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Diamond-Coated Fibre Bragg Grating Sensors for Radiation-Hard Environmental Monitoring in High-Energy Physics

Fibre-optic sensors (FOS) are attractive for environmental monitoring in high-energy physics (HEP) experiments due to their small size, multiplexing capability, immunity to electromagnetic interference, and potential radiation tolerance. However, the development of radiation-hard fibre sensors capable of monitoring parameters such as humidity remains challenging for future detector environments. This work investigates diamond-coated fibre Bragg gratings (FBGs) as a potential platform for radiation-tolerant humidity sensing, motivated by the exceptional radiation hardness, chemical stability, and surface sensitivity of diamond.

Boron-doped FBGs were functionalised with nanodiamond coatings using a dip-coating approach, with the coating process investigated as a function of deposition cycles. The coated sensors were characterised alongside bare boron-doped FBGs and conventional polymer-coated FBG humidity sensors under controlled relative-humidity cycling. Preliminary measurements show that the nanodiamond-coated FBG exhibits a repeatable humidity-dependent change predominantly in reflected optical power, while comparatively little change is observed in Bragg wavelength or spectral width. This behaviour differs from the wavelength response of polymer-coated FBGs, where humidity-induced swelling produces strain transfer to the fibre. The observed optical-power response of the diamond-coated sensor suggests that the sensing mechanism may instead originate from humidity-dependent interactions at the diamond-coated fibre surface and associated changes in optical attenuation.

The response during increasing and decreasing humidity cycles is further investigated to assess sensitivity, reversibility, hysteresis, and adsorption/desorption behaviour. Scanning electron microscopy is used to correlate coating morphology and nanodiamond coverage with the optical response. The study forms part of a broader programme investigating radiation effects and radiation-hardening strategies for fibre-optic sensors intended for particle-detector environments. Future irradiation studies will determine whether diamond functionalisation can provide a viable route towards robust, radiation-tolerant environmental sensors for HEP detector systems.

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