Flexible Shape Memory Composite (SMC) Substrate
Enabling large reconfiguration of structures

National Aeronautics and Space Administration

NASA

TECHNOLOGY SOLUTION

Materials and Coatings

Novel Shape Memory Composite Substrate

Enabling Efficient Actuation of Deployable Structures

Shape memory polymers, like shape memory alloys, have the capability to return to their original shape from a temporary (or programmed) shape when some external stimulus is applied (e.g., temperature, electric field). However, shape memory polymers have not seen the same level of implementation as the alloys because (1) they do not have high actuation forces (i.e., the force of the shape change) and (2) the polymers do not spread stimuli well, as such, the actuation is not constant across the material.

NASA inventors have developed a novel shape memory polymer composite (SMC) substrate by combining a shape memory polymer with thin carbon fiber sheets and an in-situ heating mechanism. The in-situ heating and a carbon fiber layer result in heat being spread evenly across the polymer and significantly higher actuation forces compared to the polymer alone. The capabilities of the composite substrate will enable deployable systems across various industries.

BENEFITS

- Increased structural capabilities: the SMC substrate can be used as a load-bearing component in larger structure (not possible with shape memory polymers).
- Improved actuation and heat distribution: the carbon fiber backbone and the in-situ heating increase the actuation force and ensuring that the shape change occurs evenly.
- Controllable actuation: integrated temperature and strain sensors allow for controlled heating and shape change sensing of the SMC.
- Reduced mass and volume: the SMC substrate does not require an external mechanical deployment mechanism or other stowage constraints like typical deployable systems.
- Reduced complexity and part count: removing additional stowage and deployment mechanisms significantly reduces the complexity and risk of the system.

APPLICATIONS

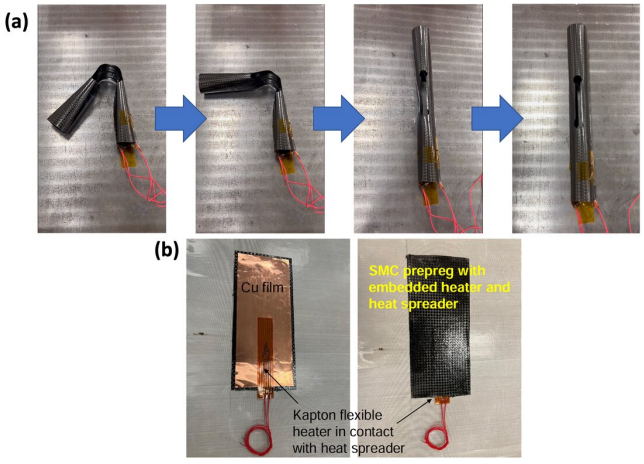
The technology has several potential applications:

- Aerospace: stowable and deployable hinges, tape-springs, booms, solar arrays, antenna supports, habitat frames
- Defense: actuators to enable deployable tent/shelter structures, solar panels, antennas mounts, and camera or sensor poles
- Automotive: actuators or larger components (e.g., body panels) that are activated/repaired with heat
- Other industries: various actuators (e.g., appliances or medical devices)

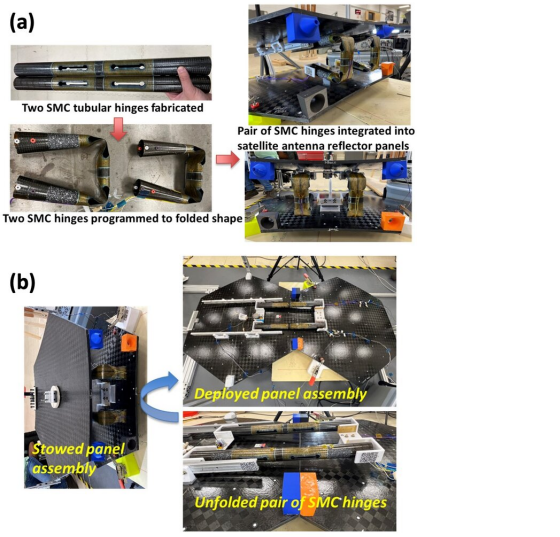
THE TECHNOLOGY

The new SMC substrate has four components: a shape memory polymer separately developed at NASA Langley; a stack of thin-ply carbon fiber sheets; a custom heater and heat spreader between the SMC layers; and integrated sensors (temperature and strain). The shape memory polymer allows the as-fabricated substrate to be programmed into a temporary shape through applied force and internal heating. In the programmed shape, the deformed structure is in a frozen state remaining dormant without external constraints. Upon heating once more, the substrate will return slowly (several to tens of seconds) to the original shape (shown below).

The thin carbon fiber laminate and in situ heating solve three major pitfalls of shape memory polymers: low actuation forces, low stiffness and strength limiting use as structural components, and relatively poor heat transfer. The key benefit of the technology is enabling efficient actuation and control of the structure while being a structural component in the load path. Once the SMC substrate is heated and releases its frozen strain energy to return to its original shape, it cools down and rigidizes into a standard polymer composite part. Entire structures can be fabricated from the SMC or it can be a component in the system used for moving between stowed and deployed states (example on the right). These capabilities enable many uses for the technology in-space and terrestrially.



(a) Image showing the process of shape change in response to external stimulus (heat generated by electric power) in a SMC hinge (b) the three layers of the SMC substrate.



Photos showing (a) the folding and integration of two SMC hinges into satellite antenna reflector panels and (b) the stowage and deployed panel assembly with integrated SMC hinges.

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