ARUNKUMAR PALANIAPPAN

About Faculty:

Dr. Arunkumar Palaniappan, with **around 3 years of teaching and research experience** at VIT, Vellore got his doctoral and postdoctoral training in the field of **biomaterials and tissue Engineering**. He completed his doctoral research in the area of composite injectable gels with Prof. Rohit Srivastava at **Indian Institute of Technology, Bombay**, in the year 2016. After that, he underwent two postdoctoral training, one at the University of Cincinnati Medical Centre and the second one at The Ohio State university. His research interests include polymeric hydrogels, cardiovascular tissue engineering, nanomaterials for water treatment and for the detection of persistent pollutants.

Research Areas:

- 3D *in vitro* tissue models
- 3D bioprinting
- Cardiovascular tissue engineering
- Nano-biomaterials
- Water treatment technologies
- Nano-sensors

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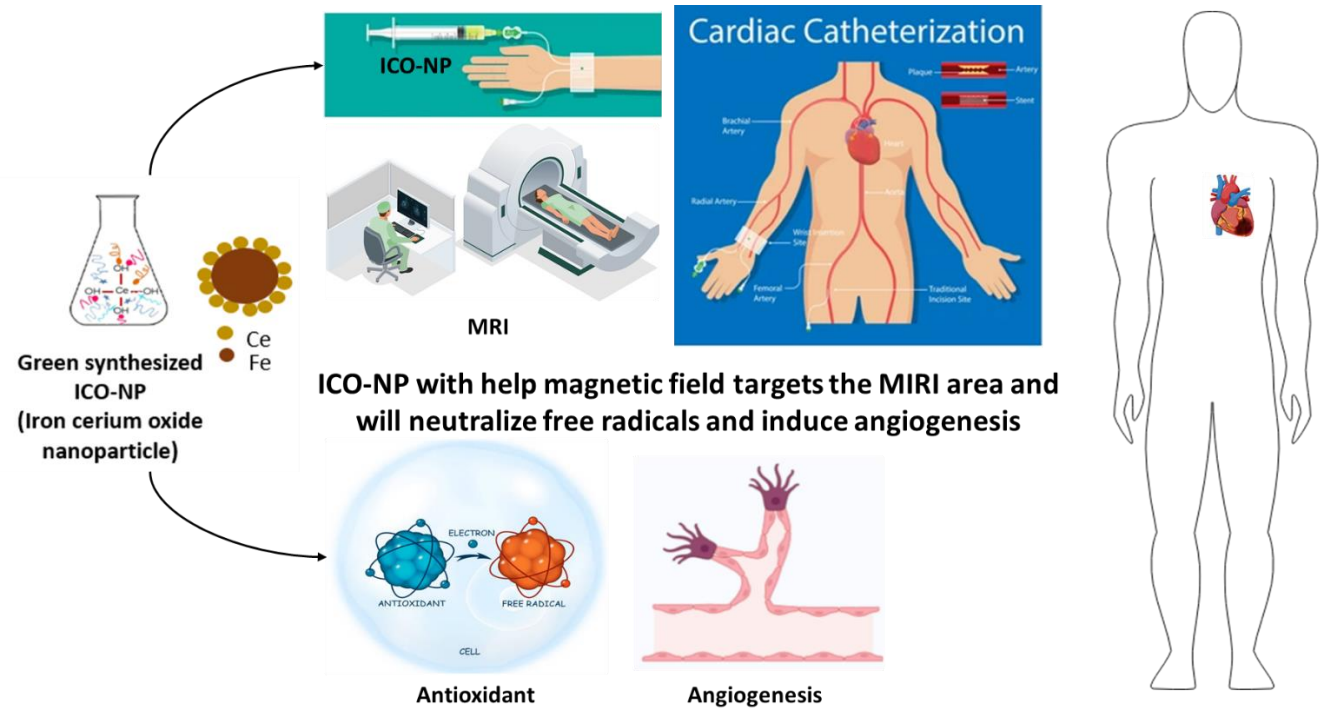
Dr Palaniappan's lab works on the interface of material science, chemistry and biology towards biomedical and environmental applications.

Research Projects running in Dr. Palaniappan's lab

1. **Green synthesis, characterization and *in vitro* evaluation of iron oxide - cerium oxide nanocomposite (ICO-NP) as a potential image guided therapeutic agent for myocardial ischemia-reperfusion injury (MIRI)**

Cardiovascular diseases (CVDs) are one of the leading causes of global mortality. Myocardial ischemia reperfusion injury (MIRI) is an adverse after effects of myocardial ischemia, cardiac surgery, or circulatory arrest. The primary cause of ischemia is the lack of blood flow to the heart leading to cardiac tissue damage or dysfunction. The most successful technique to decrease the size of the scar tissue after myocardial infarction and improving the clinical prognosis is to utilise thrombolytic treatment or primary percutaneous coronary intervention. Conversely, restoring blood flow to the ischemic myocardium, can also result in tissue damage. Thus, the project aims to develop a green synthesized Iron-cerium oxide nanocomposite which helps in neutralizing the free radicals and also it helps to induce the angiogenesis in the target region. Besides, this nanocomposite will be utilized as an MRI contrast agent, thus helping in localization of nanoparticle at the target region-leading to image-guided therapy. One of the main advantages of this method is it is environmentally friendly approach with low toxicity and also it has

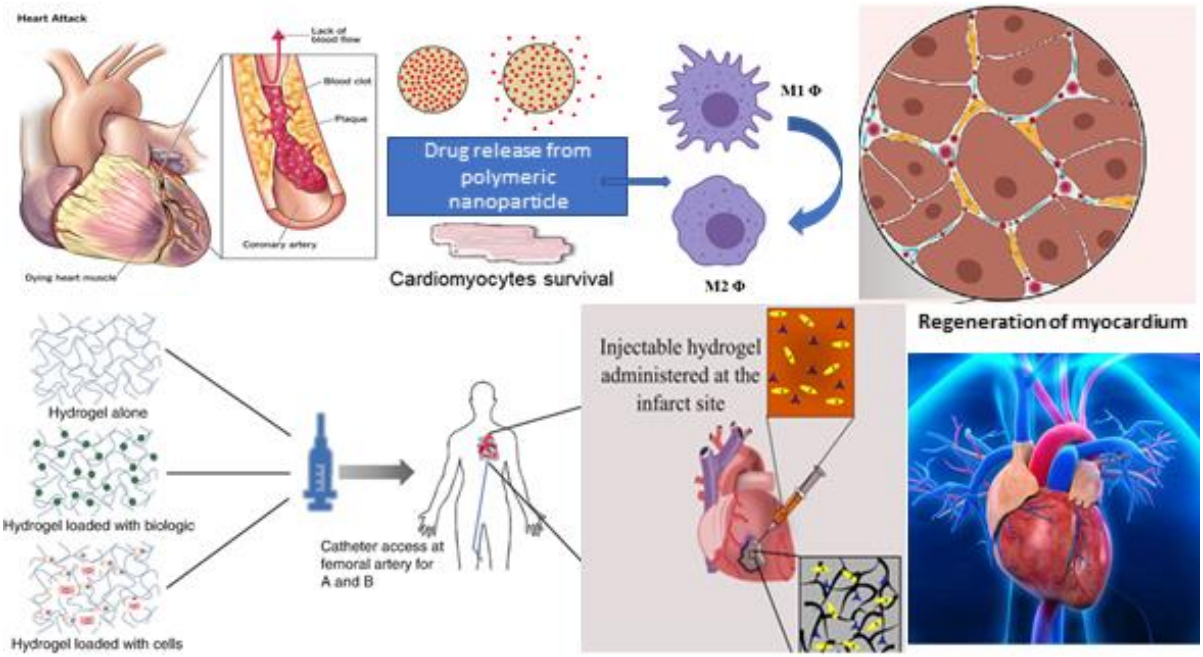
antioxidant regenerative potential which helps in developing an image guided therapeutic agent to treat Myocardial ischemia reperfusion injury.



2. Drug Loaded Polymeric Nanomaterials as A Potential Immunomodulatory Agent for The Treatment of Myocardial Infarction

Myocardial infarction (MI), commonly known as a heart attack, occurs when blood flow decreases or stops to a part of the heart, causing damage to the heart muscle due to the lack of oxygen and nutrients. It is evident that MI is the leading cause of morbidity and mortality worldwide. It is responsible for over 15% of mortality each year, among the vast majority of people suffering from NSTEMI than STEMI. The prevalence of MI is higher among men in all age-specific groups than women. Researchers are focusing on different treatment strategies other than the conventional ones, in which most recent and effective method is found to be immunomodulation compared to all other types.

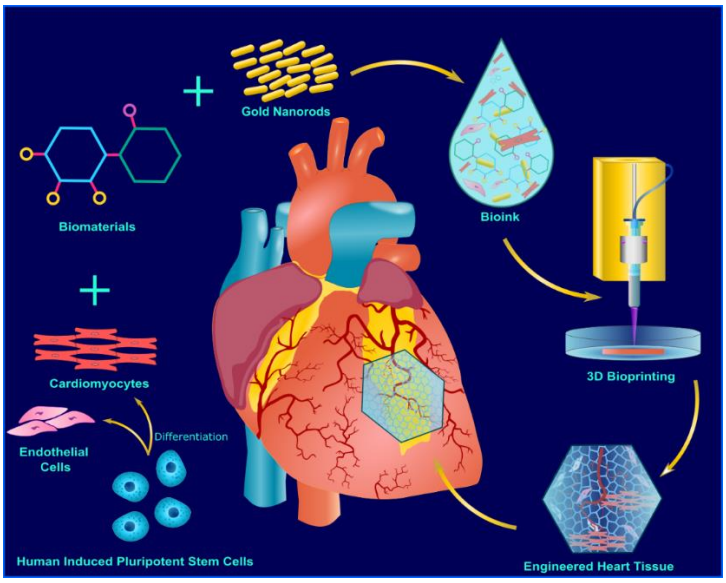
Immunomodulation of macrophages plays a major role in polarization to M1 and M2 type wherein M1 is pro inflammatory phenotype and M2 is anti-inflammatory phenotype which contains several other subtypes which is responsible for numerous other functions. Although macrophages have all these features, to maintain them in between these two polarization states is a critical factor. These immunomodulatory mechanisms especially in transition of M1 macrophages to M2 macrophages, thereby help in repair and regeneration of vital organs and here comes the advantage of choosing a right drug for macrophage polarization and a carrier molecule suitable for the drug. The role of macrophage polarization in cardiac regeneration and repair is still poorly understood at all levels and thereby recognition of this is what we put in front through this work. Thus, the drug loaded polymeric nanocomposite can be used for the *in vitro* evaluation of diseased state and thereby for the treatment of myocardial infarction.



3. Design and Optimisation of Highly Vascularised 3D Bioprinted Engineered Cardiac Tissue (ECT)

Aim: To develop an engineered cardiac patch that mimics cardiac tissue and can be implanted on the

Background: Cardiovascular diseases (CVDs) are one of the leading causes of mortality, accounting for 28% of all deaths in India in 2016. Ischemic heart diseases (IHD) contribute to 62% of all deaths among CVDs. Current treatment regimen for IHD ranges from the administration of pharmacological drugs and surgery in the initial phase to heart transplantation in for patients with complete heart failure. Heart transplantation is limited by the lack of suitable and availability of donors and the inherent risk of organ rejection. Engineered cardiac patches offer a viable solution for both therapeutic and regenerative purposes. They can also be used as an in vitro 3D cardiac tissue model for drug screening applications.



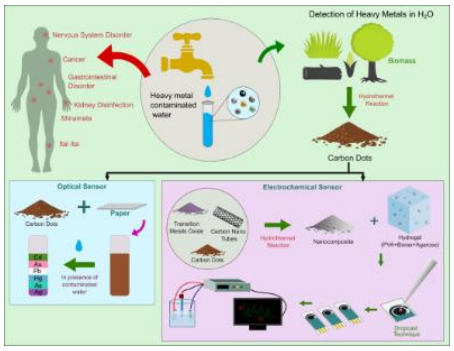
Expected Outcome:

- Development of affordable, off the shelf 3D printable patient specific bioink.
- Development of an indigenous, highly vascularized cardiac patch using 3D bioprinting technology.
- Developing cheaper " Made in India" cardiac patch for Indian population.

4. Development of novel fluorescent sensors for the detection of toxic analytes

Presently, the environment pollution is of grave concern to human health and is being researched intensely across globe. Substituted phenols and its derivatives and other organic chemicals are extensively used in many industries like food, cosmetics, pharmaceuticals, pesticides and photography. These can cause severe health problems, for instance, birth disorders, cancers, neurodegenerative diseases, hormonal imbalances, drowsiness, headaches and cyanosis. These compounds are considered as environmental pollutants owing to their high toxicity and recalcitrance to degradation and thus, the successful elimination of these perilous contaminants is a matter of concern.
Heavy metal ions are also known to cause adverse effects to the environment immensely. Heavy metals like lead, mercury, cadmium, aluminium, etc. pose serious threat to our environment, ecosystem and ultimately to human health. Therefore, detection of these metal ions with high selectivity is of great importance. Different methods exist in the literature for the detection of environmental pollutants includes classical titrimetry, electrochemical techniques, spectrophotometry, chemiluminescence, chromatography and fluorimetry. Among these methods, fluorescence and electrochemical detection methods offer a promising opportunity due to the unique advantages of rapidity, sensitivity, convenience, simplicity, easy operation, and low cost. Spectrofluorimetric sensing methods are generally based on fluorescence “turn on or turn off” of fluorophore, organic dyes such as coumarin, xanthenes, cyanine etc., which along with the various fluorescence parameters can be utilized for developing sensor design strategies.

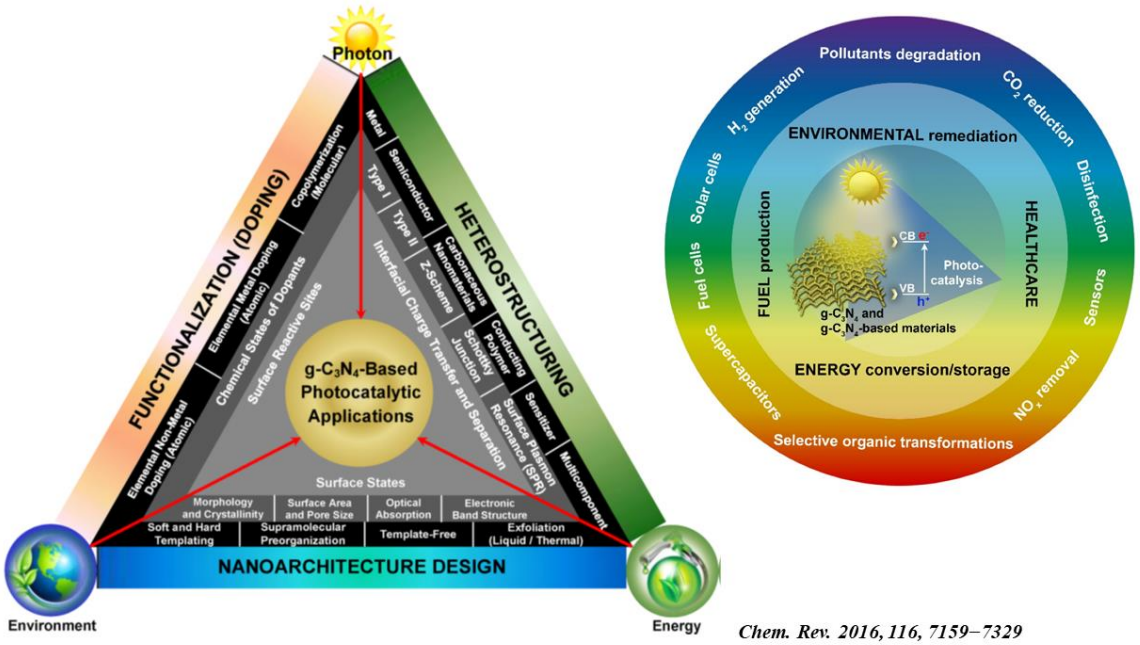
Compared to other fluorophores, carbon quantum dots (CQDs) possess good biocompatibility and high resistance to photobleaching. However, their low quantum yields (less than 10%), considerably limit their broad applications. Fluorescent probes based on carbon quantum dots are gaining more and more attention because of excellent physical and chemical properties and potential applications. Carbon dots are generally quasi-spherical nanoparticles comprising amorphous to nanocrystalline and always consist of sp2 /sp3 carbon, oxygen/nitrogen-based groups, and post-modified chemical groups. Currently, by monitoring the fluorescence intensity changes under external physical or chemical stimuli, CQDs have been used to detect different metal ions. Among these methods, those which have incorporated the use of quantum dots (QDs) stand out because of features such as good reproducibility and selectivity, and the possibility for multiplexed detection, and because they preserve the outstanding characteristics of methodologies concerning simplicity, ease-of-use, and cost-effective instrumentation. Our group is investigating on the green synthesized carbon quantum dots, that are yet to be explored for the detection of various environmental pollutants with high selectivity and specificity.



https://www.technopat.net/2018/03/29/quantum -dot-lcd-tv-nedir/

5. Graphitic carbon nitride based nanoengineered photocatalysts for environmental and energy application

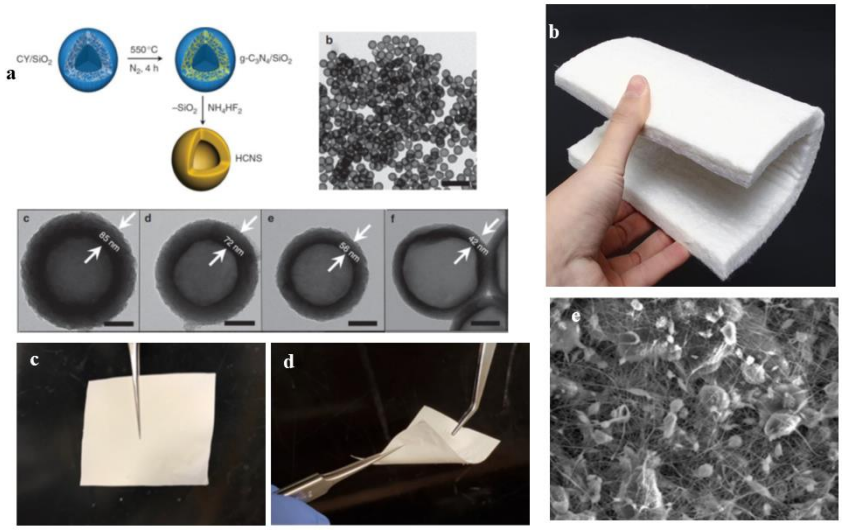
Graphitic carbon nitride (GCNs) are metal-free polymeric n-type semiconductor photocatalyst, which have excellent optical and photoelectrochemical properties, thermal stability, chemical inertness, nontoxicity, abundance, and low cost. GCNs have emerged as a promising organic semiconducting material that could efficiently replace inorganic semiconductors in environmental remediation, energy conversion/storage, fuel production, and healthcare.



Chem. Rev. 2016, 116, 7159−7329

GCNs can be used in photocatalysis as particle dispersions, fabricated catalyst or in photoelectrochemical mode. Several hybrid structures have been envisaged to improve photocatalytic performance of semiconductors such as semiconductor-semiconductor, semiconductor-metal, semiconductor-carbon allotropes nano-assemblies. It is important we understand the intricate interface

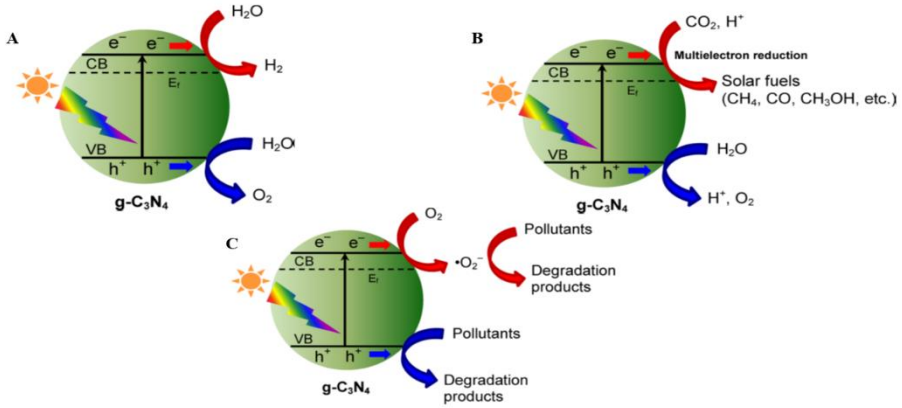
electron dynamics in all of these assemblies which will allow us to use these systems in various application.



Various fabrication strategies for GCN based materials. a) hollow GCN [Nat Commun 3, 1139 (2012)] b) Aerogel c) foldable electrospun nanofibers [Journal of Colloid and Interface Science 575 (2020) 433–442]

We are also interested in fabrication of novel photocatalytic devices using GCNs. We plan to synthesize novel hybrid material and are interested in novel fabrication process (hollow spheres, nanofibers, aerogels as shown in the figure) to improve their catalytic properties. We are interested in developing visible light, more importantly sunlight (abundantly available in our country) driven photocatalysts. We are interested in following applications

- **Environmental remediation** - the degradation of persistent organic pollutants for water or air purification
- **Solar Fuels Production** - production of fuels, H_2 from water or methane/methanol from CO_2



A) Schematic of photocatalytic water splitting for H_2 and O_2 evolution under light irradiation using pristine GCN as a reference photocatalyst. B) Schematic illustration of photocatalytic reduction of CO_2 with H_2O to various solar fuels under light irradiation using pristine GCN as a reference photocatalyst. C) Schematic of photocatalytic degradation of pollutants under light irradiation using pristine GCN as a reference photocatalyst. [Chem. Rev. 2016, 116, 7159−7329]

Honours and Awards

1. Recipient of Department of Science and Technology- SERB Start-up Research Grant (SRG), INR 28,00,000. 2020-2022.
2. Recipient of Department of Science and Technology (Govt. Of India) travel grant for attending an international conference in Rome, Italy, 2013.
3. Recipient of MHRD PhD fellowship in IIT Bombay, 2011-2016.
4. Recipient of Department of Science and Technology (Govt. Of India) scholarship during my M.Tech program in Amrita University (2009-11).
5. Selected among the first 20 TEAMS to present our commercially viable scientific idea in a national level competition- BEST 2010 (Biotechnology Entrepreneurship Student Teams) conducted by Association of Biotechnology Led Enterprise (ABLE), India.
6. Recipient of "Runner-up II" award for the best oral presentation in 15th International Conference of Controlled Release Society-Indian Chapter held at Institute of Chemical Technology, Mumbai in 2016.
7. Recipient of "Aringhar Anna award for meritorious students" (For topping the school in standard xii-2002)

Projects ongoing:

DST SERB SRG titled **"Design and fabrication of 3D printed gold nanorods loaded vascularized conducting starch composite-based cardiac patch-An attempt to make an indigenous engineered cardiac patch"**. Role: PI, Amount sanctioned: 2737372.

Peer-reviewed publications

1. Anupama Devi V. K., Rohin Shyam, **Arunkumar Palaniappan**, Amit Kumar Jaiswal1, and A. Joseph Nathanael. Self-healing Hydrogels: Preparation, Mechanism and Advancement in Wound Healing, Drug Delivery and Tissue Engineering Applications. Polymers, 2021, 13 (21), 3782. Impact factor: 4.32.

2. Divya Sridharan, **Arunkumar Palaniappan**, Britani N Blackstone, Julie A Dougherty, Naresh Kumar, Polani B Seshagiri, Nazish Sayed, Heather M Powell, Mahmood Khan. In situ differentiation of human-induced pluripotent stem cells into functional cardiomyocytes on a coaxial PCL-gelatin nanofibrous scaffold. Materials Science and Engineering: C, 2021, 118, 111354. ***Impact factor: 5.88.***

3. Naresh Kumar, Divya Sridharan, **Arunkumar Palaniappan**, Julie A Dougherty, Andras Czirok, Dona Greta Isai, Muhamad Mergaye, Mark G Angelos, Heather M Powell, Mahmood Khan. Scalable Biomimetic Coaxial Aligned Nanofiber Cardiac Patch: A Potential Model for "Clinical Trials in a Dish". Frontiers in Bioengineering and Biotechnology, 2020, 8, 567842. ***Impact factor: 4.210***

4. **Pala Arunkumar**, Julie Dougherty, Jessica Weist, Naresh Kumar, Heather Powell, Mahmood Khan. Sustained release of bFGF encapsulated PCL microspheres promote angiogenesis *in vivo*. Nanomaterials 2019, 9(7), 1037. ***Impact factor: 4.034***

5. **Pala Arunkumar**, Muhammad Qasim, Heather Powell, Mahmood Khan Current research trends and challenges in tissue engineering for mending broken hearts. Life Sciences, 229, 2019, 233-50. ***Impact factor: 3.234.***

6. Himanshu Shekhar, **Arunkumar Palaniappan**, Tao Peng, Melanie R.Moody, Shaoling Huang, Kevin J.Haworth, David D.McPherson, Christy K. Holland. Characterization and Imaging of Lipid-Shelled Microbubbles for Ultrasound-Triggered Release of Xenon. Neurotherapeutics, 24 April 2019, 1-13. ***Impact factor: 5.719.***

7. **P Arunkumar**, Deepak S Chauhan, Rajendra Prasad, Sumit Kumar Mishra, B Pradeep K Reddy, Abhijit De, Rohit Srivastava. Facile synthesis of plasmonic zein nanoshells for imaging-guided photothermal cancer therapy. Materials Science and Engineering: C, Volume 90, 1 September 2018, Pages 539-548. ***Impact factor: 5.88.***

8. **P Arunkumar**, S Indulekha, S Vijayalakshmi, R Srivastava. *In vitro* comparative studies of Zein nanoparticles and composite Chitosan thermogels based injectable formulation of Doxorubicin. Journal of Drug Delivery Science and Technology. Volume 40, August 2017, Pages 116-124. ***Impact factor: 2.297.***

9. **P Arunkumar**, S Indulekha, D Bahadur, R Srivastava. Dual responsive magnetic composite nanogels for thermo-chemotherapy. Colloids and Surfaces B: Biointerfaces. Volume 155, 1 July 2017, Pages 304-313. ***Impact factor: 3.997.***

10. **P Arunkumar**, S Indulekha, D Bahadur, R Srivastava. Thermoresponsive polymeric gel as an on-demand transdermal drug delivery system for pain management. Materials Science and Engineering: C, Volume 62, 1 May 2016, Pages 113-122. ***Impact factor: 5.88.***

11. **P Arunkumar**, S Indulekha, S Vijayalakshmi, R Srivastava. Poly (caprolactone) microparticles and chitosan thermogels based injectable formulation of etoricoxib for the potential treatment of osteoarthritis. Materials Science and Engineering: C, Volume 61, 1 April 2016, Pages 534-544. ***Impact factor: 5.88.***

12. **P Arunkumar**, S Indulekha, S Vijayalakshmi, R Srivastava.Synthesis, characterizations, in vitro and in vivo evaluation of Etoricoxib-loaded Poly (Caprolactone) microparticles – a potential Intra-articular drug delivery system for the treatment of Osteoarthritis. Journal of Biomaterials science, Polymer edition, Vol.27, 2016, pp 303-316. ***Impact factor: 1.911.***

13. K.S.Snima, **P.Arunkumar**, R.Jayakumar, Vinoth-Kumar Lakshmanan. Silymarin Encapsulated Poly(D, L-lactic-co-glycolic acid) Nanoparticles: A Prospective Candidate for Prostate Cancer Therapy. Journal of Biomedical Nanotechnology. 2014 Apr; 10(4):559-70. ***Impact factor: 5.068.***

14. Himanshu Shekhar, Robert T. Kleven, **P Arunkumar**, Tao Peng, Kunal B. Karani, Shaoling Huang, David D. McPherson,and Christy K. Holland. In vitro characterization of sonothrombolysis and echocontrast agents to treat ischemic stroke. Scientific Report, 2019, 9-9902**. *Impact factor: 4.122.***

Peer-reviewed Conference Proceedings

15. Himanshu Shekhar, Arunkumar Palaniappan, Cameron McDaniel, Daniel J. Hassett, Christy K. Holland. Characterization of lipid-encapsulated microbubbles for delivery of nitric oxide. The Journal of the Acoustical Society of America, September 2018, 144(3):1825-1825.

16. Himanshu Shekhar, Arunkumar Palaniappan,Tao Peng, Melanie R.Moody, Shaoling Huang, Kevin J.Haworth, David D.McPherson, Christy K. Holland. Lipid-shelled microbubbles for ultrasound-triggered release of xenon. The Journal of the Acoustical Society of America, September 2018, 144(3):1851-1851.

17. Kevin J Haworth, Bryan H Goldstein, Karla P Mercado-Shekhar, Rohan Srivastava, P Arunkumar, Haili Su, Ellena M Privitera, Christy K Holland, Andrew N Redington. Dissolved oxygen scavenging by acoustic droplet vaporization using intravascular ultrasound. Ultrasonics Symposium (IUS), 2017 IEEE International,September 2017.

18. P Arunkumar, S Indulekha, R Srivastava, P Sharma, S Vijayalakshmi. In situ PCL micro particles loaded chitosan composite gels as an intra-articular drug delivery system for the treatment of osteoarthritis. European Cells and Materials. Vol. 26. Suppl. 6, 2013. 100. ISSN 1473-2262. Impact factor: 3.667.

19. S.Indulekha, P. Arunkumar, D. Bahadur, R. Srivastava. Novel Thermoresponsive Poly (N-vinyl caprolactam) Sponges as an On-demand drug delivery system for pain management. European Cells and Materials Vol. 26. Suppl. 6, 2013. 99. ISSN 1473-2262. Impact factor: 3.667.

20. P.Arunkumar, K.S.Snima, S.V.Nair, R.Jayakumar, Vinoth-Kumar Lakshmanan. Proceeding of National Symposium: Emerging Trends in Biotechnology, 2012 organized by Department of Biotechnology, CUSAT during 12-13th December 2012.

21. P Arunkumar, S Indulekha, S Vijayalakshmi, R Srivastava. Composite injectable Chitosan gel, Controlled Release Society (CRS) Indian Chapter conference titled “Advances in Technology and Business Potential of New Drug Delivery Systems”, Feb 19th and 20th 2016, Mumbai.

Book Chapter

1. Rohin Shyam, Pearlin Hameed, P Suya Prem Anand, Loganathan Rangasamy, Arunkumar Palaniappan*, Geetha Manivasagam. 3D Printing Technology for Fighting COVID-19 Pandemic. pp 81-109, Emerging Applications of 3D Printing During CoVID 19 Pandemic. Springer, Singapore. https://link.springer.com/chapter/10.1007/978-981-33-6703-6_5.

2. Divya Sridharan, Arunkumar Palaniappan, Britani N Blackstone, Heather M Powell, Mahmood Khan. Electrospun Aligned Coaxial Nanofibrous Scaffold for Cardiac Repair. Wound Regeneration. pp 129-140. Humana, New York, NY.

3. Arunkumar Palaniappan and Indulekha Singaravelu. Nanodeliverables. pp 15-35, Biotechnology Products in Everyday Life. Springer Nature Switzerland AG 2019. https://doi.org/10.1007/978-3-319-92399-4.

Patents

1. An US patent filed on “Gas-Encapsulated Acoustically Responsive Stabilized Microbubbles and Methods for Treating Cardiovascular Disease”. US20180036437A1. Inventors: Christy K Holland, Himanshu Shekhar, Arunkumar Palaniappan.

2. An Indian patent granted on “Zein-Gold nanoshells and applications there of” Patent no: 319491. Inventors: P.Arunkumar, Deepak S Chauhan, S.Indulekha, R.Srivastava.

3. An Indian patent granted on "Near Infra-red responsive thermosensitive nano-shells and applications there of". Patent no: 377864. Inventors: P.Arunkumar, Deepak S Chauhan, S.Indulekha, R.Srivastava, A.De.

4. An Indian patent published on “Polycaprolactone micro/nano loaded chitosan composite in situ gelling system as a local drug delivery system”. Patent no: IPA No. 3471/MUM/2014. Inventors: P.Arunkumar, S.Indulekha, S.Vijayalakshmi, R.Srivastava, G.Shetty, A.Mullaji.

5. An Indian patent published on “PolyNvinylcaprolactam based thermoresponsive on demand transdermal/topical drug delivery systems”. IPA No. 3808/MUM/2014. Inventors: P.Arunkumar, S.Indulekha, D.Bahadur, R.Srivastava, G.Shetty, A.Mullaji.

Research group:

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Thesis Title: Development of novel fluorescent sensors for the detection of toxic analytes.

About: Kalaipriya Ramajayam is a Ph.D. scholar at Vellore Institute of Technology (VIT). She had completed her Master's degree at Periyar University, Salem. She had her internship in Indira Gandhi Centre for Atomic research centre (IGCAR). She also has experience in the areas like Schiff base chemistry. Her area of research is based on " Development of novel fluorescent sensors for the detection of toxic analytes.". Her long-time goal is to translate her research into a marketable product that could be helpful for the welfare of society. She is also passionate about focusing her research on the fabrication of sensor, which could be a platform for toxic analyte detection.

Maya B
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Thesis title: Drug Loaded Polymeric Nanomaterials as A Potential Immunomodulatory Agent for The Treatment of Myocardial Infarction

Maya is a PhD scholar with CBCMT at Vellore Institute of Technology. She is doing her research in Cardiac tissue engineering, particularly, Immunomodulation for cardiac remodelling and repair. She have a background in Biochemistry and Biomedical Technology as she has obtained her Master's degree in Biochemistry from University of Kerala and MPhil in Biomedical Technology from Sree Chitra Tirunal Institute for Medical Science and Technology,Trivandrum. During MPhil, she did her project in Tissue culture Laboratory and the work was based on corneal tissue engineering, focussing on corneal repair and replacement using suitable biomaterial. She also worked as a project trainee at HLL Lifecare Limited, Trivandrum (Natural Products Laboratory) for her master's project where, she attained a basic knowledge in evaluating anti-oxidant and anti-cancer activities of different plant extracts.

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Thesis title: Design and fabrication of 3D - printed gold nanorods loaded highly vascularised conducting cardiac patch – An attempt to make an indigenous engineered cardiac patch.

About: Rohin Shyam is a Ph.D scholar and Junior Research Fellow with CBCMT at Vellore Institute of Technology conducting his research in 3D bioprinting for vascularised cardiac tissue constructs. He obtained his Master's degree in Biomedical Engineering from the FH Technikum Wien, Vienna, Austria and a Bachelor's degree in Mechanical Engineering from Monash University, Melbourne, Australia. He is an experienced engineer with specialisation in cardiac image segmentation and design, fabrication and process engineering. He has worked at the General Hospital of Vienna and Ford Motor Company Australia.
https://www.researchgate.net/profile/Rohin_Shyam2

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Thesis title: Green synthesis, characterization and in vitro evaluation of iron oxide - cerium oxide nanocomposite (ico-np) as a potential image guided therapeutic agent for myocardial ischemia-reperfusion injury (miri).

About: Purnimajayasree has a background in biotechnology. She earned her bachelor's and master degree in Hindusthan College, Coimbatore. She did her final Master project in Indian Institute of Horticulture Research on Cloning and expression of a nematicidal cry gene. After her master's she worked for Madhu Jayanti International Private Limited under R&D and Quality Control Sector. At Present she is pursuing her PhD with her research focus on the herbal nanoformulation for cardiac tissue engineering.

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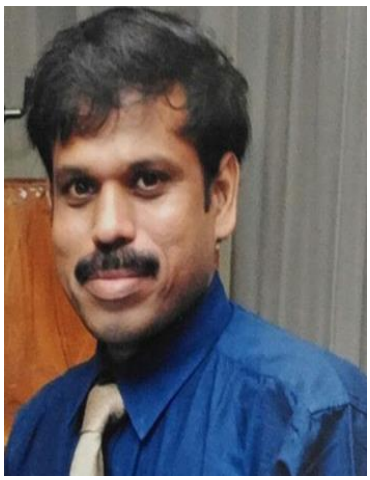
Thesis title: Graphitic carbon nitride based nanoengineered photocatalysts for environmental and energy application

About: Selvaganapathy has background in Chemistry and Nanoscience, He completed his Masters from Bharathiar university, Coimbatore-Tamilnadu. He has previous research experience in Biomaterials(ceramics), Nanomaterial synthesis and fabrication techniques. He is currently working in the field of Photocatalysis for environmental applications.
LinkedIn: https://www.linkedin.com/in/selvaganapathy-ssg-0b725a1a6/
ResearchGate: https://www.researchgate.net/profile/Selvaganapathy-Ssg



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Thesis title: Adipose tissue derived stromal vascular fraction (ATD-SVF) in neural tissue engineering – an in vivo study on rat spinal cord injury (SCI) model.