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Soil Character Analysis via Wide Band Optical Wave Guide Sensor

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Abstract

In present studies, the new optical sensing platform based on planar optical waveguide (OPWG) for soil element estimation was reported. Different fertilizer, chemical, bio fertilizer etc. were physically entrapped and claded on the surface of optical planar waveguide. Ag^+/K^+ ion-exchanged glass optical waveguides were prepared and employed for the fabrication of soil sensor. The fabricated sensor showed concentration dependent linear response in the range of different fertilizer samples. This indicates that the developed sensor has higher sensitivity towards bio fertilizer as compared to earlier reported sensors using various systems. The proper confinement of composite metal ions was confirmed by scanning electron microscopy (SEM) images. The constructed OPWG sensor is versatile, easy to fabricate and can be used for soil element measurements with very high sensitivity.

Keywords: Planar Optical Wave guide; Soil; Fertilizers.

Introduction

Over the last two decades there has been significant interest in rare-earth-ion-doped planar waveguide sensors [1-9] for number of optical applications. Low-cost, compact components can be very useful for optical signals transmitting process [8]. The first optical waveguide sensor (OWS) has been described in 1980s [3, 4]. A highly sensitive OWS biochemical sensor was constructed using grating couplers [5]. The chemical/biological sensing applications of integrated optical techniques have been a subject of various research undertakings. The optical sensing techniques have several advantages over electrical methods such as high sensitivity, imperviousness to electromagnetic interference and safety in detection of combustible and explosive materials. A typical planar optical waveguide (OWS) consists of a substrate and a thin top layer (waveguide layer) with refractive index larger than that of the substrate; the covering material (clad) is usually air. An interesting feature of such waveguides is that the electric field associated with a light wave propagating in the waveguide layer is very strong at the surface of the OWS; hence, highly sensitive optical monitoring can be performed for chemical species located at the OWS surface on the basis of absorption and scattering of the guided light.

In this paper, the fabricated sensor showed the concentration dependent linear response in the range of different fertilizer samples. This indicates that the developed sensor has higher sensitivity towards bio fertilizer as compared to chemical fertilizer.

The proper confinement of composite metal ions was confirmed by scanning electron microscopy (SEM) images. The constructed OPWG sensor is versatile, easy to fabricate and can be used for soil element measurements with very high sensitivity.

Experimental Work

A planar waveguide is fabricated on a soda lime microscope glass slide of size 76 mm × 26 mm × 0.8 mm, refractive index (RI) = 1.515. The composite ion-exchanged optical wave guide (OWG) having a major limitation for the sensitivity of conventional Ag^+ - ion-exchanged OWGs is the large attenuation of propagating light, mainly due to the roughness of the OWG surface [1-7]. Composite glass ion-exchanged OWG overcome this problem by combining a low-loss K^+-ion-exchanged OWG with a highly sensitive Ag^+-ion-exchanged OWG on a glass substrate using a tapered velocity coupler as shown in Figure 1. The attenuation losses due to surface scattering are here restricted to the comparatively small high-sensitivity region of the surface. To obtain this structure, a preheated glass substrate was first dipped into molten KNO_3 and $AgNO_3$ at 350 ^{0}C for 30 min. Then, a piece of frosted glass covered with a thin layer of $AgNO_3$ mixed with KNO_3 was fixed onto the K^+-ion-exchanged glass OWG with a clamp. The Ag^+-ion-exchange takes place at the surface of the K^+-ion-exchanged glass OWG, but there is no further diffusion of K^+ ions at this temperature. In Figure 1, the arrow shows how the guided light is transferred from one part of the OWG to another part via. adiabatic transition.

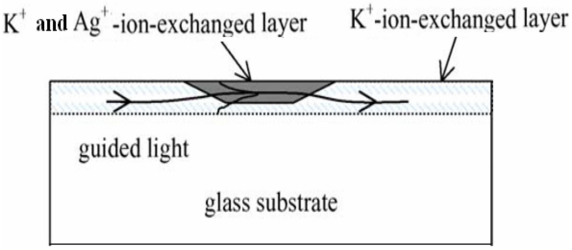


Figure1. Structure of the ion-exchanged composite OWG.

Results and Discussions

Characterization of optical waveguide sensor

The results obtained from the experimentation gives Na^+ ion exchange with K^+ and Na^+ ion exchange with Ag^+ system. OWG is a very useful material for electron transport study or measurements because of its very high electrical receptivity and dielectric strength. However, though chemical synthesis and modifying the functional material, it is possible to achieve both chemical stability and a wide range of electronic properties. The material characterization includes X-ray diffraction, scanning electron microscopy (SEM) and EDAX of the selected optimized samples. The waveguides prepared at the different exposure time were then tested by coupling with laser and measured the change in resistance of the LDR of the detector circuit.

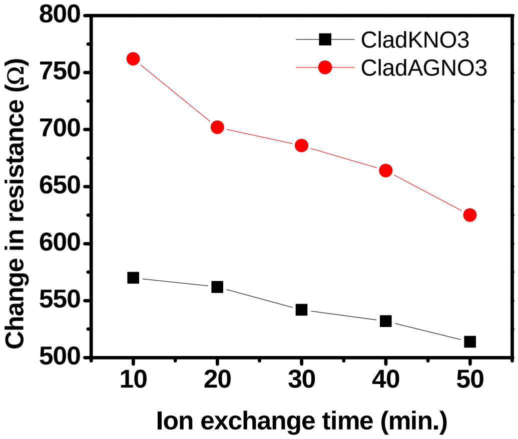


Figure 2. Variation of change in resistance across the detector with ion exchange time

From Figure 2, it seen that with increasing ion exchange time the resistance across the detector is decreasing. It indicates that with increasing time, the exchange of ions are more in number i.e. concentration of K^+ ions are more on the surface and hence in 50 min. time, the exposure Na^+ replaced by K^+ is more and Na^+ replaced by Ag^+ is more also it is enhanced after cladding as can be seen in Figure.

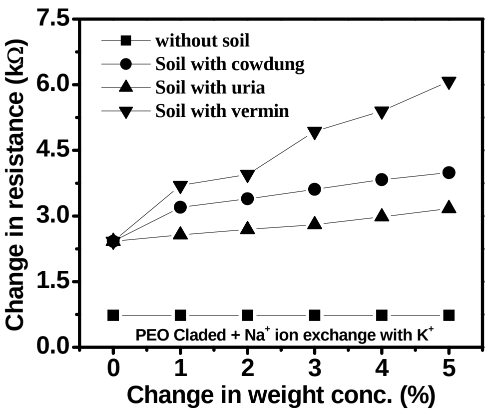
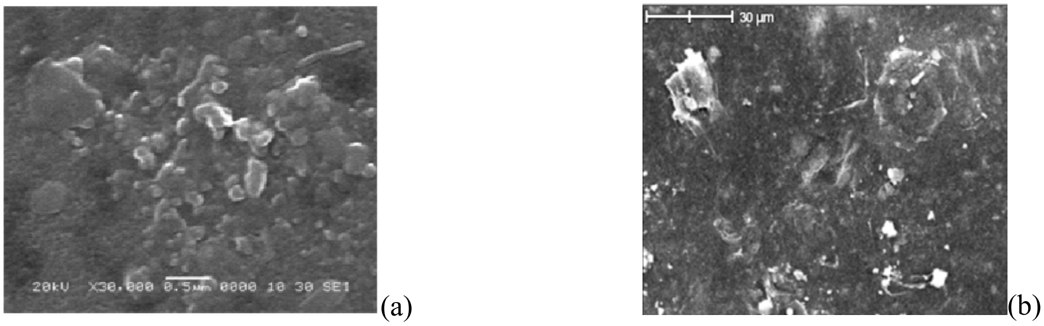


Figure 3.Variation of change in resistance of PEO Cladded with Na^+ exchange with K^+ samples with change in weight concentration

From the Figure 3, it is seen that the change in resistance is increases with increase in concentration of fertilizer. It is also observed that the resistance increases more in case of vermin compost as compared with cowdung and urea. It may be because of more nitrogen releases in case of vermin compost fertilizer.

Material characterization

Figure 4 shows the SEM micrographs of the films of various ion exchange samples. In Figures 4 (a) and b, void size appears to be the almost same. The number of pores is increasing and their size appears to increase during ion exchange process. Figure 4(b) shows agglomeration of particles with least number of pores. The EDAX of the samples shows the presence of K and Ag elements on the surface of the samples (EDAX not shown). The refractive indices (RI) of clads are less than guide RI as required for waveguides. These are higher than air RI. Therefore, they offer higher transmission loss and more leaky field in the clad [1-6].



(a) (b)

Figure. 4 SEM images of films of (a) K^+ and (b) Ag^+ ion exchange samples

The leaky field increases with increase in RI due to adsorbed moisture and gas. The porous nature of the clad allows light to penetrate deeper inside the clad elongating evanescent field of guide into the clad. During this process, some part of the light reflects back to the guide from clad guide interface or scatters from the pores of the clad and overlaps with evanescent field of guide at the clad-guide interface. This maintains the coupling between the guide and the clad [5-11]. It is reported that the porosity provides a large number of scattering centers, which effectively acts as luminescence centers due to scattering and enhance the light intensity in the clad region in addition to the elongation of evanescent field [9, 10]. The increase in clad width provides larger area for water adsorption increasing the sensitivity with length. Further, decrease in sensitivity for clad width greater than 3 mm may be due to the absorption of light by the material itself. The Ag^+ nanocomposite is more sensitive to humidity in comparison to potassium K^+. This clearly shows that Ag^+ nanoparticles play an important role in enhancing the humidity sensing as well as nitrogen sensing. The plants need nitrogen for many important biological molecules including nucleotides and proteins. However, the nitrogen in the atmosphere is not in a form that plants can utilize. Many plants have a symbiotic relationship with bacteria growing in their roots: organic nitrogen as rent for space to live. These plants tend to have root nodules in which the nitrogen-fixing bacteria live. Not all bacteria utilize the above route of nitrogen fixation. Many that live free in the soil utilize other chemical pathways.

Conclusions

An optical waveguide sensor has been proposed that is potentially suitable for detecting nitrogen and moisture contain in the fertilizer mixed soil. Ag^+ nanocomposite clad on a planar optical waveguide can serve as an excellent candidate for optical sensing. This sensor is repeatable, reproducible with fast response and recovery. The added advantages of the sensor are small size, less cost and easy fabrication.

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