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A robust optical fiber sensor for the detection of petrol adulteration

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ABSTRACT

An intrinsic intensity modulated no core fiber sensor (NCFS) is presented in this paper for rapid detection of adulteration in petrol with kerosene. The sensing principle is based on the phenomenon of absorption of evanescent waves. The sensing head of NCFS is fabricated by stubbing a small section of no core fiber (NCF) between two multi-mode fibers (MMF). A high sensitivity 390 nW/% and 110 nW/% are obtained by the proposed sensor for low and high level of adulteration. The intensity variation and confinement loss with different concentrations of the kerosene in petrol are then verified theoretically by using finite element method. It is found that the theoretical results agree very well with experimental results. The proposed sensor exhibits fast response time and good repeatability in addition to its high sensitivity. The sensor can be useful in industries and automotive companies due to its small size, easy to fabricate, safe with inflammable fuels and required small amount for detection.

1. Introduction

Last few decades have witnessed the considerable progress in the fabrication and improvement of optical fiber based sensors in industry for chemical sensing [1–7]. The optical fiber based sensors offer several benefits over the conventional sensing mechanism especially small in size, immune to electromagnetic interference and capable of using in hazardous media [8–10]. The optical fiber based sensors are categorized in refractometric sensor and the sensor based on evanescent wave absorption. The first kind of sensor is based on the change in intensity while the evanescent field of propagated light is absorbed by surrounding media [11–14] in the second type of sensor.

Amongst all kinds of fuel, petrol has great importance in daily life. The petroleum product is the back bone of economy of any country. Due to its huge demand, petrol prices are increasing day by day and so its adulteration. The kerosene is the cheapest domestic fuel of our society and is available on subsidized rate. Adulteration of kerosene in petrol is a very common malpractice to earn high profit because of its easy miscible nature. This illegal adulteration not only leads in unavailability of kerosene to poor but it also affect the function and performance of engine and causes the environmental pollution [15]. There are many processes available in market to check the adulteration of petrol like filter test, titration technique, viscosity and density check, flash point, odor based method, ultrasonic technique, etc. [16–20]. All the methods proposed above have several limitations in term of sensitivity, rigorous method and accuracy level.

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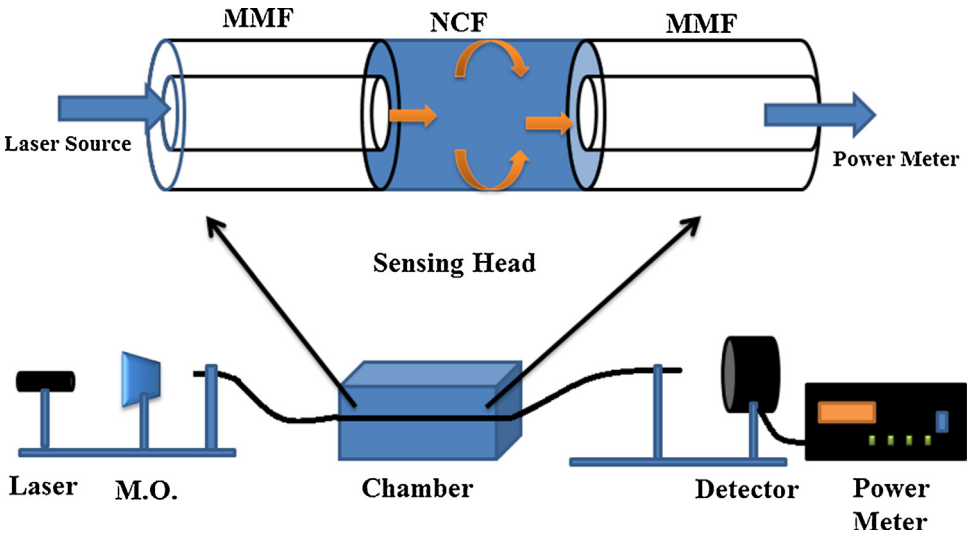

Fig. 1. Schematic diagram of experimental setup used for characterization.

Various types of optical fiber based sensors have been already reported to determine the adulteration of engine fuel [21–25]. These sensors use tapering method and modified sensing structure in order to enhance the sensitivity. These structures may enhance the sensitivity; however they suffered various drawbacks like cross sensitivity, fragile and difficult to move from one place to other.

In this study, the petrol adulteration is investigated experimentally and verified using theoretical simulation. Intensity modulated NCFS is proposed for detecting adulteration of petrol using the evanescent wave absorption principle. The experiment was performed several times for petrol of same concentrations to obtain the accurate result. The proposed sensor is less fragile as it does not require any tapering to enhance the sensitivity and also have fast response time of 5–6 s.

2. Theory and principle

It is well known that the disappearance of core in NCF leads enhancement of power in evanescent waves (EW) [26]. The proposed sensor transfers the light from guided modes to leaky modes [27] and hence there will be an interaction between evanescent waves and surrounding environment. When the launched light is reflected at the interface of NCF and adulterated fuel, the field associated with waves will extend beyond their boundary in adulterated media which is referred as evanescent field. When this evanescent field interacts with adulterated fuel, it results in the attenuation of output power of launched light due to absorbing nature of outer media. The transmission of power in NCF can be correlated with Lambert-Beer's law of absorption [28,29] which may be written as

$$P(l) = P_0 \exp(-f\alpha l) \tag{1}$$

Here Eq. (1) represents the standard form of lambert beers' law. Where, f is the fraction of power propagated through fiber and α may be termed as evanescent absorption coefficient and l is the distance along fiber length.

3. Experimental setup

The schematic diagram of experimental setup is shown in Fig. 1. It consists of fabricated sensor, laser source (632.8 nm), microscopic objective (MO), liquid chamber and detector. A small section of NCF of 3 cm length was stubbed between two MMF using fusion splicer Type-39 [30] to form sensing probe. The core/cladding diameter of used MMF is 50/125 μm and NCF has diameter 125 μm. The fibers were purchased from thorlab. When the laser light was launched into one end of MMF it gets splitted in NCF and again gets recoupled in another MMF. The output power was recorded by power meter.

4. Result and discussion

In the experiment, the sensing head was immersed completely in adulterated petrol. To increase the adulteration the kerosene was added drop wise in petrol solicited from local outlet of Bharat Petroleum. The refractive indices of different concentrations of adulterated petrol were measured by using abbe's refractometer (DR 194). The RI of pure petrol and kerosene was measured to be 1.433 and 1.392 respectively. Fig. 2(a) and (b) show the variation in refractive index and absorbance with different concentrations of kerosene. It is clear from Fig. 2(a) that RI of petrol increases first rapidly with concentration till about 15% and then increases gradually. The absorbance of adulterated petrol was measured by visible