Toward the fabrication of directly extruded microstructured bioresorbable phosphate glass optical fibre preforms

D. Gallichi-Nottiani[1*], D. Pugliese[1], N. G. Boetti[2], D. Milanese[3], D. Janner[1]

[1]Dipartimento di Scienza Applicata e Tecnologia (DISAT) and RU INSTM, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

[2]Fondazione LINKS-Leading Innovation and Knowledge for Society, via P. C. Boggio 61, 10138 Torino, Italy

[3]Dipartimento di Ingegneria e Architettura (DIA) and RU INSTM, Università di Parma, Parco Area delle Scienze 181/A, 43124 Parma, Italy

*** Corresponding author:** duccio.gallichi@polito.it

max. 500 words abstract:

Microstructured fibres exhibit a wide range of applications, i.e. photonic crystal fibres, large mode area fibres, hollow gas/liquid sensors, etc. Nevertheless, the fabrication of bioresorbable microstructured fibres has not been feasible so far due to a lack of bioresorbable transparent glass and more flexible fibre preform fabrication techniques. The realization of the proposed fibres leverages on three main pillars: an optically transparent bioresorbable glass, its extrusion into a preform and the fibre drawing. A custom developed calcium-phosphate glass has been designed and carefully prepared in our laboratory to be dissolvable in a biological fluid while being optically transparent and suitable for both preform extrusion and fibre drawing. This glass has been characterised both in terms of mechanical and optical properties as well as for dissolution in aqueous medium. The prepared glass shows good mechanical strength (lower than silica but higher than standard bioresorbable polymers), wide wavelengths range of optical transparency (from 200 to 2600 nm), and a tailorable dissolution kinetics (depending on the content of MgO added to the composition). Furthermore, the proposed glass is thermally stable, i.e. can be processed both in the extruder and in the drawing tower. In this work, we will report on the recent steps taken by our research group toward the fabrication of directly-extruded microstructured fibre preforms made of a bioresorbable phosphate glass.

There are many ways to fabricate a preform and its quality directly impacts on the surface of the produced optical fibre. Compared to standard stack-and-draw or rod-in-tube techniques, extrusion displays the advantage of allowing a higher degree of complexity of the fibre, especially regarding asymmetrical or non- cylindrical preforms. However, a careful tuning of each extrusion parameter must be achieved to obtain a good quality preform. Several extrusion experiments have been carried out with different glass preforms' shapes. Analyses of these preforms by means of Optical Profilometry and Atomic Force Microscopy have been carried out to assess the roughness of the surface of the extrudate. To support the production of an optimized die for the preform extrusion, a simplified laminar flow model simulation has been employed. This model is intended as a tool for a fast and reliable way to catch the complex behaviour of glass flow during each extrusion and can be regarded as an effective design guide for the dies to fulfil specific needs for preform fabrication. Particularly, different die shapes were analysed, so as to determine which would lead to a better result in terms of symmetry of the shape and homogeneity of the flow distribution. After die optimisation, extrusion of a capillary was realised, and a stacking of extruded tubes was drawn to produce a microstructured optical fibre made of bioresorbable phosphate glass. The combination of these two properties, i.e. bioresorbability and fibre microstructure, show a promising pathway toward a new generation of implantable biomedical devices.

max. 300 words abstract:

The steps toward the fabrication of directly-extruded microstructured fibre preforms made of a bioresorbable phosphate glass are herein presented. Microstructured fibres show a wide range of applications, i.e. photonic crystal fibres, large mode area fibres, hollow gas/liquid sensors, etc. Nevertheless, the fabrication of bioresorbable microstructured fibres has not been feasible so far due to a lack of bioresorbable transparent glass and more flexible fibre preform fabrication techniques. A custom developed calcium-phosphate glass has been designed and carefully prepared in our laboratory to be dissolvable in a biological fluid while being optically transparent and suitable for both preform extrusion and fibre drawing. This glass has been characterised both in terms of mechanical and optical properties as well as for dissolution in aqueous medium. Furthermore, the proposed glass is thermally stable, i.e. can be processed both in the extruder and in the drawing tower. Several extrusion experiments have been carried out with different glass preforms' shapes. Analyses of these preforms by means of Optical Profilometry and Atomic Force Microscopy have been carried out to assess the roughness of the surface of the extrudate. To support the production of an optimized die for the preform extrusion, a simplified laminar flow model simulation has been employed. This model is intended as a tool for a fast and reliable way to catch the complex behaviour of glass flow during each extrusion and can be regarded as an effective design guide for the dies to fulfil specific needs for preform fabrication. After die optimisation, extrusion of a capillary was realised, and a stacking of extruded tubes was drawn to produce a microstructured optical fibre made of bioresorbable phosphate glass. The combination of bioresorbability and fibre microstructure, show a promising pathway toward a new generation of implantable biomedical devices.