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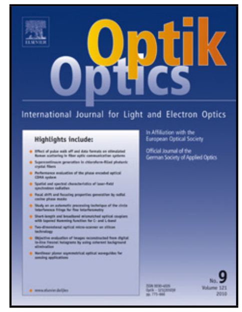

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Fiber optic index sensor enhanced by gold nanoparticle assembly on long period grating

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The sensing performance of long period grating (LPG) in integration with colloidal gold nanoparticles (LPG-AuNPs) is investigated. An LPG coupled with a higher cladding mode of $LP_{0,10}$ is fabricated on single mode fiber (SMF) with higher sensitivity to refractive index compared with lower cladding modes such as $LP_{0,2}$, $LP_{0,3}$ and $LP_{0,4}$ via symmetric CO_2 laser irradiation. A bilayer of poly (allylamine hydrochloride) (PAH) and gold nanoparticles is deposited on the grating portion via layer-by-layer self-assembly technique. It is found that the sensitivity is increased from 460 nm/ refractive index unit (RIU) to 759 nm/RIU using the LPG-AuNPs.

Key words: Long period grating, sensor, Au nanoparticle, layer-by-layer

Optics techniques have been considered as a powerful tool for many sensing applications [1-5]. Particular attention has been focused on the optic fiber long period grating (LPG) based sensor owing to their advantages such as low insertion loss, electromagnetic field immunity, simple fabrication, low back reflection and fast speed. For the above reasons the LPG has been used for a wide range of applications in both optic fiber communication applications such as band-rejection filters [6], gain equalizers [7], and dispersion compensation [8], as well as in optic sensing systems such as gas, chemical and biological sensors [9-15]. The resonance condition for light coupled from the fundamental core mode to the co-propagating cladding mode is governed by the phase matching condition $\lambda_i=(n^{eff}_{core}-n^{eff}_{clad(i)})\Lambda$, where λ_i is the resonance wavelength of the ith cladding mode, and n^{eff}_{core} and $n^{eff}_{clad(i)}$ are the effective refractive indices of the fundamental core mode and the ith cladding mode, respectively. The mode coupling results in a series of attenuation bands in the transmission spectrum of the LPG. A part of the power distribution of the cladding mode extends to the surrounding of the cladding as the evanescent field, thus the cladding attenuation is dependent on the optical properties of the surrounding media. This makes the LPG an excellent candidate for refractive index (RI) and chemical sensing. By careful design, the LPG can be extremely sensitive to the RI of the surrounding media. For example, recent study shows that the higher the cladding mode, the higher the sensitivity is to the deposition of the thin film in the portion of grating for an LPG fabricated in SMF-28 [16]. At the same time, the integration of optical fiber and nanomaterials such as gold or silver nanoparticles has drawn a lot of interest due to their foreseen prospect in high sensitivity, special functionality and specific response, resulting in the potential applications in chemical and biological sensing [17-19]. Sergiy Korposh et al. demonstrate the ability of LPG modified with a film nanoassembled by the alternate deposition of SiO_2 nanoparticles and poly(diallyldimethyl ammonium chloride) (PDDA) to obtain quantitative measurements for the detection of organic compounds that can be infused into the porous film, which changes the RI of the film [20]. Another study demonstrated an improved RI sensitivity from -17.93 nm/ refractive index unit (RIU) to -23.45 nm/ RIU by incorporating a layer of colloidal gold nanoparticles (AuNPs) on the LPG fabricated in SMF-28 [21]. There are several approaches for the deposition of thin films of sub-μm thickness onto the portion of LPG, such as electrostatic self-assembly (ESA) [18], Langmuir-Blodgett (LB) [17], layer-by-layer (LbL) self-assembly [16] and dip-coating [22, 23] techniques. Several research groups have demonstrated optical sensors for sensitive and selective measurements for pH, humidity, and chemical and biological components [24–31] though surface modification of the LPG.

In this study we explored the enhancement of the sensing performance of LPG with AuNPs. Since high-order cladding modes such as LP $_{0,10}$ in LPG are significantly more sensitive than their lower-order counterparts [16], $LP_{0,10}$ is coupled in the LPG during the fabrication process in order to achieve a high RI sensitivity. Au NPs were prepared by adding 4mL 1% aqueous sodium citrate into 40 mL 5 mM $HAuCl_4$ solution, which was exposed to UV lamp for 30 min under stirring [32]. A bilayer of polyelectrolyte poly(allylamine hydrochloride) and AuNPs with the average diameter of ~50 nm is deposited on the LPG through the LbL assembly technique. The LbL process is an efficient way for the deposition of functional coatings on the LPG in that it is easy to control the coverage density and thickness of the coating by changing the deposition conditions such as pH of the polyelectrolyte solution, concentrations and layer number. The LPGs with and without the AuNPs are used for the RI sensitivity test. It has shown that the LPG with AuNPs has a sensitivity of 759 nm/RIU, whereas the LPG without AuNPs has a RI sensitivity of 460 nm/RIU.