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Binarne i hybrydowe kompozyty epoksydowe z piankami węglowymi i materiałem grafenowym w roli napełniaczy

Binary and hybrid epoxy composites with carbon foams and graphene material as a fillers

Abstract

One of the main goals of modern materials engineering is the design and production of composite materials that are characterized by high mechanical strength and good thermal and electrical properties, while ensuring their low weight and high resistance to external factors, thus extending the possibility of their use. So far, porous carbon materials, which include, among others, carbon foams, have been used as fillers of polymer matrices to a limited extent. Carbon foams are strongly porous carbon materials of high content of the C element. They are obtained by foaming carbon, polymer or biomass precursors, most often, but not always, using a blowing agent, and the subsequent carbonization and/or graphitization process. The most important properties of carbon foam are: very low density, good mechanical strength, good thermal and electrical conductivity, high thermal and chemical resistance and the ability to absorb various types of energy.

The aim of this doctoral thesis was to investigate how carbon foam grains, used as a separate filler or in combination with graphene material in an epoxy matrix, affect the properties of polymer-carbon composites. The doctoral dissertation involved designing, manufacturing and investigating the structure and properties of binary epoxy composites with various grain fractions of basic carbon foam obtained from a cross-linked epoxy/phenol-formaldehyde precursor and the foam whose carbon skeleton was modified with graphene nanoplatelets, as well as hybrid epoxy composites, in which crushed basic carbon foam was used as the main filler and commercial graphene nanoplatelets were introduced independently as an additional filler. For comparative purposes, binary epoxy composites reinforced with graphene nanoplatelets or graphite powder were also fabricated and tested. The main objective of the work was achieved by investigating the structure and properties of the carbon materials subsequently used as composites fillers. The most important research methods used were Raman spectroscopy, Fourier transform infrared spectroscopy (FTIR)

and scanning electron microscopy (SEM). Next, the morphology and properties of binary and hybrid epoxy composites were characterized using the methods such as: differential scanning calorimetry (DSC), scanning electron microscopy, dynamic mechanical analysis (DMA), thermogravimetric analysis, hardness and elastic deformation measurement using the Brinell method, and tests of tribological properties.

The analysis of composites morphology showed very good dispersion and very good adhesion of carbon foam particles to the epoxy matrix and quite good dispersion but weaker adhesion of graphite particles and graphene nanoplatelets to the matrix. It was stated that the presence of foam particles had a positive effect on the viscoelastic properties of the composites and significantly improved their thermal resistance. It was also found that the introduction of any of the carbon fillers to the epoxy matrix significantly influenced the tribological properties of the composites. The presence of foam fillers and graphite resulted in a decrease in the friction coefficient of the composites, while the use of graphene filler resulted in an increase in the friction coefficient. The loss mass and wear coefficient of the composites correlate well with the value of the friction coefficient of the composites. Their lowest values were recorded for binary composites with both types of carbon foam, while the highest for the binary composites with graphene nanoplatelets. The hybrid composites were characterized by intermediate values of tribological parameters, higher than those for binary composites with carbon foams and lower than those for binary composites with graphene filler.

In general, the obtained results showed that the properties of epoxy-carbon composites are significantly influenced by the type, particles size and the amount of filler used, as well as the procedure of composites preparation. The beneficial effect of crushed carbon foams used as fillers independently or in a configuration with graphene nanoplatelets on the mechanical, thermal and tribological properties of epoxy composites was also confirmed.

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