L.10: Studies on Fiber Bragg Grating (FBG) for chemical sensing

A FBG based refractive index sensor has been developed in Laser System Engineering Section (LSES) of RRCAT for sensing different chemicals. For this purpose, the cladding around FBG is partially removed by HF etching to make it sensitive to changes in the surrounding medium refractive index. Then the clad etched FBG was used to test the solutions of different refractive index medium. Sensitivity of the etched FBG was monitored in air, ethanol and ethylene glycol.

The experimental set-up for HF based etching and external medium sensing is shown in fig. L.10.1. It comprises of a home written FBG, a broad band ASE source (1525 - 1600 nm), a 3 dB directional coupler to collect the reflected spectrum from the sensor head, and an optical spectrum analyzer (OSA) to monitor the changes in the Bragg grating reflection wavelength. A microscope was used to measure the cladding diameter of FBG at different stages of the etching process.

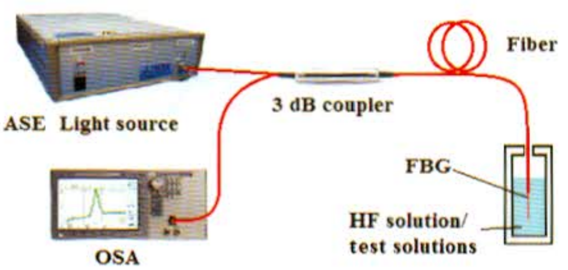

Fig.L.10.1 FBG clad etching/refractive index sensing set-up

The UV exposed region of the gratings is etched with 40% HF solution. During the process of etching, the room temperature was maintained at 25°C. As the optical fiber without acrylic coating layer is immersed in an etching liquid, the cladding is etched gradually and the clad radius decreases.

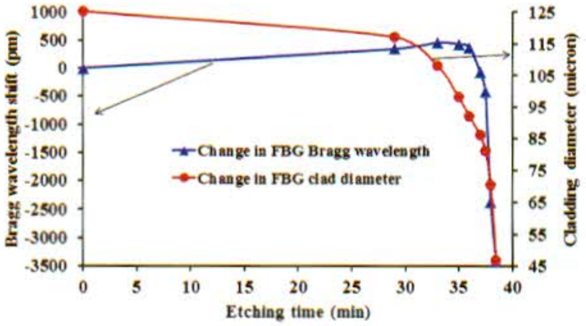

Fig.L.10.2 Shifts in Bragg wavelength and FBG cladding diameter with etching time.

The shift in the Bragg wavelength and cladding diameter were recorded with respect to etching time. Figure L.10.2 shows the variation in Bragg wavelengths and FBG cladding diameter with etching time.

It is clear from the fig. L.10.2 that during etching, the Bragg wavelength shifted from 1533.948 nm to 1534.406 nm in 35 min and after this the Bragg peak shifted drastically to 1530.879 in the next 3 min. The initial increase in Bragg peak was due to generation of heat caused by chemical reaction of HF with silica glass. After about 35 minutes, the Bragg peak started to decrease as a consequence of decrease in effective refractive index caused by cladding diameter reduction. The average etching rate of cladding diameter was around 2.03 μm /min. The chemical sensing of FBG is based on the change in the Bragg wavelength with surrounding medium refractive index, as given by :

$$\delta\lambda_B = 2\,\Lambda\,\delta\eta\,(n_{sur} - n_{cl})$$

where Λ is grating period, $\delta\eta$ is the change in the fraction of the total power of the unperturbed mode that flows in the etched region, n_{cl} is cladding refractive index and n_{sur} is surrounding medium refractive index. From above equation, it is clear that the difference in the surrounding medium refractive index and clad refractive index decides the shift in the Bragg peak wavelength shift.

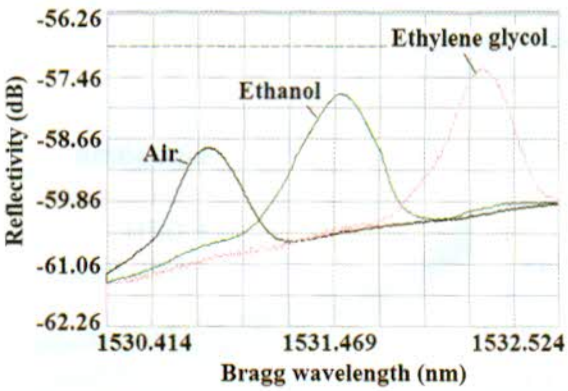

Fig.L.10.3 OSA traces showing Bragg wavelength shift for air, ethanol and ethylene glycol

This etched FBG was immersed in the solutions of ethanol and ethylene glycol. The corresponding Bragg peak wavelength shifts are shown in Fig. 3. The Bragg peak wavelength difference from air to ethanol was about 684 pm and from air to ethylene glycol was 1266 pm. Refractive index sensitivity was 1900 pm/refractive index unit (RIU) for ethanol and 3014 pm/RIU for Ethylene glycol.

The developed FBG sensor has potential to measure different degree of contaminations in chemical/biochemical samples.

Reported by:
O. Prakash (oprakash@rrcat.gov.in) and J. Kumar