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A novel fibre optic sensor of relative humidity for application in cultural heritage

Rosaria D'Amato, Michele Arturo Caponero, Barbara Palazzo, Gaetano Terranova, Andrea Polimadei

ENEA, FSN-TECFIS-MNF, CR Frascati, viale Enrico Fermi 45 00044 Frascati (Roma) Italy, rosaria.damato@enea.it, michele.caponero@enea.it, barbara.palazzo@enea.it, gaetano.terranova@enea.it, andrea.polimadei@enea.it

***Abstract* – In this work we present a novel relative humidity sensor of low invasiveness and visibility, well suited for applications in cultural heritage and in particular to monitor the moisture content in stone and wooden artworks. The sensor is based on fibre optic technology, produced by depositing a thin coating of a hygroscopic material on a thin and transparent, barely visible, fibre optic. The novelty of the projected sensor is in the proposed hygroscopic material, which is a mixture of Agar and Chitosan. This material overcomes the critical issues of sensors previously described, based on the same technology but produced with different polymers, typically pure Agar. We present results of the tests that proved the effectiveness of the proposed material and the results of long term measurements in the field.**

1. INTRODUCTION

Fibre Bragg Grating (FBG) are fibre optic sensors that have attracted an increasing interest among researchers in a number of applications. The relevance of FBGs is mostly due to their immunity to electromagnetic interferences, their small size and flexibility, as well as the possibility to design minimally invasive sensing systems [1].

Although FBGs are intrinsically sensitive to strain and temperature, FBG-based sensors have been developed for various parameters, as for instance pressure and displacement. Among the large number of applications, FBG-based sensing systems have already been used for relative humidity (RH) measurements [2]. Humidity measurements has become necessary in a number of areas, such as food process, pharmaceutical and chemical industries, structural health monitoring and so on [2]. The monitoring of temperature and moisture plays an important role also in building sector, in particular for the diagnosis of the stone and wood deterioration, even and above all in the cultural heritage conservation field. The FBG technology results to be particularly suitable for applications in cultural heritage due to its characteristics of low-visibility and tailoring to different surfaces [3].

The most popular and effective approach to develop FBG-RH sensors relies on the use of a hygroscopic material. The FBG is coated by this material that changes its volume with humidity (it swells when RH increases); if there is a good adhesion between this material and the FBG, the swelling strains the FBG itself, that can be used to indirectly measure RH [4].

Recently Agar and Agarose were used as hygroscopic materials for preparation of novel FBG-RH sensors. Agarose, the major component of Agar, is an algal polysaccharide, comprising alternating D-galactose and 3,6-anhydro-L-galactose repeating units. With its excellent ability to form thermo-reversible gels in hot water, Agar finds numerous applications, which include food industry, pharmaceutical formulations, electrophoresis, tissue engineering or as a matrix for soft-matter organic devices [5-7]. This fact could render FBG- RH sensors suitable for monitoring in the above cited applications, beyond cultural heritage.

The use of these polymers has advantages respect to other materials for the ease of preparation and coating stages, for the wide range of operation in terms of RH values and for the fast response [8, 9].

The swelling nature of hygroscopic materials causes also refractive index changes in accordance with the humidity and modulates the light propagating through the fibre. The latter phenomenon has been employed in the design and development of fibre optic humidity sensor in which the swelling polymers are chitosan and agarose [10].

In the same way as Agarose, Chitosan is a renewable and biocompatible biopolymer. Chitosan is a linearly linked polysaccharide derived from natural biopolymer chitin, and composed of randomly distributed (1–4)- linked D-glucosamine (deacetylated unit) and *N*-acetyl- D-glucosamine (acetylated unit). Because of its biocompatible, non-toxic, antimicrobial and metal- binding properties, it has been widely studied in chemical, biochemical and biomedical fields, and it is extensively used in pharmaceutical and biomedical fields [11]. However, the same characteristics may render it suitable for sustainable cultural heritage approaches [12]. Chitosan chemical nature renders its swelling properties highly dependent not only onto the starting material characteristics (*i.e.* molecular weight and deacetilation degree), but also on the device preparation process parameters (*i.e.* polymer concentration and acid content.