Active Project (2014 - 2015)

The Microwave Assisted Composite Manufacturing and Repair (MACMAR) Project

Center Innovation Fund: JSC CIF (Also Includes JSC IRAD) Program | Space Technology Mission Directorate (STMD)

ABSTRACT

The inherent microwave property of carbon nanotubes (CNTs) generates the thermal energy required to induce reversible polymerization of the matrix in these self-healing composites. Microwaves will be used to demonstrate advanced composite manufacturing and repair using self-healing composites.

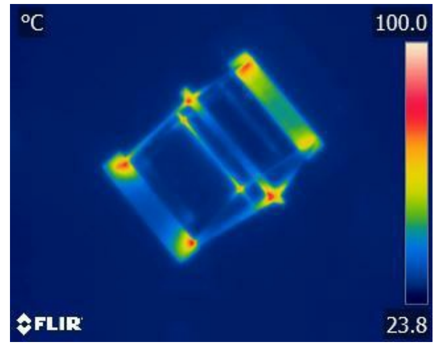
ANTICIPATED BENEFITS

To NASA funded missions:

NASA funded missions could benefit from the use of lightweight materials and structures that are damage tolerant and multifunctional. This technology could lead to the manufacture of structural components without the need for traditional composite tooling. The composite response to microwave energy may also allow the potential for structural health monitoring. The proposed technology has a broad potential for infusion. Any vehicle, habitat, or other structure built of composites would benefit from this technology. It could be used for primary or secondary structures in the Orion Multi-Purpose Crew Vehicle, Commercial Crew Development, Space Launch Systems or other Space Exploration Systems (Habitats, Rovers, Probes, etc.).

To NASA unfunded & planned missions:

These composite materials offer significant mass savings with reduced manufacturing time and operational costs. Processing with microwave energy could lead to significantly less processing time during composite manufacturing (minutes compared to hours of cure time and eliminate the use of traditional adhesives and tooling). The operational costs can be reduced by minimizing down time due to repair or replacement material and uses less energy. The multifunctional nature and healing capability of the composite can offer improvements in electrostatic dissipation, thermal management, radiation



Demo of small composite architecture using microwave energy

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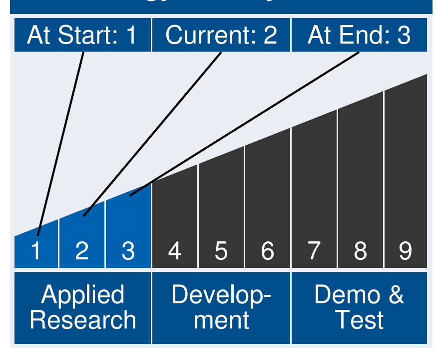
Technology Maturity



Some NASA technology projects are smaller (for example SBIR/STTR, NIAC and Center Innovation Fund), and will have less content than other, larger projects. Newly created projects may not yet have detailed project information.
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shielding, structural health monitoring, micrometeoroid mitigation and restricted gas permeation.

To the nation:

The proposed technology could be infused to meet a variety of National needs such as wind turbines for renewable energy, energy efficient transportation (vehicles, trains and aircraft) or military applications (helicopters, unmanned aerial vehicles, support vehicles, missile casings). Team members have a close relationship with those working conventional composites, and on-ramps and requirements may be easily identified and shared.

DETAILED DESCRIPTION

The Microwave Assisted Composite Manufacturing and Repair (MACMAR) project leverages on the previous work on self-healing composites that shows the addition of carbon nanotubes (CNTs) enhances the healing process while introducing multifunctional properties. The inherent microwave property of the CNTs generates the thermal energy required to induce reversible polymerization of the matrix in these composites. The primary goal is to show that a microwave source can be used to bond composite panels. These self-healing composites could be exploited for composite welding, curing and damage. The ability to remove post-manufacturing defects or impact induced damage could lead to improved damage tolerance. Microwave assisted welding and curing could lead to more cost effective composite manufacturing and potentially significant cost savings by reducing/eliminating tools and fastened joints.

Partnerships: This work will be a collaborative effort between other NASA centers, other federal agencies and small business. The Air Force Research Laboratory (AFRL) will support with additional characterization of the composite welds. Langley Research Center (LaRC) will provide collaborative consultation

Management Team

Program Director:
- John Falker

Program Executive:
- Douglas Terrier

Program Manager:
- Ronald G Clayton

Project Manager:
- Erica Worthy

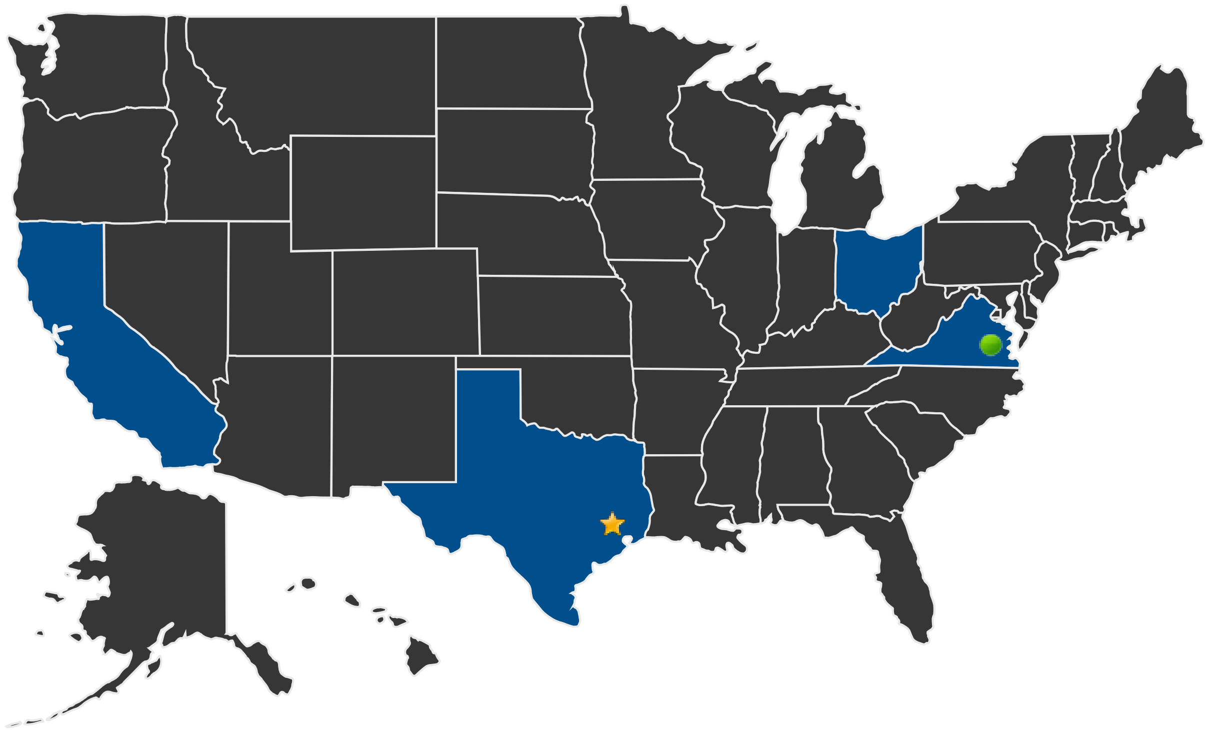
Principal Investigators:
- Edward Sosa
- Erica Worthy

Technology Areas

Primary Technology Area:
Human Exploration Destination Systems (TA 7)
└ Materials, Structures, Mechanical Systems & Manufacturing (TA 12)

on composite manufacturing and specifications. A small business will provide the composite material. Composite welding and composite weld morphology will be performed at JSC.

U.S. LOCATIONS WORKING ON THIS PROJECT



U.S. States With Work

Lead Center:
Johnson Space Center

Supporting Centers:

- Langley Research Center

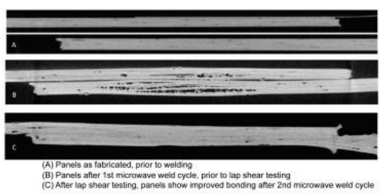
Other Organizations Performing Work:

- Air Force Research Laboratory (AFRL)

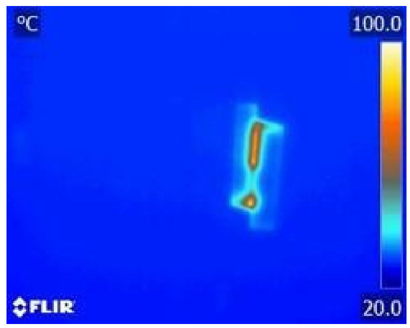
Contributing Partners:

- nanoComposix

IMAGE GALLERY



Computer Tomography Images of Composite Samples



Composite Manufacturing using Microwave Energy

DETAILS FOR TECHNOLOGY 1

Technology Title

Microwave Assisted Composite Manufacturing and Repair

Technology Description

This technology is categorized as a material for other applications

The scope of this project is to demonstrate that microwaves can be utilized for advanced composite manufacturing and repair. The primary goal is to show that a microwave source can be used to bond composite panels through localized heating of the joint interface. Previous work on self-healing composites shows that the addition of carbon nanotubes (CNTs) enhances the healing process while introducing multifunctional properties (J. Composite, Vol. 2014). The inherent microwave property of the CNTs generates the thermal energy required to induce reversible polymerization of the matrix in these composites. The thermally reversible polymerization causes bond dissociation, resulting in polymer mobility that allows healing of the damage. The advantages of using microwaves, as opposed to resistive heating, are rapid heating rates and the ability for localized heating when a focused source is used. It is proposed that the microwave assisted repolymerization of these self-healing composites could be exploited for composite welding, curing of prepreg material and removal of manufacturing or impact induced defects. Microwave assisted welding and curing could lead to more cost effective composite manufacturing. The ability to remove post manufacturing defects (i.e. voids, cracks) or impact induced damage will lead to improved damage tolerance. This will lead to the significant mass savings that composites have promised but not yet achieved. The main focus of this project work will be to demonstrate that microwaves can be used for advanced manufacturing processes.

Capabilities Provided

The composite is a lightweight material that is damage tolerant and multifunctional. The multifunctional nature and healing capability of composite can offer improvements in mechanical strength, electrical conductivity and thermal conductivity. Advanced manufacturing technology using microwaves could lead to additional cost savings, as well as greater safety and reliability. The proposed technology meets both demands. This innovative approach to utilizing microwaves for advanced composite manufacturing could lead to the elimination of tooling and mechanically fasten joints. The elimination of composite tooling or machining leads to a reduced risk of introducing manufacturing defects. Microwave heating of composites could result in faster curing times and out-of-autoclave processing.

Potential Applications

Recent work on our thermally healable composite has shown that under microwave exposure, damaged areas heat more rapidly resulting in localized heating when imaged under an infrared camera. Therefore, not only could microwaves be used to manufacture composites, but they could also be used for damage inspection. Furthermore, monitoring the disappearance of the hot spots during microwave exposure could indicate composite healing thus leading to real time structural health monitoring. Finally, the use of a focused microwave source for composite curing could lead to additive manufacturing of structures.

Performance Metrics

Metric	Unit	Quantity
mechanical bond strength	ft-lbs	70% bond strength

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