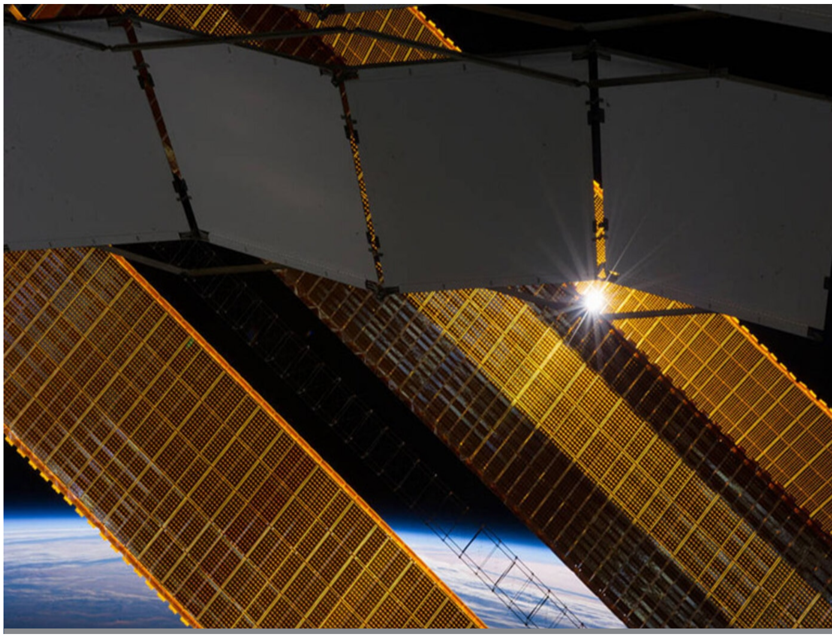


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

Conductive Carbon Fiber Polymer Composite

The Light Weight and Strength of Carbon Fiber Composite with the Thermal Conductivity of Metal Alloys

A team of inventors from NASA Langley and NASA Ames have created a new type of carbon fiber polymer composite that has a high thermal conductivity. This was achieved by incorporating Pyrolytic Graphite Sheets (PGSs) and Carbon Nanotubes (CNTs), which enhance the material's ability to transfer heat when compared to typical carbon fiber composites.

Carbon fiber polymer composites are frequently used in aerospace structures because they are light, strong, and require minimal maintenance. However, they typically have poor thermal conductivity, which limits their use to applications where heat transfer is not required. Where heat transfer is needed, aluminum alloys are used instead, but they have drawbacks such as lower strength, higher weight, and increased maintenance needs compared to composites.

The new material developed by NASA addresses this issue by combining the benefits of a carbon fiber composite with the high thermal conductivity of metal alloys. NASA is currently working on using this material for in-space applications, such as heat exchangers or radiators for removing carbon dioxide from the crew cabin atmosphere. On Earth, the composite could be used to create new radiators or heat exchangers for use in automotive or electronics applications.

BENEFITS

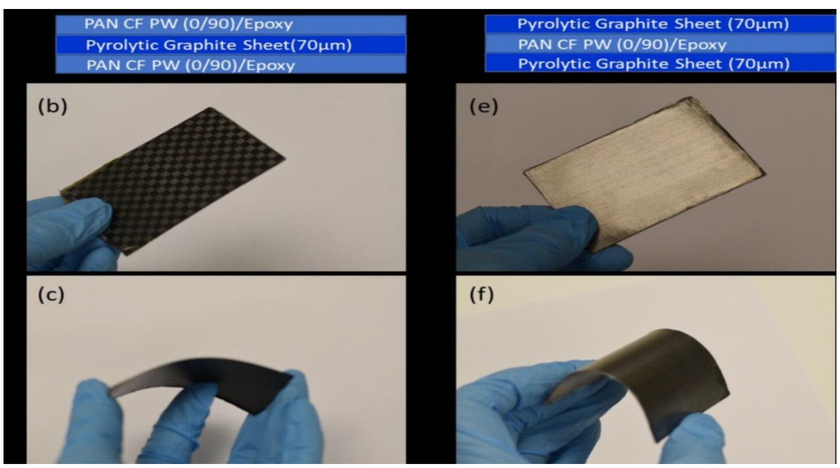
- High In-Plane Thermal Conductivity: compared to state-of-the-art materials like carbon fiber composites (over 10 times) and aluminum alloys used in space structures and heat exchangers (2 times higher)
- Improved Through-Thickness Thermal Conductivity: adding perforations improves thermal conductivity not just on the surface but also through the thickness of the material.
- Reduced Weight: replacing some aluminum with composites lightens the weight of components like heat exchangers.
- Reduced Heat-Induced Damage or Shape Distortions: this conductive composite can wick heat away from hot surfaces to avoid heat build up leading to damage and distortion.

THE TECHNOLOGY

The new composite developed by NASA incorporates PGS and CNTs to enhance its thermal conductivity while preserving the mechanical properties of the underlying carbon fiber polymer composite. NASA has also improved the composite manufacturing process to ensure better thermal conductivity not only on the surface, but also through the thickness of the material. This was achieved by adding perforations that enable the additives to spread through the composite.

The process for developing this innovative, highly thermally conductive hybrid carbon fiber polymer composite involves several steps. Firstly, a CNT-doped polymer resin is prepared to improve the matrix's thermal conductivity, which is then infused into a carbon fiber fabric. Secondly, PGS is treated to enhance its mechanical interface with the composite. Thirdly, perforation is done on the pyrolytic graphite sheet to improve the thermal conductivity through the thickness of the material by allowing CNT-doped resin to flow and better interlaminar mechanical strength. Finally, the layup of PGS and CNT-CF polymer is optimized.

Initial testing of the composite has shown significant increases in thermal conductivity compared to typical carbon fiber composites, with a more than tenfold increase. The composite also has higher thermal conductivity than aluminum alloys, with more than twice the thermal conductivity of the Aluminum 6061 typically used in the aerospace industry. For this new material, NASA has completed a proof-of-concept demonstration and work continues to use the material in a heat exchanger system and further characterize the properties including longevity and radiation impact analysis.



For the two layup configurations shown, (b c) fabricated sample of CF epoxy/PGS 70/CF epoxy composite, and (e f) fabricated sample of PGS 70/CF epoxy/PGS 70 composite.

APPLICATIONS

The technology has several potential applications:

- Aerospace Thermal Management: highly efficient heat exchangers and radiators that are lightweight, durable, and have excellent thermal performance high performance
- Aerospace Structures: as payload booms and solar cell arrays for in-space use
- Aerospace CO2 Removal: improved thermal conductivity of the composite would allow for more efficient removal of CO2 from the atmosphere of crew spaces, reducing the risk of harmful buildup.
- Automotive and Electronics: composite could be used to develop new radiators and heat exchangers for electric vehicles.

PUBLICATIONS

Jin Ho Kang and Keith L. Gordon, et. al. Highly Thermally Conductive Hybrid Carbon Fiber Polymer Composite for Radiator Application.52nd International Conference on Environmental Systems, 16-20 July 2023, Calgary, Canada.

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LAR-20254-1, LAR-TOPS-370

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NP-2022-11-3087-HQ