To,

The Director,

NITK, Surathkal

DEPT. OF MECH ENGG, NITK
Ref. No.: NITK/ME/055/2022
Date : 5 / 4 /2022

April 05, 2022

From:

Dr. Mrityunjay Doddamani and Dr. A. S. S. Balan,

Mechanical Engg., NITK Surathkal

Through: HOD Mechanical, Dean (Alumni Affairs and Institutional Relations)

Sub: Request for project fund reg.

Dear Sir,

We, wish to explore a novel Shape Memory Bio-Polymer for Medical Applications using 4D Printing. This concept might revolutionize the way scaffolds are realised and put to use with human bone marrow mensenchymal stem cells for various functional tissue applications.

We kindly request you to fund us Rs. 5 lacks lakhs for this exploratory research project through the funds supported by Alumni. NITK alumni has funded several projects in past and we hope that, they would fund Rs. 5 lacks lakhs for our project titled *4D Printing of Shape Memory Bio-Polymer for Medical Applications.*

We, kindly request the NITK alumni to fund the above project in medical field for Rs. 5 lacks lakhs.

We, request you to do the needful.

Thanking you.

Forwarded with Recommendation

5.4.2022

Dr. Ravikiran Kadoli
Professor & Head
Dept. of Mechanical Engineering
National Institute of Technology Karnataka, Surathkal
Srinivasnagar - 575 025, Mangalore (INDIA)

Yours's

(Dr. Mrityunjay Doddamani) (Dr. A S S Balan)

Encl.:

1. Project document.

→ Dean (AAIR)

Recommended for forwarding to Alumni groups for funding

Submitted for approval

→ Director.

Apr

4D Printing of Shape Memory Bio-Polymer for Medical Applications

Dr. Mrityunjay Doddamani	Dr. A. S. S. Balan
Assistant Professor Grade I	Assistant Professor Grade II
Mechanical Engineering	Mechanical Engineering
NITK, Surathkal	NITK, Surathkal

Specific Aim of the Project :
4D printing of biomedical scaffolds using plant oil polymers and investigation of their biocompatibility with human bone marrow mensenchymal stem cells for various functional tissue applications.

Objectives of the Project:

- To print smart biomedical scaffolds using plant oil polymers which have inherent functionalities that are able to reshape or transform themselves in response to external stimuli.
- To investigate the 4D printed material biocompatibility with human bone marrow mensenchymal stem cells for various functional tissue applications.
- To eradicate the need for animal trials.

Summary of Proposed Project:
The demand for organ transplantation has rapidly increased all over the world during the past decade due to the increased incidence of vital organ failure, the rising success and greater improvement in post-transplant outcome. However, the unavailability of adequate organs for transplantation to meet the existing demand has resulted in major organ shortage crises. As a result there has been a major increase in the number of patient on transplant waiting lists as well as in the number of patients dying while on the waiting list. This organ shortage crisis has deprived thousands of patients of new and better quality of life and has caused a substantial increase in the cost of alternative medical care. There are several pathways have been shown to provide practical and effective solution to this crisis in future. One of the solutions is 3Dprinting of biological systems ie 3D bioprinting. Recent developments in bioink made primarily from nanocellulose alginate which is extracted in part from seaweed, has opened a noval avenue in bioprinting. In the beginning, this might mean printing skin or cartilage, which are relatively simple structures and are more straight forward to grow outside the body. Some success in printing parts of lung, kidney and heart muscle have observed since 2007.Although 3Dprinitng has many benefits, it still suffers from rigid and static parts that cannot actuate or transform shape right off the print bed. Post processing of 3D printed parts can still be tedious and time consuming just like machined parts. The 3D printer’s print bed size is another issue because it limits the number of parts and size of

parts that can be printed in one iteration. One solution to these problems is to use a material that can dynamically change shape over time when exposed to an external stimulus after it has been 3Dprinted. This emerging technique is referred as 4D printing. 4D bioprinting is defined in literature as "the printing of smart, environmentally responsive biological structures, tissues and organs. 4D bioprinting begins with the printing of multiple cells or biological matrices resulting in structures that undergo subsequent designed and anticipated (not spontaneous) but self-originated development in response to an environment."

For instance, water-expansible hydrophilic materials are 4D printed into self-evolving structures which perform geometric folding, curling, expansion and various other programmed shape changes after they are submerged in water. 4D active composite materials are developed by printing shape memory polymer fibers in an elastomeric matrix achieving a programmed action through the stimulation of the shape memory fibers. The time-dependent shape and/or functional changes realized with 4D fabrication techniques have shown great application potential for biomedical scaffolds. This recent invention of 4D printing naturally points to the general concept of 4D bioprinting. Shape memory Alloys (SMA) and Polymers (SMP) are being used. One of the primary being that the organs could be generated using a sample of the patients own cells, thus limiting or eliminating organ rejection issues and corresponding treatments that carry negative side-effects. One of the major issue is the biological compatibility of many different shape memory polymers (SMP) has not been tested. Also their reaction stimulus that causes their shape change would have to be safe for the biological body and easily controllable. However the principles and terms inherent to the concept of 4D bioprinting are still in early development. 4D bioprinting could become a major advancement in the design and application of bio-scaffolds and biomedical devices.

In this proposed work, the key objective is to utilize plant oil polymer-soybean oil epoxidized acrylate as a liquid resin for fabricating 3D biomedical scaffolds and evaluate their biocompatibility with human bone marrow mesenchymal stem cells (hMSCs) which have great potential for various functional tissue applications. Unlike other renewable polymers such as proteins and polysaccharides which have been widely used as biomaterials, plant oil polymers are just emerging as suitable biomaterials for implantation. Fully exploring the use of plant oil polymers will provide a wide range of biomaterials which are valuable and complementary to existing natural biomaterials. The study on plant oil polymers as liquid resins for stereolithographical fabrication of biomedical scaffolds is rarely reported thus far. Furthermore, the fabricated scaffolds possess excellent shape memory effect, facilitating 4D functionality. This research significantly advances the development of biomedical scaffolds with renewable plant oils and 3D fabrication techniques.

Keywords: 3Dprinting, 4D printing, Shape Memory Alloys, Shape Memory Polymers,

<u>Proposed Work-Plan</u>

1
- Study of 4D Printing Techniques
- Selection of 4D Printing strategy for Bioprinting

2
- Selection of plant oils for shape memory biopolymer(SMP)-Scaffold Design
- Selection of cells for tissue culture for intended application

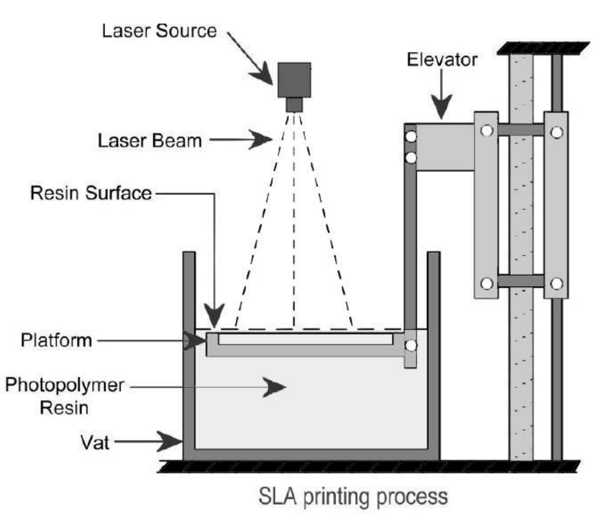
3
- Numerical simulations of SMPs behaviour model /protocol using **ABAQUS & COMSOL**
- Prediction of 4D printed object actuation and design optimization

4
- 3D printer design and Open source platform software for optimization of printing parameters and Scaffold printing as per **ASTM52900**
- **SEM,FITR,DSC,DMA Experiments**

5
- Injecting the hMSCs on scaffold , vascularization and investigation of morphological changes for achieving desired 4D effect
- FDI regulation check and trials

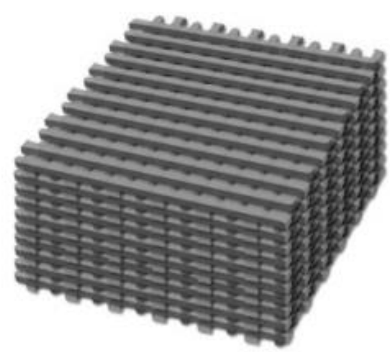
6
- Identification of potential usage for bioprinting and other areas
- Report preparation and presentation

<u>Proposed Setup</u>

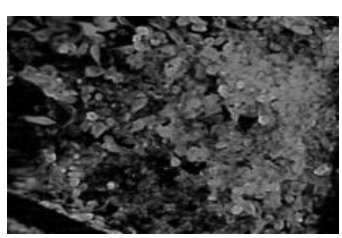


4D Micro SLA

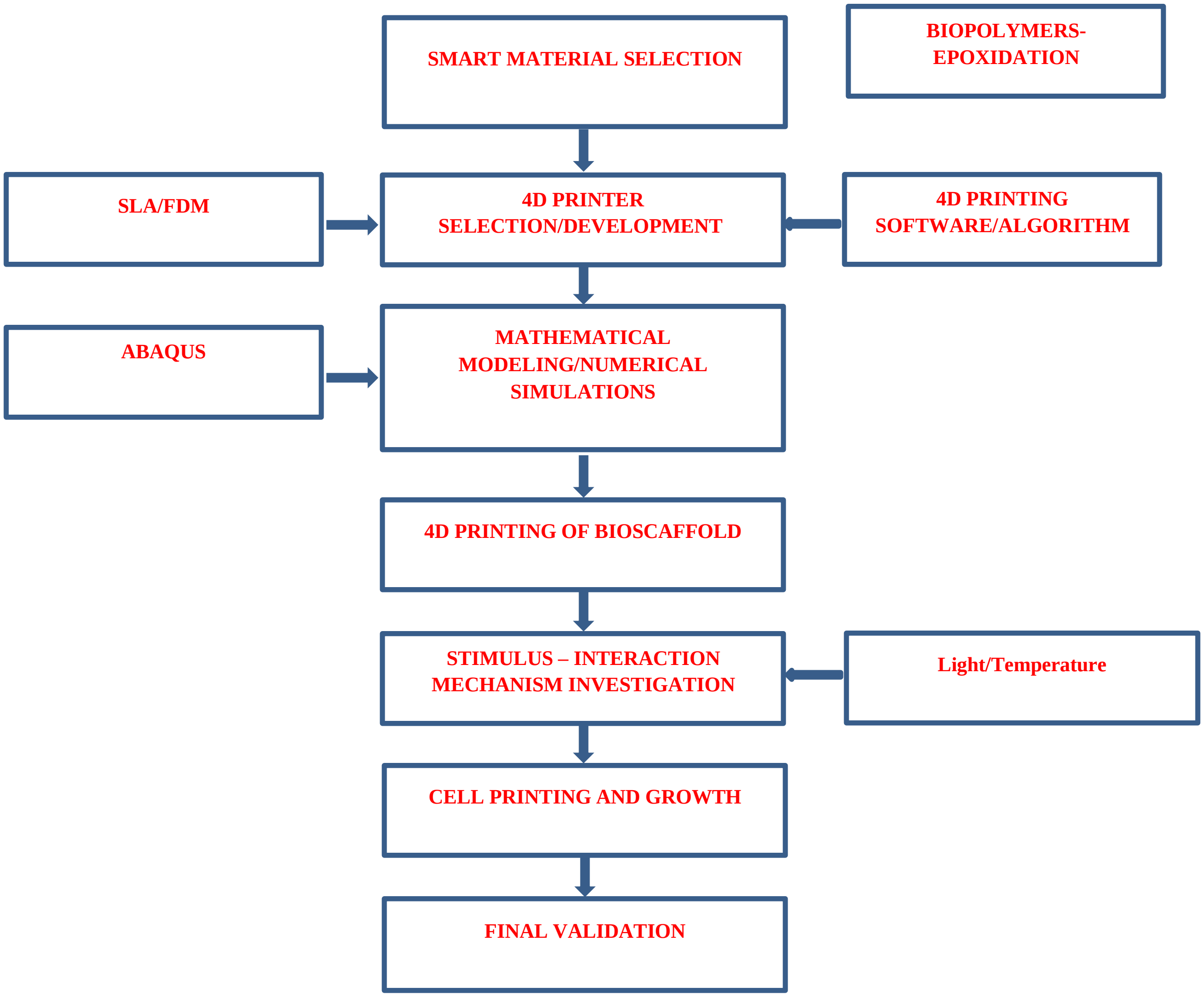
Bio scaffold



Cell Printing & culture



Proposed Methodology



Outcomes of the proposal

1. Development of new biodegradable scaffold using Plant oil polymers for various functional tissue applications
2. Identification of optimal printing parameters for 4D printing of bio-scaffold and providing the guidelines on feasibility of developed biopolymers for 4D bio-printing.
3. Synthesis of Graphene and its use in combination with Plant oil polymers
4. Surface Engineering of Graphene to be compatible with the Plant oil polymers
5. Characterization of newly developed plant oil polymers and graphene-based materials for efficient bio printing process

Cost of the Proposed Project

Items	Cost (lacks)
Micro-SLA printer compatible with open source platform	3.5
Consumables (Plant polymers and other chemicals)	1.5
Total	5

Rs. Five lacks only

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