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# Sustainable Green Polymers of Bacterial Origin and their Biomedical and Environmental Applications

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## Introduction

There is a huge need to find replacements for petrochemical-derived plastics which are not sustainable, degradable and lead to high concentrations of recalcitrant plastics in the soil and in the sea. In addition to bulk applications such as packaging and coating, medical applications also use a lot of plastics for packaging, implants, tissue engineering and drug delivery. However, there is hardly any attention paid to their sustainability and environmentally friendly aspects. In this work we have focused on the production and use of bacteria-derived sustainable green polymers for use in biomedical and environmental applications. Two types of green polymers have been focused on, including polyhydroxyalkanoates (PHAs) and bacterial cellulose (BC). PHAs are polyesters produced by a range of bacteria.These polymers are biodegradable in the soil and in the sea. In addition, they are also resorbable in the human body and are highly biocompatible. Hence the PHAs can be used for the development of green packaging materials, coatings and biomedical applications. BC can also be produced by a range of bacteria including *Gluconobacter xylinus and Sarcinia ventriculi.* BC is also a green polymer, is sustainable and degradable in the soil. It is also highly biocompatible and can be used in biomedical applications.

## Experimental

This work involved the production of two types of PHAs, a short chain length PHA, P(3HB), and a medium chain length PHA, mcl-PHA. These were produced using *Bacillus subtilis* and *Pseudomonas mendocina* respectively. Both fermentations involved fed batch cultures and the polymers were then extracted and purified using Soxhlet extraction, followed by differential precipitation. The polymers were then characterized using GC-MS, FTIR, NMR and tensile testing.

## Results and Discussion

Polyhydroxyalkanaotes are polyesters with monomer chain length ranging between $C_4$-$C_{16}$. They are divided in to two main types, short chain length PHAs (scl-PHAs) with monomer chain length $C_4$-$C_5$ and medium chain length PHAs (mcl-PHAs) with monomer chain length $C_6$-$C_{16}$.The scl-PHAs are normally hard and brittle whereas the mcl-PHAs are soft and elastomeric in nature. Hence, we have used the scl-PHA, Poly(3-hydroxybutyrate) for bone tissue engineering, drug delivery and the mcl-PHAs for cardiac, nerve, pancreas, kidney and skin regeneration. For bone tissue engineering we have used neat P(3HB) and composites of P(3HB) with Bioglass®, hydroxyapatitite and carbon nanotubes (Figure 1). The mcl-PHAs have been used for development of cardiac patches, nerve guidance conduits, wound healing patch, bioartificial pancreas and bioartificial kidney (Figure 1). Processing techniques used include additive manufacturing, electrospinning and melt electrospinning.

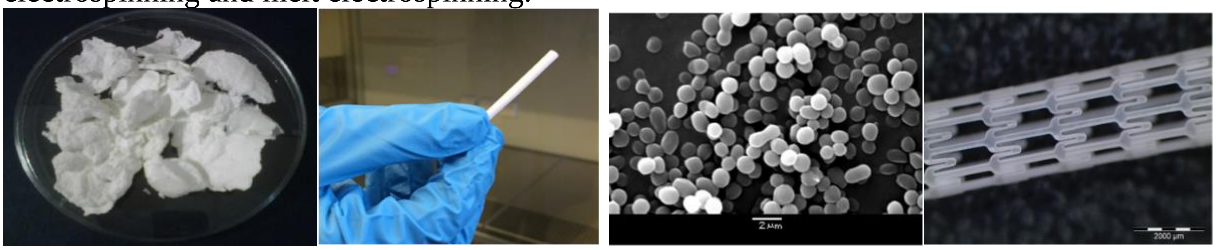

**Figure 1: (A) P(3HB) produced using *Bacillus subtilis*; PHA based (B) Nerve guidance conduit (C) Microspheres for drug delivery (D) Coronary artery stent**

Bacterial cellulose has also been produced under static culture conditions using *G. xylinus*. This is a highly nano-fibrillated structure and hence is a great substrate for cell attachment and growth (Figure 2). We have surface modified bacterial cellulose to create antibacterial bacterial cellulose. We have also used BC as a filler for P(3HB) based composites since BC is one of the stiffest known materials. In the context of environmentally friendly applications, we have used BC as a green and sustainable coating on plastic substrates.

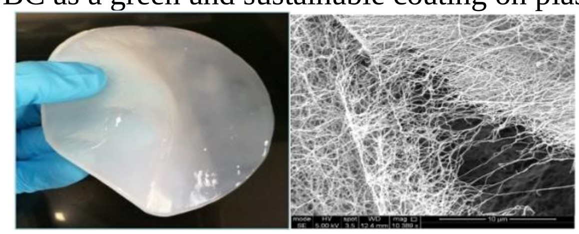

**Figure 2: (A) Bacterial cellulose pellicle (B) SEM of the Bacterial cellulose**

## Conclusions

This work conclusively shows that both Polyhydroxyalkanoates and Bacterial cellulose are green and sustainable polymers with great potential in environmental and biomedical applications.

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## Biography

Professor Ipsita Roy is a Full Professor of Biomaterials, Department of Materials Science and Engineering, Faculty of Engineering, University of Sheffield. She obtained her doctorate at the University of Cambridge, UK. Her postdoctoral work was at the University of Minnesota, USA. IR jointly leads the Advanced Biomedical Materials CDT with the University of Manchester and is the Biomaterial Lead from Sheffield at the Henry Royce Institute. She is part of the Steering Committee of Royce Bio. She has published over 100 papers in biomaterials journals and has delivered plenary lectures at numerous national and international conferences (H index : 45 and 8566 citations).