The doctoral dissertation of M.Sc. Eng. Piotr Augustyn entitled: Laser-modified and current metallized thermoplastic polymer composites with electromagnetic field shielding properties.

ABSTRACT

The subject of this dissertation was to identify and attempt to solve the main problems of the current metallisation of polymer composites by selecting conductive fillers, determining their content in thermoplastic polymer matrices, and appropriate laser irradiation. The aim of the filler selection and laser modification was to achieve a local increase in electrical conductivity and effective current metallisation of such composites. Furthermore, the developed composites were characterised by electromagnetic radiation shielding properties.

Based on the available literature, theoretical issues related to the topic of the dissertation were analysed. These include problems related to the methods of metallization of polymeric materials currently used in industry, metallization of "structurally conductive" polymers, selection of conductive fillers for polymer composites and current metallization of polymer composites. The parameters and conditions for performing electroplated deposition of coatings on metals were discussed as a kind of reference for the current metallization of polymers. To realise the thesis of this dissertation, research techniques such as thermal analysis, wettability and surface free energy studies, mechanical properties studies including tensile strength and dynamic mechanical analysis, adhesion bond strength determination, electrical properties studies including surface resistivity studies, electrical permeability studies, electromagnetic field shielding effectiveness studies, surface morphology studies and EDX chemical composition studies were used.

The research in this dissertation was divided into two main parts: preliminary research and fundamental research. In the preliminary research, the most common polymeric materials, such as acrylonitrile-butadiene-styrene (ABS), polystyrene (PS), polylactide (PLA), polyamide 6 (PA6), polyethylene terephthalate (PET), and polycarbonate (PC), were studied in order to select the matrix most suitable for laser ablation. An Nd:YAG laser emitting radiation with a wavelength of 1064 nm was used in the study. The result of this part of the research was the selection of ABS as the composite matrix material. ABS matrix composites containing carbon fillers: conductive carbon

black (CB), carbon nanotubes (CNT), carbon nanofibres (CNF), graphene flakes (GNP) and metallic fillers: copper fibres(Cu(F)), copper powders (Cu(P)), brass (CuZn) and tin (Sn) were made. The surface resistivity of the composites and the effect of laser radiation on the surface resistivity value were investigated. The result of the preliminary research was the selection of an ABS matrix composite with admixtures: tin powder and copper fibres. These composites were the subject of fundamental research.

In the fundamental studies, the produced composites were subjected to a detailed analysis of thermal, mechanical, chemical, and electrical properties and surface morphology. The surface resistivity of these composites is characterised by a value typical of dielectrics, which allows them to be used as substrates for electrically conductive paths in electrical, electronic or mechatronic systems. Two types of lasers were used to modify the composites: a Nd:YAG with a wavelength of 1064 nm, and a femtosecond Jasper X0-20 with a basic wavelength of 1030 nm together with a module for the generation of higher harmonics HGM with a wavelength of 343 nm. A comparative analysis of the results of modifying the surface of composites with IR(λ=1030 nm), UV(λ=343 nm) and those modified first with UV and then with IR radiation was performed. A comparative analysis of the surface metallisation effects of composites modified with UV and then IR for different laser beam parameters was also carried out.

Based on the results obtained, it was found that ABS matrix composites doped with a mixture of copper fibres and tin powder in proportions of 15% vol. Cu(F) and 10% vol. Sn or 12.5% vol. Cu(F) and 12.5 vol. Sn enable selective current metallization of the composite surface, after prior modification of the surface layer with laser radiation at 343 nm followed by 1030 nm. The conductive dopants introduced into the composite matrix significantly increase the electromagnetic field shielding effectiveness. This makes it possible to use the composite as casings, baffles or screens limiting the impact of electromagnetic fields, both on electronic equipment and people, in the industrial (radio-technical, electrotechnical, electronic) and military sectors. Part of the dissertation is the subject of a patent application at the Patent Office under number P.442699 and before the European Patent Office under number EP.23168818.