



**AFRL-AFOSR-JP-TR-2020-0013**

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Development of fiber reinforced Infra-Red (IR) Light Activated Shape Memory Polymer (SMPs) Materials A framework for evaluation of structural performance, self-repairing capabilities and long-term behavior

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**10/06/2020**  
**Final Report**

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Asian Office of Aerospace Research and Development  
Unit 45002, APO AP 96338-5002

<b>REPORT DOCUMENTATION PAGE</b>				<i>Form Approved</i> OMB No. 0704-0188	
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<b>1. REPORT DATE (DD-MM-YYYY)</b> 06-10-2020		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED (From - To)</b> 09 Sep 2016 to 08 Sep 2019	
<b>4. TITLE AND SUBTITLE</b> Development of fiber reinforced Infra-Red (IR) Light Activated Shape Memory Polymer (SMPs) Materials A framework for evaluation of structural performance, self-repairing capabilities and long-term behavior				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b> FA2386-16-1-4043	
				<b>5c. PROGRAM ELEMENT NUMBER</b> 61102F	
<b>6. AUTHOR(S)</b> Jayantha Epararachchi				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> UNIVERSITY OF SOUTHERN QUEENSLAND West Street Toowoomba, 4350 AU				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> AOARD UNIT 45002 APO AP 96338-5002				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b> AFRL/AFOSR IOA	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b> AFRL-AFOSR-JP-TR-2020-0013	
<b>12. DISTRIBUTION/AVAILABILITY STATEMENT</b> A DISTRIBUTION UNLIMITED: PB Public Release					
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> A PhD Project was completed, and a thesis titled Light activated shape memory polymer composite based smart structures: A Framework for material development and activation methodologies has been submitted. Candidate: Madhubhashitha Herath Multiple book chapters, journal papers, and other publications were produced.					
<b>15. SUBJECT TERMS</b> Shape, Memory, Polymer, IR, Infrared, Light-activated					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  SAR	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b> KNOPP, JEREMY
<b>a. REPORT</b>  Unclassified	<b>b. ABSTRACT</b>  Unclassified	<b>c. THIS PAGE</b>  Unclassified			<b>19b. TELEPHONE NUMBER (Include area code)</b> 315-227-7006

UNIVERSITY  
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USQ- AOARD

Project: 16IOA043

**Title: Development of fiber reinforced IR light activated  
shape memory polymer materials**

**Final Report**

PI: Associate Professor Jayantha Epaarachchi

Project Administration AAFOSR/IOA

Dr. Jeremy Knopp (Technical Director)

Dr. Scott Robertson (Former Program Officer)



**Acknowledgements:**

Author like to acknowledge the funding support from Asian Office of Aerospace Research and Development (AOARD), Air Force Office of Scientific Research (AFOSR), U.S. Air Force under the grant No: FA2386-16-1-4043. The support offers to us by Dr. Jeremy Knopp (Program Manager) and Dr. Scott Robertson (Former Program Manager) has been invaluable for the completion of this project successfully. Author like acknowledge diligent support and the tireless work of PhD candidate Mr. Madhubhashitha Herath for the completion of this project with many novel achievements. Also, author like to acknowledge untiring support from Associate Professor Mainul Islam (USQ) for co-supervising this project to the successful completion. Finally, the author like to thank technical and administration staff at Centre for Future Materials (CFM), Technical Officers at School of Mechanical and Electrical Engineering, Technical Staff at USQ Workshop, Administration staff at HES-Central Operation and Office of Research for invaluable support during this project

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**Final Report of AOARD 16IOA043 - Grant NO: FA2386-16-1-4043**

**Reporting date 07<sup>th</sup> December 2019**

**Project duration 09<sup>th</sup> September 2016 – 08<sup>th</sup> September 2019**

**Project Leader: Associate Professor Jayantha Epaarachchi**

**Title: Development of fibre reinforced IR light activated shape memory polymers**

**ABSTRACT:**

The Shape Memory Polymers (SMP) are capable of recovering their original shapes upon exposure to an external stimulus such as electricity, magnetic field, heat, moisture, microwave and light. They are lightweight, have a high strain shape recovery ability are easy to process and required properties can be tailored for different applications. Most interestingly light-activated SMP actuators can be activated remotely sending IR light through fibre-optic cables. Non-contact activation of the shape memory effect (SME) is an intrinsic requirement especially in sheltered or no-touch environments, for example inside the human body in biomedical applications. The polymeric nature of the SMP and its poor stiffness have resulted in considerable difficulty in incorporating these materials in real structural application. To overcome the inherent low stiffness, low stress recovery, and low electrical conductivity, Multi Walled Carbon Nano-Tubes filled (MWCNT), Glass Fibre Reinforced SMP Composites (SMPC) has been proposed. This proposal will scientifically investigate (a) light-activated shape recovery, mechanical and structural properties of fibre reinforced SMP composites; (b) effects of temperature variation on shape recovery, self-healing phenomenon and fatigue/fracture behaviour due to thermal cycles and dynamic loading.

The set outcomes of this project will be achieved through a systematically planned laboratory testing program. The thermo- mechanical properties of SMP and SMPC will be established. Further the shape recovery and SMP activation through embedded fibre optic fibres will be thoroughly investigated. The outcomes of the project will set a number of benchmarks for enhanced performance of glass fibre/MWCNT reinforced SMP composites. The firsthand knowledge expected from this project will accelerate the development of breakthrough SMP technologies in lifesaving medical equipment, state-of-the-art technologies in the space and aerospace engineering, mechanical, civil and chemical engineering fields.

## List of Direct Achievements:

A **PhD** Project was completed, and a thesis titled “Light activated shape memory polymer composite based smart structures: A Framework for material development and activation methodologies” has been submitted.

**Candidate: Madhubhashitha Herath**

## List of Publications

### Book Chapters

- B1** - Wessam Al Azzawi, **Madhubhashitha Herath**, Jayantha Epaarachchi, Modeling, analysis, and testing of viscoelastic properties of shape memory polymer composites and a brief review of their space engineering applications, Creep and Fatigue in Polymer Matrix Composites 2nd Edition, 2019, pp. 465-495.

### Journal Articles

- J1** - **Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Liang Fang, Jinsong Leng, Light Activated Shape Memory Polymers and Composites: A Review, European Polymer Journal, 2020, 136, 109912. IF: 3.862 Rank:Q1
- J2** - **Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Fenghua Zhang, Jinsong Leng, Liang Fang, Cheng Yan, Gang Ding Peng, Wolfgang Schade, Remote actuation of light activated shape memory polymers via D-shaped optical fibres, Smart Materials and Structures, 2020, 29(4), pp. 1-9. IF: 3.543 Rank:Q1
- J3** - **Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Cheng Yan, Fenghua Zhang, Jinsong Leng, Effects of selectively triggered photothermal particles on shape memory polymer composites: An investigation on structural performance, thermomechanical characteristics and photothermal behavior, Journal of Intelligent Material Systems and Structures, 2019, 30(20), pp. 3124-3135. IF: 2.172 Rank:Q1

**J4 - Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Jinsong Leng, Carbon Fibre Reinforced Shape Memory Polymer Composites for Deployable Space Habitats, Engineer - Journal of the Institution of Engineers, Sri Lanka, 2019, 52(1), pp. 1-9.

**J5 - Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Wessam Al Azzawi, Jinsong Leng, Fenghua Zhang, Structural performance and photothermal recovery of carbon fibre reinforced shape memory polymer, Composites Science and Technology, 2018, 167, pp. 206-214. IF: 7.094 Rank:Q1

### Conference Proceedings

**C1 - Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Fenghua Zhang, Jinsong Leng, 4D Printed Shape Memory Polymer Composite Structures for Deployable Small Spacecrafts, ASME Conference on Smart Materials Adaptive Structures and Intelligent Systems, Louisville KY, USA, 2019.

**C2 - Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Liang Fang, Fenghua Zhang, Jinsong Leng, Performance of Rare Earth Organic Complexes Based Light Activated Shape Memory Polymer Composites, 22nd International Conference on Composite Materials, Melbourne, Australia, 2019.

**C3 - Madhubhashitha Herath**, Jayantha Epaarachchi, Mainul Islam, Jinsong Leng, Near Infrared Light Activated Shape Memory Polymer Composite for Space Applications, 11th Asian-Australasian Conference on Composite Materials, Cairns, Australia, 2018.

**C4 - Madhubhashitha Herath**, Wessam Al Azzawi, Jayantha Epaarachchi, Mainul Islam, Scott Robertson, Jinsong Leng, Fenghua Zhang, Thermomechanical Behaviour and Shape Memory Characteristic of Carbon Fibre Reinforced Epoxy, International Conference on Nanoscience and Nanotechnology, Wollongong, Australia, 2018.

## Associated Awards

- **Madhubhashitha Herath**, Young Researcher Award at 11th Asian-Australasian Conference on Composite Materials – 2018.
- **Madhubhashitha Herath**, Best Student Paper Finalist at ASME Conference on Smart Materials, Adaptive Structures and Intelligent Systems – 2019.
- **Madhubhashitha Herath**, Pitchfest Finalist at Australian International Airshow and Aerospace & Defense Exposition – 2019.
- **Madhubhashitha Herath**, Best Poster Runner Up at Open Day Center for Future Materials USQ – 2020.
- **Madhubhashitha Herath**, Best Poster Runner Up at Open Day Center for Future Materials USQ – 2018.

## Collaborations

- Professor Jinsong Leng at Harbin Institute of Technology, China
- Professor Gang Ding Peng at University of New South Wales, Australia
- Associate Professor Liang Fang at Nanjing Tech University, China
- Professor Cheng Yan at Queensland University of Technology, Australia
- Professor Wolfgang Schade at Fraunhofer HHI, Germany

## International Visits

- Harbin Institute of Technology, China, Invited by Professor Jinsong Leng
- Nanjing Tech University, China, Invited by Associate Professor Liang Fang
- NASA Jet Propulsion Laboratory, USA, Invited by Dr. Ken Wolfenbarger