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Study and development of an optical waveguide cap for biomedical application

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Abstract. In this study, a light-activated cap was developed, envisaging a biomedical application. The cap was composed of an optical source that illuminates an optical waveguide coated with graphene oxide (GO). Interaction of the light with GO boosts its properties through photothermal and photodynamic effects. A laser diode and polymethyl methacrylate (PMMA) filaments were explored as optical source and optical waveguide, respectively. The deposition of GO on the surface of the filaments was performed by dip-coating method. The optical and thermal properties of the cap, composed of the laser coupled to the PMMA optical waveguide, were evaluated using an IR viewer and a thermal camera. Herein, the obtained experimental results are reported.

1 Introduction

Phototherapy, which comprises photothermal therapy (PTT) and photodynamic therapy (PDT), is being increasingly studied and adopted to treat different diseases. In PTT, light stimulates a photosensitizer agent that converts it into heat, resulting in a local temperature increase. In PDT, a photosensitizer generates reactive-oxygen species (ROS) upon irradiation [1]. Due to the strong NIR absorption, graphene oxide (GO) has been explored as a photosensitizer agent [2]. Besides, the outstanding and unique mechanical, optical, electrical, thermal, chemical and biological properties of GO make it suitable for a wide range of biomedical applications.

This work proposes the development of a GO-based light-activated cap for biomedical applications. The cap includes an optical source coupled to an optical waveguide that illuminates the GO deposited on the surface of the optical waveguide.

2 Experimental results

2.1. Optical source

The optical source consists of a commercial laser diode (RLD85PZJ4, ROHM Semiconductor) with a maximum optical power of 220 mW at 850 nm. The laser was spectrally characterized using an optical spectrum analyzer (OSA, AQ6370, Yokogawa). Figure 1 shows the emission spectrum of the laser with a peak wavelength of 851nm.

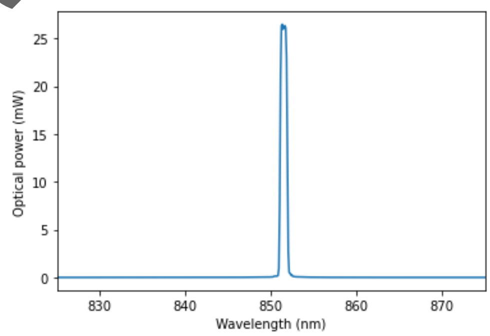

Fig 1. Emission spectrum of the laser.

The optical power was also measured using an optical power meter (PM300F-50 + FieldMaxII-TO, Coherent), for different applied voltages. The optical power curve is shown in Figure 2.

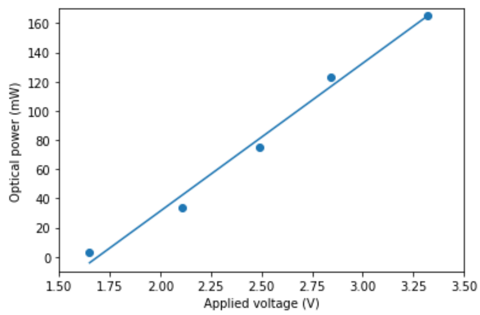

Fig 2. Optical power curve of the laser.

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The optical power presents a linear response with a slope of 101mW/V in a voltage range of [1.65V, 3.32V]).

2.2 Optical waveguide

Polymethyl methacrylate (PMMA, 5200615, Herz) transparent filaments with a 1.75mm diameter were used as optical waveguides.

For the preparation of the optical waveguides, the curvature was reduced through temperature and the end faces were polished. The characterization was performed by measuring the optical power of the optical waveguide, coupled to the laser in a cap, for different lengths, using an optical power meter.

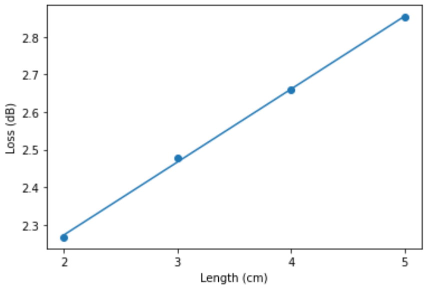

Fig 3. Optical power loss of the PMMA filament.

The PMMA optical waveguide presented a propagation loss of 0.19dB/cm at 850nm, which is similar to literature (0.2dB/cm at 850nm, [3]).

2.3 Graphene oxide (GO) coating

The optical waveguides were coated by the dip-coating technique. After dipping, the optical waveguide is dried in an oven at 60 ºC. The cycle was repeated four times to increase the GO on the surface. Stereomicroscope images of uncoated and GO-coated optical waveguides are shown in Figure 4.

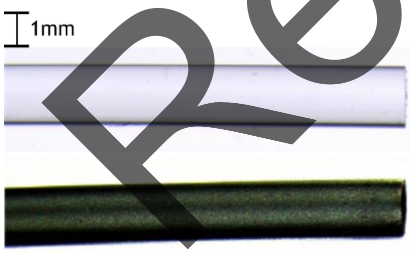

Fig 4. Stereomicroscope images of uncoated (top) and GO-coated (bottom) PMMA optical waveguides.

A homogeneous GO coating was deposited on the surface of the optical waveguide.

2.4 Cap application

The cap was designed in CAD software (Fusion 360, Autodesk) and produced by 3D printing (Zortrax M200, Zortrax). Inside the cap, the optical source is coupled to the optical waveguide.

The optical and thermal properties of the cap were evaluated using an IR viewer (ABRIS M viewer, irvi infrared viewers) and a thermal camera (TE-EV1, Thermal Expert), respectively. Figure 5 shows IR images and thermographs of the cap with the laser at 150mW illuminating a 4cm-length PMMA optical waveguide coated with 4 dips of GO. The uncoated optical waveguide was also observed as a control.

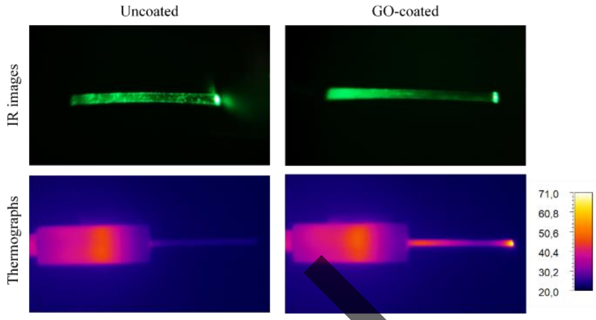

Fig 5. IR images and thermographs of uncoated and GO-coated PMMA filaments.

The IR image and the thermograph show that more light interacting with GO leads to a higher photothermal effect. The temperature of the surface reached 45 ºC and 71 ºC at the beginning and at the end of the optical waveguide, respectively. The control proves that the heat is only generated due to NIR and GO interaction.

3 Conclusion

In this study, a GO-based light-activated cap was developed, using a laser diode that illuminates a 4cm GO-coated PMMA optical waveguide inside a 3D printed cap. A photothermal effect was observed on the surface of the GO-coated (4 dips) optical waveguide using the laser emitting at 150mW, with a mild temperature increase (25 ºC) at the beginning of the optical waveguide and a significant temperature increase (51 ºC) at its end.

As future work, some modifications will be made to the optical waveguides to increase the light losses by scattering so light interacts more homogeneously with GO on the surface, contributing to the final application.

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