very effectively increase both mechanical properties and fire resistance of vulcanizates.

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