E3S Web of Conferences **413**, 02032 (2023) https://doi.org/10.1051/e3sconf/202341302032
*INTERAGROMASH 2023*

# New superstructural thermoplastics and carbon composite materials based on them

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**Abstract.** New superconstructional polyarylates with glass transition temperatures from 216 to 280°C and polyethersulfones with glass transition temperatures from 230 to 255°C have been developed. On the basis of these polymers, industrial polysulfone PSFF-30, PSF-150, polyethersulfone E-3010, polyetherimide Ultem 1000, PEEK and PEKK, and two types of carbon fabrics, thermoplastic prepregs and consolidated carbon composite plates were obtained, and their mechanical properties under compression and three-point bending were determined.

## 1 Introduction

The current level of technology and technology constantly requires the creation of new structural and superstructural materials, not only with improved performance characteristics (heat resistance of at least 200 ° C, modulus of elasticity of at least 2.5 GPa, impact resistance, wear resistance, chemical and radiation resistance, fire resistance, low water absorption, etc. .), but also with good technological properties (solubility and fusibility, high fluidity and thermal-oxidative stability of melts, weldability, low technological shrinkage, fiber formation, good wetting of fillers, etc.) [1-5]. Taking into account the market demand for high-quality products from thermoplastic polymer composite materials, in the Research Center "Composites of Russia" BMSTU based on industrial and newly created superstructural thermoplastics [6–9].

Taking into account the domestic raw material base, highly heat-resistant polyarylates (PAR) were developed with a glass transition temperature from 216 to 280 ° C, capable of processing through solutions and melt, the main properties of which are given in table 1.

**Table 1.** Properties of the developed polyarylates (TU 22269-001-78498082-2023).

| № | Name of the indicator, dimension | Polyarylate brand | | | |
|---|---|---|---|---|---|
| | | F-200 | F-230/30 | F-230/10 | F-250/30 |
| 1 | Appearance | Powder | Powder | Powder | Powder |
| 2 | Powder particle size, micron | 50-150 | 50-150 | 50-150 | 50-150 |
| 3 | Bulk density of powder, g/l | 110 | 110 | 110 | 110 |
| 4 | Glass transition temperature, | 280 | 260 | 240 | 216 |

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| | | | | | |
|---|---|---|---|---|---|
| | °C (DSC) | | | | |
| 5 | Temperature 5% polymer melt weight loss (TGA) | 455 | 450 | 450 | 445 |
| 6 | Reduced viscosity of a 0.5% solution in DMF at 25°C, dl/g | 0,50 | 0,45 | 0,43 | 0,43 |
| 7 | Melt flow rate, g/10min at 340°C | Doesn't flow | 3,0 | 5,6 | 7,6 |
| 8 | Tensile strength, MPa | 50-70 | 46-70 | 50-60 | 48-60 |
| 9 | Relates elongation at break, % | 4,0-5,5 | 4,5-5,7 | 5,0-6,5 | 6,0-7,3 |
| 10 | Modulus of elasticity at break, GPa | 2,9-3,3 | 2,8-3,2 | 2,7-3,0 | 2,6-2,9 |

The synthesized polyarylates are soluble in such solvents as: 1,2-dichloroethane, methylene chloride, tetrahydrofuran, dioxane, dimethylformamide, dimethylacetamide. Solutions of polyarylates can be used for impregnating reinforcing fabrics, applying protective and electrical insulating coatings, and forming fibers [10, 11].

## 2 Objects and methods of research

The processing of the developed polyarylates through the melt, including in the manufacture of prepregs, should be carried out by methods with a short processing cycle: direct pressing or injection molding with rapid cooling [12, 13]. The recommended stay of polyarylates in the melt is 5-10 minutes. In order to increase the thermal-oxidative resistance of PAR melts, synergistic mixtures of antioxidants of phenolic and phosphite types were selected.

High-heat-resistant polyethersulfones (PES) with increased thermal-oxidative resistance during processing from the melt have been developed, the properties of which are shown in Table 2.

**Table 2.** Properties of the developed polyethersulfones (TU 222645-002-78498082-2023)

| № | Name of the indicator, dimension | Polyethersulfone brand | | | |
|---|---|---|---|---|---|
| | | PES-230 | PES-240 | PES-250 | PES-255 |
| 1 | Appearance | Powder | Powder | Powder | Powder |
| 2 | Powder particle size, micron | 50-150 | 50-150 | 50-150 | 50-150 |
| 3 | Bulk density of powder, g/l | 75-100 | 100 | 110 | 110 |
| 4 | Glass transition temperature, °C (DSC) | 230 | 240 | 250 | 255 |
| 5 | Temperature 5% polymer melt weight loss (TGA) | 459 | 466 | 475 | 477 |
| 6 | Reduced viscosity of a 0.5% solution in DMF at 25°C, dl/g | 0,38 | 0,35 | 0,36 | 0,36 |
| 7 | Melt flow rate, g/10min at 340°C | 5,4 | 4,9 | 2,5 | 1,3 |
| 8 | Tensile strength, MPa | 60-75 | 63-80 | 65-85 | 66-86 |
| 9 | Relates elongation at break, % | 4,0-5,5 | 4,5-5,7 | 5,0-6,5 | 6,0-7,3 |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Modulus of elasticity at break, GPa | 2,9-3,3 | 2,8-3,3 | 2,7-3,3 | 2,6-3,3 |

Synthesized PES are soluble in such solvents as: chlorobenzene, dimethylformamide, dimethylacetamide, N-methylpyrrolidone.

Processing of developed polyethersulfones through the melt can be carried out by extrusion, injection molding, direct compression or injection molding. The recommended stay of polyethersulfones in the melt is no more than 30 minutes.

## 3 The discussion of the results

Based on the developed polyethersulfones and industrial superstructural thermoplastics of domestic and foreign production, thermoplastic carbon fiber prepregs and composite consolidated plates 3-4 mm thick were obtained, made by hot pressing of prepregs. The ratio of carbon fiber/thermoplastic was 50:50 wt%. The properties of these composites are shown in Table 3.

**Table 3.** Properties of carbon fiber composites with a thermoplastic matrix

| № | Thermoplastic | $T_c$, $T_{melt}$ °C | Carbon textile | Thermoplastic application method | Compression | | bend | |
|---|---|---|---|---|---|---|---|---|
| | | | | | σ, MPa | E, GPa | σ, MPa | E, GPa |
| 1 | PES-240 | 240 | TR50 | Electrostatic | 433,0 | 0,692 | 949,7 | 55,4 |
| 2 | PES-250 | 250 | TR50 | Electrostatic | 449,0 | 0,821 | 1103,3 | 64,4 |
| 3 | PSF-150 | 190 | UC239 | Solution | 311,3 | 0,873 | 746,3 | 71,7 |
| 4 | PSFF-30 | 210 | TR50 | Solution | 452,8 | 0,840 | 1044,0 | 70,7 |
| 5 | PSFF-30 | 210 | UC230 | Solution | 448,7 | 1,477 | 1080,0 | 90,2 |
| 6 | PSFF-30 | 210 | TR50 | Electrostatic | 451,3 | 1,300 | 1110,0 | 56,0 |
| 7 | Ultrason E-3010 | 230 | TR50 | Electrostatic | 425,25 | 1,032 | 995,0 | 75,65 |
| 8 | PEEK | 140, 345 | TR50 | Electrostatic | 527,5 | 0,971 | 1096,7 | 44,6 |
| 9 | PEKK | 155, 332 | TR50 | Electrostatic | 548,3 | 1,047 | 1350,0 | 84,3 |
| 10 | Ultem 1000 | 217 | TR50 | Electrostatic | 401,5 | 1,013 | 1163,3 | 77,8 |

As can be seen from the table, the strength and modulus in compression and bending of the obtained samples of carbon composites based on synthesized polyethersulfones PES-240 and PES-250 (Tc=240 and 250°C), polysulfone PSFF-30 (Tc=210°C), polyetheretherketone (Tc=146°C and Tmelt=346°C), as well as polyetherketone ketone (Tc=162°C and Tmelt=332°C) are quite close and depend little on the method of applying the thermoplastic to the carbon fabric. The main difference between the considered composites is related to their heat resistance, which depends on the values of Tc and Tm, and cost. At the same time, it should be noted that the cost of the developed PES is significantly lower than the cost of PEEK and PEKK.

It can be assumed that the relatively low values of strength and modulus in compression and bending for samples of carbon composites based on PES grades "Ultrason E6020" and "Ultrason E3010" are associated with poor wettability and adhesion of carbon fibers by this polymer.

## 4 Conclusion

Thus, the obtained results indicate that the developed polyethersulfones PES-240 and PES-250 are promising for the creation of carbon composites with thermoplastic matrices capable of short-term operation at temperatures close to 240 and 250°C. For the production of thermoplastic carbon-fabric tape prepregs based on them, a line will be used, including units for electrostatic powder spraying, thermoplastic melting and hot calendering of the material.

## 5 Acknowledgement

This work was carried out within the framework of the program of state support for the centers of the National Technology Initiative (NTI) on the basis of educational institutions of higher education and scientific organizations (Center NTI "Digital Materials Science: New Materials and Substances" on the basis of the Bauman Moscow State Technical University).

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