Selectively tuning the temperature and humidity sensitivity of CYTOP fibre Bragg grating sensors

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Polymer optical fibre Bragg grating (POFBG) sensors received high interest from the scientific community due to the unique physical, mechanical, and optical properties of polymers used to fabricate the fibres. Compared with their silica counterparts, polymer optical fibre (POF) sensors have higher fracture toughness, more bending flexibility, enhanced mechanical sensitivities (such as stress, force, and pressure) due to their lower Young's modulus, and ability to detect humidity in the case of water-absorbing polymers. Another distinct characteristic of polymers is their negative thermo-optic coefficient, which can be utilised for compensation purposes and tackle the cross-sensitivities issues arising in the multiplexed sensing systems. The drawbacks of POFs are the high optical attenuation, hysteresis effects observed during stress-strain load cycles, low temperature operating range, and variate material properties under various environmental and physical conditions. Due to the complicating nature of polymers, inconsistent or non-linear responses of POFBG sensors were reported during temperature and humidity measurements. By exposing the polymer below its glass transition temperature but accidentally above its β-transition temperature (known as thermal annealing), the fibre can shrink in length, and the material properties can be significantly modified. The sensitivity of sensors when monitoring temperature can also change when the polymer absorbs water or when the fibre is under mechanical tension (axial strain). The fibre pre-strain effects were previously investigated, indicating that the applied pre-strain reduces the thermal expansion coefficient (positive in value) that counteracts the thermo-optic coefficient (negative in value), which both determine the temperature sensitivity of the POFBG sensor. The applied fibre pre-strain can also affect the swelling coefficient, which determines the sensor's sensitivity to humidity.

In this work, we demonstrate the possibility of tuning the temperature and humidity sensitivities of POFBG sensors to the desired level by applying a specific amount of fibre pre-strain. In addition, the sensors were fabricated in a novel low-loss optical fibre with a core made of Cytop (high-transparent amorphous fluoropolymer) and a cladding made of Xylex (blend of polycarbonate and polyester). Thermal annealing treatment was also utilised to increase the operating temperature range and improve the performance of sensors. No hysteresis effect has been observed during strain characterisation, with measured sensitivity being 1.27±0.01 pm/με. By utilising fibre pre-strain, the temperature sensitivity of sensors can be tuned from -70±1 pm/°C to 21±1 pm/°C, and the humidity sensitivity from 0.7±0.1 pm/%RH to 11.7±0.1 pm/%RH. An array of 4 POFBG sensors with selectively tuned temperature and humidity sensitivities along the same fibre piece has been demonstrated.