# PHOTOSENSITIVE POLYMERIC MATERIALS DEDICATED TO LIGHTWEIGHT HEART PUMP ROTOR DESIGN

ROMAN MAJOR[1]*, MACIEJ GAWLIKOWSKI[2], PRZEMYSŁAW KURTYKA[1,2,3], ROMAN KUSTOSZ[3], JUERGEN M. LACKNER[4]

[1] INSTITUTE OF METALLURGY AND MATERIALS SCIENCE, POLISH ACADEMY OF SCIENCES, KRAKOW, POLAND
[2] FACULTY OF BIOMEDICAL ENGINEERING, SILESIAN UNIVERSITY OF TECHNOLOGY, ZABRZE, POLAND.
[3] FOUNDATION OF CARDIAC SURGERY DEVELOPMENT, ARTIFICIAL HEART LABORATORY, ZABRZE, POLAND
[4] JOANNEUM RESEARCH FORSCHUNGSGES.M.B.H., INSTITUTE OF SURFACE TECHNOLOGIES AND PHOTONICS, FUNCTIONAL SURFACES, LEOBNER STR. 94, NIKLASDORF 8712, AUSTRIA
*E-MAIL: R.MAJOR@IMIM.PL

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## Introduction

The innovative ReligaHeart ROT rotary implantable blood pump was developed. The chamber is in the preclinical research phase in patients with advanced myocardial dysfunction. It is a mechanical bearingless pump, equipped with a rotor suspended magnetically and hydraulically, which provides a flow of up to 10 l/min at 30-45% capacity. A fully magnetic rotor suspension system, without hydrodynamic bearings, is being developed to reduce shear stress on the blood and protect Von-Willebrand platelets and proteins from damage causing the risk of bleeding. ReligaHeart VASC, is currently under development and is designed for short-term cardiac support in cardiac shock. It has an implantable rotor system with a miniaturized motor and magnetic rotor suspension system. The objective of the task is to design a rotor taking into account the extended possibilities of creating structural properties of parts by SLA technology in comparison with conventional manufacturing, but also the limitations of SLA technology. The main reasons for the new 4Dblood ROT impeller design for the RH ROT pump resulted from the complex shape of the RH ROT pump impeller with hydrodynamic bearing blades. This design requires high precision impeller geometry for hydrodynamic bearing operation. In order to ensure the efficient operation of the hydrodynamic bearing in the pump design, it is necessary to maintain a distance of several hundredths of a millimetre between the impeller and the casing disc surface. The small distance between the rotor and the casing is a risk factor related to the danger of destruction of VonWilebrandt proteins by shear stress on the surface of the hydrodynamic bearing blades.

Therefore, it was decided to make an impeller suspended in the pump, working without the hydrodynamic forces coming from the hydrodynamic bearing. The levitation effect of the new impeller will be obtained by using an all-magnetic bearing generating magnetic forces through the stationary bearing and dynamic forces generated by the RH ROT pump motors.

## Materials and Methods

As part of the material fabrication work, a reactive thiol-methacrylate system was evaluated. The reaction is based on a multi-step radical mechanism leading to high monomer conversion and excellent thermo-mechanical properties. The investigated and optimised resin system was evaluated in a 3D printing process in collaboration with Lithoz. It was found that the conversion of monomer functional groups in 3D printed parts was significantly lower than the conversion that could be achieved in thin model films. This behaviour can be explained by the lower intensity of light used in the digital light projection (DLP) printing process. Since methacrylates have significant cytotoxic potential, the amount of residual methacrylates in the printed parts should be reduced to the lowest possible level. To increase the conversion of functional groups, irradiation of printed parts at 80°C was investigated. This treatment significantly increases the conversion of methacrylates to 91% using 1.6 wt% Irg784 as photoinitiator. Furthermore, the effect of the choice and concentration of photoinitiator (PI) in the resin system on methacrylate conversion was also investigated. In addition to Irg784, the biocompatibility of the germanium PI Ivocerin was also investigated. A concentration of 2.4 wt.%. Irg784 leads to 86 % methacrylate conversion immediately after printing, which increased to 95 % after exposure (at 80°C). In a further experiment, the effect of post-curing on thermo-mechanical properties was investigated using dynamic mechanical analysis. Microstructure investigations were performed on two selected materials from the group containing carbon nanotubes. Cell viability was assessed after 24 h incubation using confocal microscopy. FDA (fluorescein tetraacetate) and PI (propidium iodide) were used in cell staining. Lipophilic FDA penetrates the intact cell membrane in a living and metabolically active environment.

## Results and Discussion

It was found that additional irradiation at elevated temperatures leads to a significant increase in the glass transition temperature (51°C before and 66°C after curing. In order to increase the thermo-mechanical properties of the developed photopolymer, the addition of carbon nanotubes (CNTs) was planned. It should be noted that the addition of CNTs leads to a significant increase in resin viscosity. In order to overcome this limitation, the addition of thermal radical primers was evaluated. These compounds lead to the formation of radicals by thermally induced decomposition reactions. Based on the results obtained, there were significant differences in the density of nanotubes located in the materials. The density of nanotubes observed in the so-called bright field (BF) was very low. High-resolution analysis and inverse Fourier transform confirmed the presence of carbon nanotubes. Their effect on the material properties was evaluated in terms of cytotoxicity. The results of the direct cytotoxicity tests are shown in FIG. 1.

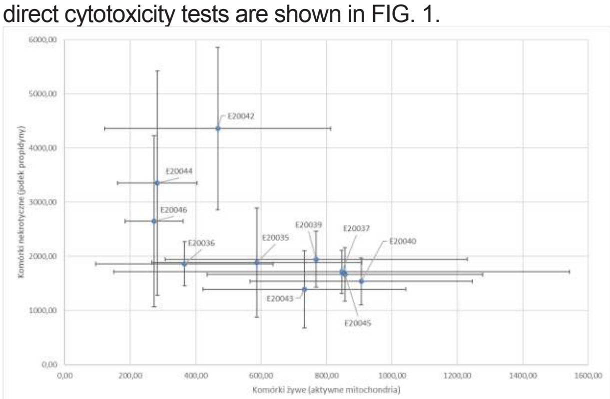


FIG. 1. Cytotoxicity analysis of the photosensitive materials.

## Conclusions

The use of light-curing materials has no toxic effects on the surrounding tissues. The use of carbon nanotubes has a beneficial effect on reducing cytotoxic properties, but from a mechanical point of view, they reduce the ductility of the material.

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