5th MMAE Symposium
ShOdhaYAntrikI-25 –1st and 2nd Dec. 2025

Shape memory Polymer based emitter membrane design and experimental analysis

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Introduction

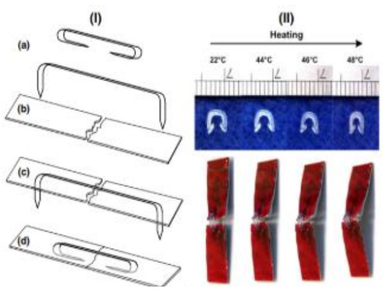
- Smart polymers that store a temporary shape and recover their original form when heated
- Offer tunable mechanical properties and large elastic deformation for actuator and membrane applications
- Enable controlled deformation, pressure regulation, and programmable actuation in emitter systems
- Study focuses on designing an SMP-based emitter and evaluating its actuation and recovery behavior

Objective

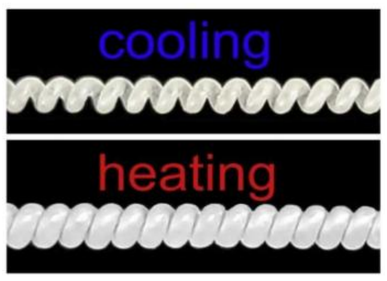
- Review various shape memory polymer (SMP) materials to identify the most suitable smart material for membrane-based actuation.
- Design, fabricate, and experimentally evaluate a PODDC-based emitter membrane for its actuation and recovery performance.

Literature Review

1 – Shape Memory Polymer Suture:
A biodegradable OCL–ODX based suture that automatically tightens by recovering its original shape at body temperature (~37–40°C).
Authors: Andreas Lendlein Year: 2002



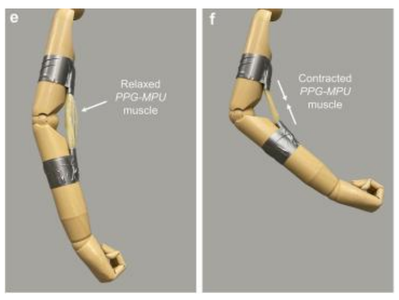
2 – Shape Memory Polymer Staple:
A PLA-based staple that recovers its closed-loop shape upon heating, enabling automatic wound tightening without manual intervention.
Authors: W.M. Huang Year: 2013



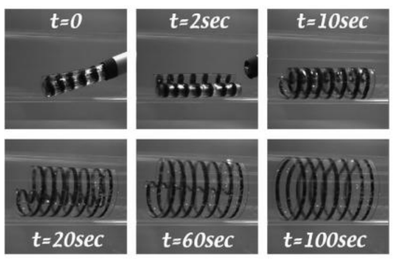
3 – Shape Memory Polymer Coil:
A UHMWPE-based coiled actuator that contracts rapidly when heated, producing large reversible actuation strains suitable for lightweight artificial muscle applications.
Authors: Nithin K. Sreelatha Year: 2019

Fig.24. Shape memory recovery process of self-deployable structure

4 – Shape Memory Polymer Hinge:
An epoxy-based SMP hinge reinforced with carbon fiber that softens and deploys when heated, achieving reliable shape recovery for structural and aerospace applications.
Authors: Tianzhen Liu Year: 2018

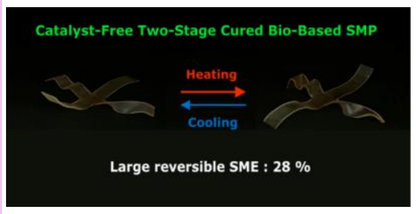


5 – Artificial Muscle Based on SMP:
A high–energy-density PPG-MPU film that contracts rapidly upon heating, enabling strong and fast actuation suitable for lightweight artificial muscle systems.
Authors: Seong Hun Kim Year: 2002

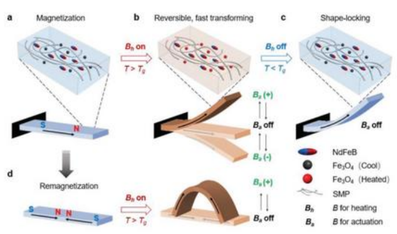


6 – Shape Memory Polymer Stent:
A biocompatible SMP stent activated near body temperature (~37°C) that expands to its programmed shape, offering a softer and flexible alternative to traditional metal stents.
Authors: Christopher M Yakacki Year: 2007

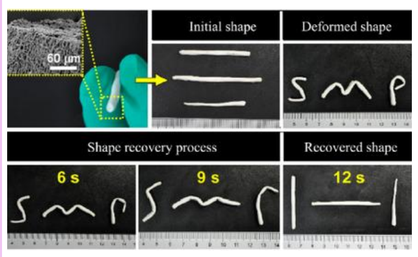
Literature Review



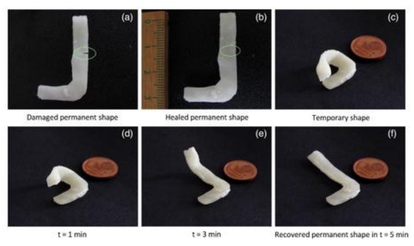
7 – PODDC Shape Memory Polymer:
A catalyst-free, biodegradable SMP with low actuation temp (~39°C) that exhibits reversible shape memory behavior and is suitable for membrane and biomedical applications.
Authors: Zi Jing Wong Year: 2023



8 – Magnetic Shape Memory Polymer:
A magnetically responsive SMP composite that heats and actuates under external magnetic fields, enabling remote, contactless shape transformation.
Authors: Qiji Ze Year: 2019



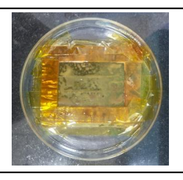
9 – PLMC Shape Memory Polymer:
A biocompatible electro spun PLMC membrane that recovers its shape rapidly (~6–12 sec) near body temp, making it suitable for biomedical scaffold and actuator applications.
Authors: Prof. Yanzhong Zhang Year: 2014



10 – Self-Healing Shape Memory Polymer:
A supramolecular PCLDMA–UPyMA based SMP that combines one-way shape recovery with intrinsic self-healing capability, enabling damage repair and shape restoration.
Authors: Giulia Scalet Year: 2019

Methodology

Fabrication Procedure for PODDC SMP Membrane -

Step	Description
Mold Preparation 	Clean Petri dish with ethanol, dry, line with Kapton tape, and place Kapton spacers to define the casting area.
Weighing of Monomers	Measure monomers using the molar ratio **OD : DDA : CA = 1 : 0.5 : 0.5** and transfer them into a clean beaker.
Melt Preparation	Heat mixture at **100–110 °C**, stirring until a uniform, transparent melt forms.
Casting the Membrane	Pre-warm mold (~60 °C), pour hot melt into the spacer-defined area, and spread evenly.
Thermal Curing – Stage I	Cure at **100 °C for 24 hours** to initiate partial crosslinking.
Thermal Curing – Stage II	Cure at **120 °C for 24 hours** to complete crosslinking.
Cooling and Demolding	Cool gradually to room temperature and gently peel off the membrane.

(a) (b) (c)

a) Permanent shape at 25 °C b) Heat membrane to 50 °C, deform to desired shape(s), then cool to 25 °C to fix temporary shapes c) Reheat to 50 °C to trigger full shape recovery