Advanced Composites and Applications

Book of Abstracts

80th International Scientific Conference of the University of Latvia 2022

February 15, 2022

UNIVERSITY OF LATVIA

80th International Scientific Conference of the University of Latvia 2022

Tuesday, 15 February 2022
10:00-12:30, online

Programme

Chair: Assist. Prof. Tatjana Glaskova-Kuzmina		
10:00-10:05	**Tatjana Glaskova-Kuzmina** *University of Latvia, Riga, Latvia*	**Opening of the Conference special section**
10:05–10:20	***Andrey E. Krauklis*** *University of Latvia, Riga, Latvia*	**Modular paradigm in the multiscale modeling of material aging**
10:20–10:35	***Anna Kufel and Stanisław Kuciel*** *Cracow University of Technology, Cracow, Poland*	**Biopolypropylene hybrid composites reinforced with natural fibers**
10:35–10:50	**Karolina E. Mazur, Natalia Pieszczek, and Stanisław Kuciel** *Cracow University of Technology, Cracow, Poland*	**Environmentally friendly polymer composites based on poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) reinforced with lignocellulosic fillers**
10:50–11:05	**Zainab Al-Maqdasi, Liva Pupure, Nazanin Emami, and Roberts Joffe** *Luleå University of Technology, Luleå, Sweden* *Riga Technical University, Riga, Latvia*	**Analysis of long-term performance of wood polymer composites with added multifunctionality**
11:05-11:20	**Leons Stankevics, Andrey Aniskevich, and Vladimir Spacek** *University of Latvia, Riga, Latvia* *SYNPO, Pardubice, Czech Republic*	**Mechanical properties of epoxy resin filled with core-shell rubber nanoparticles**
11:20-11:35	**Sharath P. Subadra, Paulius Griskevicius** *Kaunas University of Technology, Kaunas, Lithuania*	**Impact induced damage in fibre reinforced composites and the effect of matrix dominant properties on the effect of damage propagation**
11:35-11:50	**Piotr Zagulski and Rafał Chatys** *Kielce University of Technology, Kielce, Poland*	**Forecasting the aging of fiber composites made by vacuum methods**
11:50-12:05	**Kestutis Špakauskas, Paulius Griškevičius** *Kaunas University of Technology, Kaunas, Lithuania*	**Analysis of damage recovery and self-healing possibilities in fiber-reinforced composite structures with thermoplastic matrix**

12:05-12:20	**Prasad Shimpi, Daiva Zeleniakiene** *Kaunas University of Technology, Kaunas, Lithuania*	**Structural health monitoring of 3D woven composites using MXene nanoparticles**
12:20-12:35	**Tatjana Glaskova-Kuzmina, Stanislav Stankevich, Andrey Aniskevich, Evgeni Ovodok, Sergey Poznyak, Gediminas Monastyreckis, and Daiva Zeleniakienė** *University of Latvia, Riga, Latvia* *Belarusian State University, Minsk, Belarus* *Kaunas University of Technology, Kaunas, Lithuania*	**MXene-doped polymer coatings demonstrating de-icing for aircraft applications**
12.35–12:45	**Conclusions and discussions**	

Contents

MODULAR PARADIGM IN THE MULTISCALE MODELING OF MATERIAL AGING

Andrey E. Krauklis*

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Fiber-reinforced composites are broadly used in structural applications in humid, marine, and offshore environments, where their superior mechanical properties are compromised by environmental ageing. Various approaches have been proposed to predict the long-term properties based on short-term measurements (to reduce time and involved costs). Composites typically consist of three micro constituent phases: polymer matrix, reinforcing fibers and sizing-rich interphase. When the microconstituents are inside a composite material, the material aging pathways of individual microconstituents are hard to distinguish. Thus, this aspect leads to the necessity of introducing modular or multiscale modelling methods. One of the pathways to address this issue is a Modular Paradigm, which breaks down a complex composite aging phenomenon into smaller modules, as schematically shown in Fig.1.

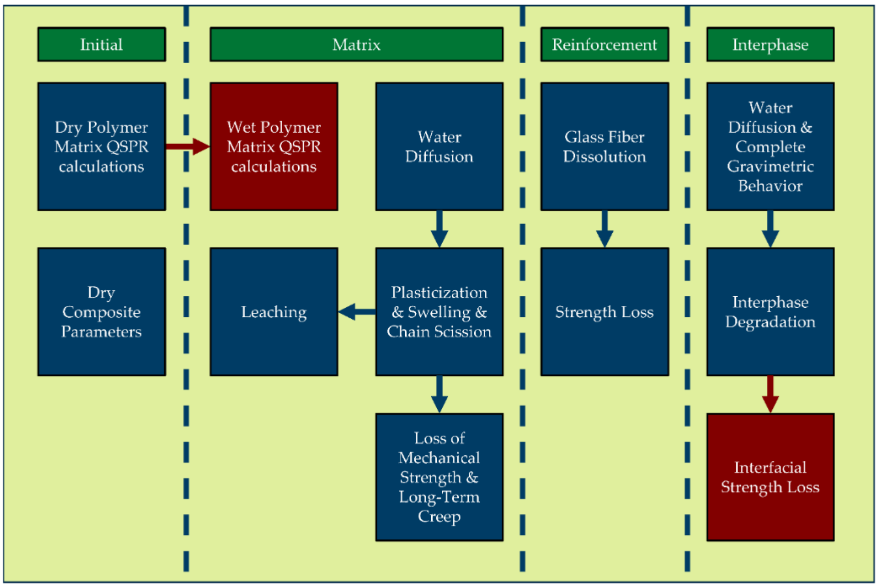

Fig.1. Schematic representation of the Modular Paradigm for modeling aging of composites.

Modular Paradigm could become a valuable tool for lifetime prediction and accelerated testing of fiber-reinforced composite materials.

Acknowledgements
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BIOPOLYPROPYLENE HYBRID COMPOSITES REINFORCED WITH NATURAL FIBERS

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In recent years, the need to produce more eco-friendly composites has increased. Bio-based polypropylene has not been used commercially yet [1]. However, NP BioPP 202-48 polypropylene (bPP), produced by Nature Plast, at 30% maximum biobased is available and it was used to produce composites. Therefore, our research aimed to develop environmental friendly hybrid composites reinforced by natural fibers. Composites based on bPP were reinforced with basalt fibers (B), wood fibers (W) and flax fibers (F). For composition with a single filler, the fibers were added in weight content of 10%. In the case of hybrid composites, the fibers were added at 5% and 10% equally (total 10% and 20%). The composites were subjected to a static tensile test, flexural test and impact test. The effect of temperature was investigated at three different temperatures: −24 °C, 23 °C, and 80 °C. To evaluate the effect of water absorption, the samples were tested after 30 days of water soaking. The influence of accelerated aging was also investigated. Scanning electron micrographs were taken after the tensile test and after the drop impact test.

The results of the tensile tests at different temperatures are presented in Figure 1. The results show that very good results were obtained for hybrid composites with basalt and flax fibers. The tensile strength was 45 MPa for composites with 20 wt.% of basalt and flax fibers which is approximately 100% higher than for neat bPP. This indicates, that hybridization can be successfully applied.

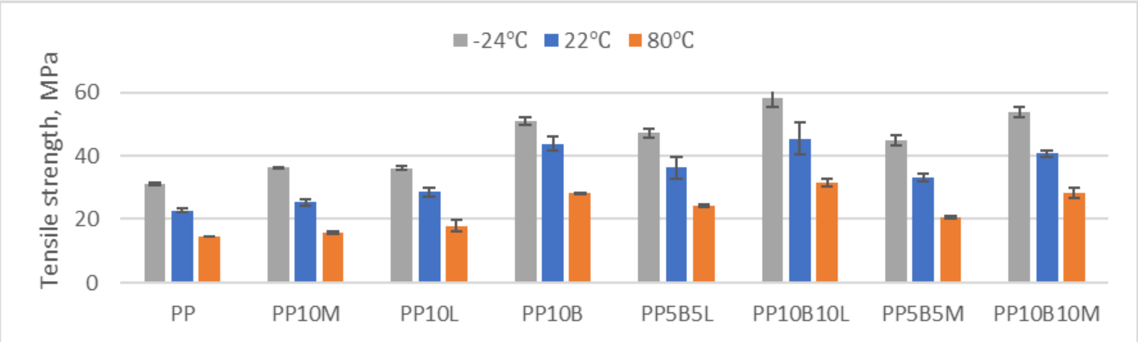

Fig.1. Tensile strength of polypropylene composites.

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ENVIRONMENTALLY FRIENDLY POLYMER COMPOSITES BASED ON POLY (3-HYDROXYBUTYRATE-CO-3-HYDROXYVALERATE) (PHBV) REINFORCED WITH LIGNOCELLULOSIC FILLERS

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The ease of availability and low price of polymer composites signify that the products made of such composites are often disposable, which poses a real threat to the environment. Therefore, many industrial and scientific societies are searching for substitutes for petrochemical composites. Biodegradable polymer composites, which have properties similar to those of synthetic composites, have become an alternative to petrochemical composites. Biodegradable materials are not as popular as petrochemical materials because of the high price of the former group. To reduce the price and improve the properties of biodegradable composites, they are often reinforced with various types of additives, which are usually natural ones to avoid interference with the biodegradation process.

Therefore, in this work, polymer composites were produced by injection molding on a biodegradable matrix such as poly (3-hydroxybutyrate-co-3-hydroxyvalerate), (PHBV). Natural fillers such as walnut shell flour (N), wood flour (W), and cellulose (C) (7.5 wt% and 15 wt%) were used as the reinforcing phase. The produced samples were subjected to wide mechanical characteristics and the obtained results were related to the microstructure. Additionally, hydrolytic biodegradation was carried out at 40 °C with the addition of bacteria to determine the life cycle of the manufactured materials. Research has shown that the addition of natural fillers will positively affect the stiffness of composites – the highest increase (30%) of Young's modulus was achieved by composites with cellulose. The lowest results were obtained for composites with walnut, which was most likely related to the size of the particles themselves and their detachment from the matrix. However, it should be noted that the drop in breaking strength for other composites was max. 10%, which is a satisfactory effect for hydrophobic composites reinforced with hydrophilic fillers.

Materials	PHBV	PHBV/7.5N	PHBV/15N	PHBV/7.5W	PHBV/15W	PHBV/7.5C	PHBV/15C
Tensile strength	34.1 MPa	27.7 MPa	27.2 MPa	31.3 MPa	30.5 MPa	34.9 MPa	31.3 MPa
Young's modulus	3.4 GPa	3.5 GPa	3.5 GPa	4.5 GPa	4.4 GPa	4.2 GPa	4.5 GPa
Flexural strength	58 MPa	53.2 MPa	47.1 MPa	50.4 MPa	47.1 MPa	52.2 MPa	49.5 MPa
Flexural modulus	4.2 GPa	4.6 GPa	4.6 GPa	3.9 GPa	3.8 GPa	3.8 GPa	4.0 GPa

Table 1. Results of the tensile and flexural tests.

Acknowledgements

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EFFECT OF NOVEL STAR-SHAPED POLYMER ON CARBON FIBRE REINFORCED POLYMER COMPOSITES

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This study is an investigation of the effects of a novel *n*-butyl methacrylate (Pn-BMA) block glycidyl methacrylate (PGMA) star-shaped polymer on bisphenol-A epoxy matrix and carbon fibre reinforced polymer composites [1]. The polymer was synthesized by the process of group transfer polymerization through the ‘arm-first’ technique. To configure the optimum loading of the polymer into the epoxy matrix, four different wt.% were chosen, 0%, 1%, 3%, and 7%. Tensile tests were performed on these epoxy specimens, where the tensile strength of the 1 wt.% loaded epoxy showed the highest improvement. This optimally loaded matrix was reinforced with carbon fibre to test its mechanical properties. Low-velocity impact and tensile tests were performed, and results were compared to that of pure epoxy composite samples. Tensile tests exhibited no major improvement in modulus however impact tests showed great potential for the novel polymer composite’s energy-absorbing ability. Scanning electron microscopy performed on the specimens post low-velocity impact test displayed the bonding characteristics and the various fractures occurring within the composite.

Acknowledgements
This work was developed under the M-Era.Net 2 research project entitled EPIC – European Partnership for Improved Composites, No.TH06020001.

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ANALYSIS OF LONG-TERM PERFORMANCE OF WOOD POLYMER COMPOSITES WITH ADDED MULTIFUNCTIONALITY

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Wood Polymer Composites (WPC) are used in a wide variety of applications because they possess advantageous properties such as lightweight and processability. On the other hand, they exhibit poor resistance to moisture uptake due to the hydrophilic nature of wood and to constant applied loads due to the creep behavior of both wood and the polymer. Recently, the addition of nano-reinforcement is seen as a way to overcome some of these shortcomings in WPC while adding new functionalities.

In this study, the time-dependent behavior of conventional and nano-doped WPC (n-WPC) are analyzed by performing short-term creep together with loading-unloading-recovery tests on samples of high-density Polyethylene (HDPE), reinforced with different content of wood flour (WF) and Graphene Nanoplatelets (GNPs). An efficient data analysis approach is employed to separate and evaluate viscoplastic (VP)/viscoelastic (VE) components of the time-dependent response. Parameters obtained from the creep experiments are used to simulate the loading-unloading-recovery test for validation of parameters and methodology. The effect of an individual type of reinforcement as well as the synergistic effect of the nano- and micro- scale reinforcement on the VP/VE responses are quantified and discussed.

The results show that the development of VP strains in WPC and n-WPC follow Zapas model [1]. Even though the creep compliance curves for all materials exhibit nonlinear VE response even at relatively low creep stresses, the addition of the reinforcement significantly reduces creep and VP strains compared to neat HDPE. The improvement in the creep resistance ranges between 65% and 92% depending on the type of reinforcement. Moreover, samples with highest amount of reinforcement (40 wt% WF + 7.5 wt% GNPs) exhibit highly nonlinear time-dependent responses and exhibit a catastrophic failure where progress of the third stage of creep cannot be noticed. Highly reinforced polymers show a possible early development of irreversible strain due to damage that interacts with VP resulting in deviations from the Zapas model at relatively high loads. However, it was possible to obtain parameters for VP and VE to validate the approach by simulating the loading-unloading-recovery test with acceptable accuracy.

Acknowledgments

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MECHANICAL PROPERTIES OF EPOXY RESIN FILLED WITH CORE-SHELL RUBBER NANOPARTICLES

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Epoxy was mixed with core-shell rubber (CSR) particles to enhance its mechanical properties. The aim of the research was to determine the changes in elastic modulus, stiffness, and fracture toughness of epoxy resin modified by adding different types of CSR additives.

The material under investigation was CHS-Epoxy 582 with 6 wt.% of CSR additives. CSR particles contained styrene-butadiene rubber, polybutadiene, and silicon. The concentration 6 wt.% of CSR additives was chosen based on previous experimental results.

Quasistatic tension tests using dog-bone samples were performed to determine the change in materials elastic modulus, elastic strength, and specific work. All samples show an increased amount of work at the break but decreased elastic modulus and strength by 10-20%.

Tapered double cantilever beam (TDCB) samples were prepared to determine the change in fracture toughness and stiffness. All samples showed an increase in fracture toughness by approximately 60%.

At 6 mass%, the CSR filled with silicon show the highest fracture toughness, promising specific work at the break, though the lowest elastic modulus.

Tests indicated an increase in sample toughness but also a decrease in stretch resistance. It seems that, although more resistant to destruction, samples may be rendered unusable in specific applications due to plastic deformations. More tests are planned for different CSR concentrations.

Acknowledgements

This research was funded by M-ERA.NET project “MERF” grant Nr. 1.1.1.5/ERANET/20/04 and M-Era.Net project “EPIC” grant No. TH06020001.

IMPACT INDUCED DAMAGE IN FIBRE REINFORCED COMPOSITES AND THE EFFECT OF MATRIX DOMINANT PROPERTIES ON THE EFFECT OF DAMAGE PROPAGATION

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The study aims to ascertain the performance of polymer composites under the effect of impact loading. Therefore, two different resins namely epoxy and PMMA was selected for the study, along with glass, carbon, and hybrid reinforcements. Thus, specimens with hybrid architecture of glass and carbon with two different resin systems along with neat non-hybrid architectures of glass and carbon respectively were prepared and subjected to impact. The hybrid effect observed during impact was characterised using an energy-based model which quantified the percentage of damage suffered by each specimen in the form of elastic and in-elastic energy which in turn predicted the amount of ductility introduced by the hybrid effect. Composites during failure are notorious for being unpredictable owing to their brittle nature. it was observed in this study that hybridising the architecture minimised the brittleness and increase controlled failure more prevalent in metals. These findings were proved by micro-level damage observations post-impact.

Latter, based on the hypothesis that impact-induced damage can be minimised by introducing a through the thickness reinforcement in the form of out-of-plane waviness was studied based on a mathematical model. The model showed a substantial increase in out-of-plane properties like shear modulus with an increase in waviness root angle. But, it was observed in the same model this degraded the in-plane modulus thus, rendering the composite unusable for structural applications apart from those prone to impact.

Since composites while being subjected to impact are subjected to global bending, it is imperative to explore the flexure and its dependence on matrix dominant properties. With this regard numerical models were implemented on the commercial solver LS DYNA wherein using the material model MAT 54, the effect of matrix dependent properties on flexure were ascertained and this could serve as a key to further understanding impact-induced damage and to find ways to avoid it, through the introduction of distortions which though could deteriorate in-plane properties but could delay impact-induced failure.

FORECASTING THE AGING OF FIBER COMPOSITES MADE BY VACUUM METHODS

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The results of research on 4-layer polymer matrix composites are presented, which include glass mat reinforcement and epoxy resins (LH160 and LH288) formed by hand lamination and vacuum methods (such as the vacuum bag method and the infusion method). In each case, the H505 hardener was used in accordance. Then, after performing a static tensile test on a Shimadzu AGX-V testing machine (according to ISO 527-4), the highest strength was found for samples (average strength from 3 samples) produced by infusion. Efforts were also made to determine the effect of natural sunlight and artificial radiation using special fluorescent UV lamps in parts of the UVA, UVB and UVC spectrum on the produced laminates. For this purpose, to reproduce the damage that appears for months or years in external conditions in the fiber composite, a QUV UV tester (Q-Lab QUV accelerated weathering tester) was used following the ISO 4892-3 standard with the manufacturer's recommendation.

The simulation of 24-hour aging with UV light for composite materials with a polymer matrix showed a beneficial effect on the strength properties of the produced layered composites, related to the plasticization of the matrix.

ANALYSIS OF DAMAGE RECOVERY AND SELF-HEALING POSSIBILITIES IN FIBER-REINFORCED COMPOSITE STRUCTURES WITH THERMOPLASTIC MATRIX

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During the investigation of PMMA based resin, it was noticed that broken resin specimens after the tensile test were bonded back together by applying heat and pressure. Up to 75% of initial strength were recovered. This observation gave new ideas for analysing the self-healing effect on fiber-reinforced composites.

To prove the concept 100x100 mm simple two plies glass fiber composite specimens reinforced with PMMA resin were fabricated and low energy free drop impact damage was done. Then, the specimens were vacuumed and placed in the oven for 1 to 3 hours at 115 °C. Specimens were visually examined and s-scanned before and after the healing process. It was an obvious decrease in delamination area after curing. After positive results, it was decided to expand experimentation.

Next, the goal for experimentation was to determine optimal cure temperature and cure time. The required temperature for the healing process is not less glass transition point [1] of PMMA resin. This temperature was determined by using the Perkin-Elmer differential scanning calorimetry (DSC) method which is a thermoanalytical technique. In our case, it was 127 °C. Optimal cure times were determined experimentally by tension and 3-point bending tests. Before that, the specimens were cured at 6 different periods between 6 and 48 hours. 3-point bending test showed that there was no thermal degradation for the resin after curing. The tension test showed that maximum load increased with increased curing time. 36 hours of curing were chosen as optimal healing time.

Composite plates with artificially induced delamination damage were fabricated. A standard post-impact compression test (D7137) was used to examine the change in strength properties of damaged composite plates. 30% of damage were recovered in the static test.

The current study already has shown promising results in static applications. Self-healing technique could also be used to increase longevity in the fatigue cycle as a crack growth prevention.

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STRUCTURAL HEALTH MONITORING OF 3D WOVEN COMPOSITES USING MXENE NANOPARTICLES

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Recent advances in structural health monitoring (SHM) of composite materials is a combination of interdisciplinary research, where integrating novel materials imparting functional properties such as high electrical and thermal conductivity to the composite materials has been achieved. Nanoparticles like MXene [1] and carbon nanotube [2] are used for SHM of polymer matrix composites. These nanoparticles can be incorporated in various ways such as applying as a coating on the surface of the composite substrate [3] or dispersing in the matrix of the composite. By measuring the piezoelectric response of these nanoparticles, the structural health of composites can be monitored. Three-dimensional (3D) weaving is a technique by which complex shapes such as ‘T’ can be manufactured without joints/seam, however, the health monitoring of such shapes has been less explored. This study aims to develop a smart 3D woven ‘T’ joint composite by vacuum infusion process, which can sense strain and damage at the joint of the composite. The MXene were delaminated by chemical etching and dispersed in deionised water. In the next stage, they were sprayed directly on the joint of a 3D woven ‘T’ shaped composite to form a conductive coating. The resultant composites were subjected to tensile and fatigue loading to study the sensitivity of MXene to applied strain. Microscope studies were carried out to observe the delamination of MXene. It was observed that the MXene network is sensitive to tensile and cyclic deformation. Microscopic studies showed that successful delamination of MXene was achieved, which were more responsive to applied loads. It can be concluded from the study that MXene conductive coating can be used for in-situ SHM of complex-shaped composites while being cost-effective and easy to manufacture.

Acknowledgements

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MXENE-DOPED POLYMER COATINGS DEMONSTRATING DE-ICING FOR AIRCRAFT APPLICATIONS

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Frozen contaminants interfere with the aerodynamic properties of the vehicle, and dislodged ice can even damage the engines. The use of MXene-doped polymer coating is very promising to impart efficient de-icing properties to structural components for aviation applications since the electrical properties of MXene nanoparticles significantly exceed those of the carbon nanofillers (e.g., graphene, multiwall carbon nanotubes, carbon nanofibres etc.) [1]. The aim of the work was to evaluate the ability for de-icing of a lightweight MXene-doped polymer coating by the application of different values of voltage and controlling of local temperature evolution by the thermal infrared camera.

In this study, the MXene colloidal solution (5 g/l) was mixed with the sodium salt of polyacrylic acid (PAANa) at different ratios 20:80, 50:50 and 80:20 by weight to obtain conductive composites. PAANa additive improves the wettability of the surface, which makes it possible to prepare high-quality composite coatings on various types of substrates. These solutions were drop-casted on glass sheets limited by using silicone sheets and dried with a technical dryer. To protect the coating from environmental effects, it was covered by the epoxy resin Biresin CR122 with the hardener CH122-5 and cured for 15 h at room temperature. The power supply EA-PS 2042-06 B was connected to the electrodes of the coating and the voltage was set to be 5, 7, 10, and 12 V DC. The temperature distribution was recorded by a thermal infrared imager RS-9075.

The evolution of temperature due to Joule heating performance at various voltages for MXene/PAANa coatings at different ratios was analyzed. The resistance of the coatings decreased with the increase in the content of MXene in the composite. By using the temperature change normalized to the density of the coatings and volt-ampere characteristics of the coatings, it can be concluded that the most effective solution of MXene/PAANa was obtained for the ratio 50:50 by weight.

Acknowledgements

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