PEO embedded planer optical waveguide sensor for unidentified soil character analysis

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Abstract

In this manuscript we have investigated the fabrication of PEO embedded planar optical waveguide (POW) sensor. To improve the sensing characteristics of POW, it has coated with conducting polymer poly ethylene oxide (PEO). The embedded waveguide prepared with variant thermal ion exchange process with various time duration of 20,40,60,80,100,120 minutes on sodium silicate glass. The properties of modified planar optical waveguide enhance the sensing activity, which can help to study the characteristics of soil by doping of different fertilizers with x wt% (x=1, 2, 3, 4, 5) of varying concentrations. The use of appropriate percentage of fertilizer in different soil yield good healthy crop. The laser technique is used to study the POW for characteristics of soil. The material characterization study done by scanning electron microscopy (SEM) and small angle X-ray diffraction (XRD) revealed the formation of K^+ ions layer in surface-near regions of the sample at optimum expose time period of 120 minutes at 380 ^{0}C. It gives an advantageous application for unidentified soil character analysis. Copyright © 2017 VBRI Press.

Keywords: Planar optical waveguide (POW), sensor, PEO, red sandy loam soil, fertilizers.

Introduction

Metal nanoparticles have attracted considerable interest in a variety of fields, due to their intriguing optical properties attributed to their surface Plasmon resonance [**1-7**]. The potassium–sodium ion exchange planer optical waveguide is used frequently to obtain composite materials with specific linear and nonlinear optical properties. From very recent studies on silver nanoparticles of a few nanometres in size based planer wave guide with appropriate reflective index variation is achieved by low temperature thermal ion exchange method [**4, 8-13**]. However, this requires a certain tuning of the ion exchange parameters as well as selection of suitable composition of the glass and sample geometry [**9-16**]. A hot-bath deposition is the most practical route for synthesis of K^+ ion, but the control of size distribution, particle morphology, and crystallinity still need further exploration [**15-21**]. In the present study the synthesized K^+ ions embedded sodium silicate glass substrate structured thin layer coated with poly ethylene oxide (PEO) and its physical properties are studies for soil element analysis are reported. The endeavor behavior has been dedicated to the preparation of K^+ ion exchanged planar optical wave guide (POW) via chemical heat bath route ion exchange technique. In addition, the novel characteristics of this class of materials formulate them in fact striking for a number of Bio-technologies, agricultural applications and biochemical sensors.

Experimental

Materials

In present study the commercially available potassium nitrate (≥99 % KNO_3) and Poly ethylene oxide (≥ 99 %,$C_{2n}H_{4n}$+$2O_{n+1}$) were obtained from (S.D. Fine Chem. Limited). All the nitrates were used without further purification for thermal ion exchange method. In this method the Potassium ions incorporation in soda lime glass by thermal ion exchange treatment. The commercial soda lime glass substrate of dimensions 25 x 75 x 0.9 mm with refractive index (RI = 1.515) glass substrates were cleaned by acetone and IPA in an ultrasonic bath, and then by piranha solution before the ion exchange.

Synthesis of K nano particles embedded in glass

The float glass surface that contains different ingredient owing to the glass fabrication process has been removed by the ultrasonication procedure before the K^+ ion by ion exchange process. Potassium particles embedded in glass were synthesized by ion exchange process. A pre-cleaned soda lime glass substrate was immersed into KNO_3 bath during the process at 380 °C for different time duration from 20-120 minutes to exchange K^+ ions into the glass. The potassium ions were introduced into the glass network by an isothermal ion exchange with KNO_3 at 380^o C and obtain the exchange optimum time period upto120 minutes.

Characterizations

In order to characterize the shape and size of the K NPs embedded glass sample was confirmed by X-ray diffraction using ['Phillips', Model 1729] X-ray diffractometer (Cu Kα λ=1.5406 Å). Energy dispersive X-ray analysis (EDAX) (Leica 440 Model) study was also carried out for elemental analysis. The lateral distributions of particles were studied by using the scanning electron microscopy SEM (Leica 440 Model).

Device fabrications /Response measurements

The Optimum planer optical waveguide (POW) samples in the form of glass substrate installed on XYZ platform of the closed home built characterization system as shown in **Fig. 1**. The standard laser of Laser diode of 680 nm, wavelength are focused on K^+ ion exchange and PEO modified POW are focused for the corresponding change in intensity. The change in intensity is recorded with and without soil sample placed over the surface. The samples were tested for soil element analysis.

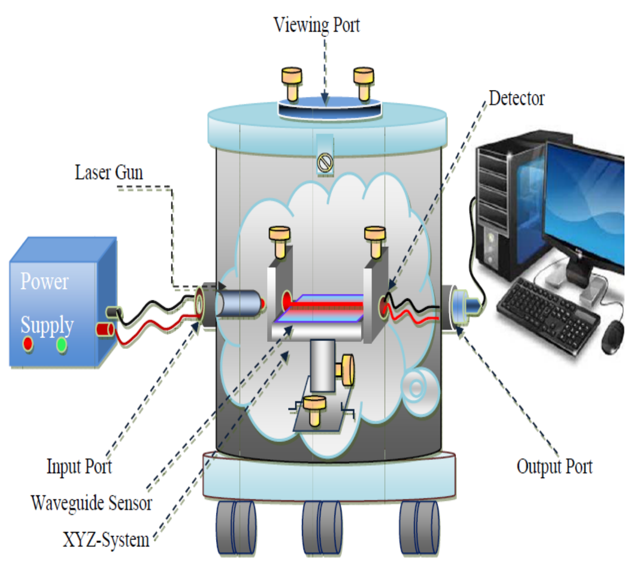

Fig. 1. Experimental setup for characterization of Planer optical waveguide (POW) for Soil character analysis.

Results and discussion

Nano crystal characterization

From **Fig. 2(a)** and **(b)**, the SEM photograph clearly reveals that the presence of potassium ions on the surface and which were transformed into crystalline potassium ions. The **Fig. 2(a)** shows the less concentration of K^+ layer is form on the surface while in **Fig. 2(b)** is show uniform distribution of K^+ concentration and some agglomeration is obtained on the surface which gives the batter sensitivity and selectivity performance for 120 minutes optimum POW sample.

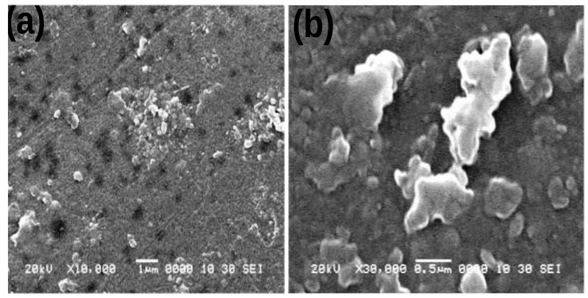

Fig. 2. SEM images of POW samples K^+ ion exchange at (a) 20min, (b) 120 minutes**.**

Fig. 3 shows the XRD spectrum of an ion-exchanged sample. The broad band peaked around 20±25° is typical for soda lime glass and also Some reflections of Na^+ ions also been seen in figure by exposed samples (202). The most common diffraction peaks at 2θ= 23.83º, 29.40º, 32.82º, 44.12º and 46.60º were observed for the planes having miller indices (021), (012), (112), (202) and (113) seen in figure indicates the presence of K^+ on the active surface of POW. From above discussion, we can say that the phase of glass substrate after ion exchange and heating at 380^oC. The replacements of Na^+ with K^+ ions are taken place due to the chemical reaction between Glass substrate and KNO_3.

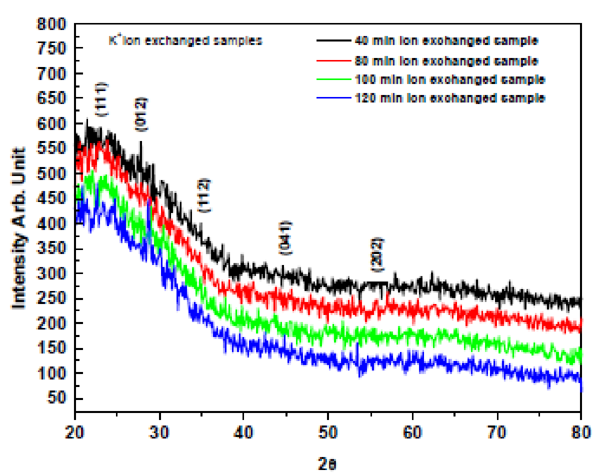

Fig. 3. The XRD patterns of various time duration K^+ ion exchange samples**.**

Sensor specification study.

The sensing behavior of the planer optical waveguide is used to study the effect of fertilizer on sensitivity factor on red sandy loam (RSL) soil sample. The different fertilizers namely urea and vermicompost fertilizers are used as an additive x wt% (x=1, 2, 3, 4, 5) to study the effect on soil character.

Sensitivity for soil modified with Urea

From **Fig. 4(a)** for K^+ ion exchange sample, the maximum values of SF ~ 780 for S_{120} ±10 min obtained for red sandy loam soil with 5wt% urea modified sample. It is observed that initially sensitivity factor increases from sample expose for 20 minutes ~350, with 5wt% urea modified soil sample and reaches maximum to SF ~ 780, for 120 min. exposed K^+ ion exchange sample. Similarly, for K^+ion exchange PEO coated POW sample [**Fig. 4(b)**], the maximum values of SF ~ 950 for S_{120} ± 10 min obtained for soil modified with urea. These results indicate that the enormous enhancement of the sensitivity factor is observed due to PEO coating on the waveguide sample compare to non-modified K^+ wave guide sample.

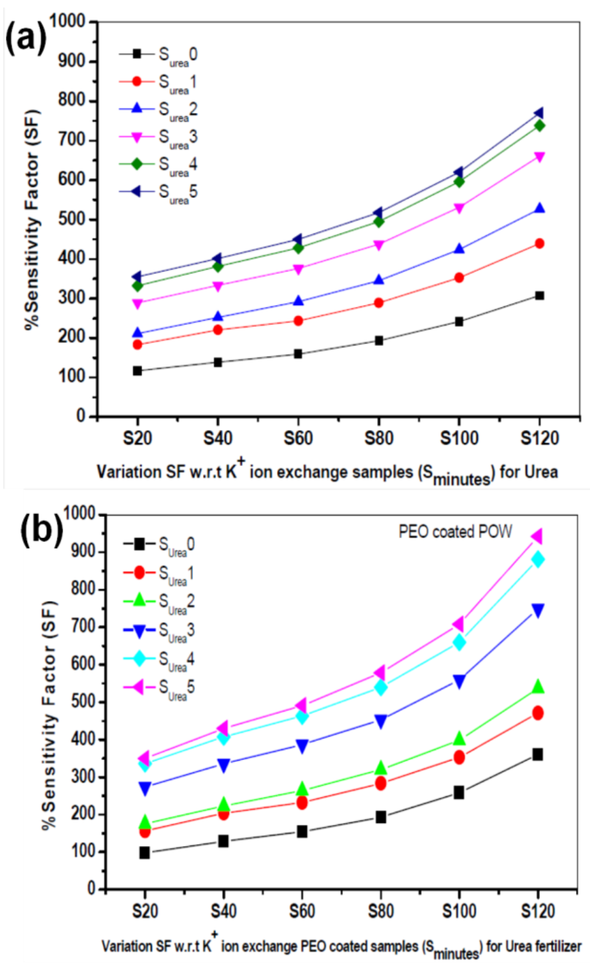

Fig. 4. Variation of sensitivity factor for K^+ ion exchange with and without PEO Coated sample for Red Sandy loam soil modified with x wt% of Urea fertilizer (x = 1, 2, 3, 4, 5).

Sensitivity for soil modified Vermi-Compost

From **Fig. 5(a)**, it is clear that the soil sensing performance of K^+ ion exchanged PEO coated sample for red sandy loam soil modified with Vermi-Compost is considerably higher as compared to K^+ ion exchange sample. The maximum value of SF~950 is obtained for K+ ion exchange sample for red sandy loam soil modified with 5wt% vermicompost fertilizer. Similarly, for K+ ion exchange PEO coated POW samples the highest value of SF ~1100 at S120 ± 10 min obtained for soil modified with 5wt% Vermi-Compost fertilizer. It is monitored that initially sensitivity factor increase form for 20 minutes ion expose sample and increases to maximum for 120 min. exposed POW sample in both the cases.

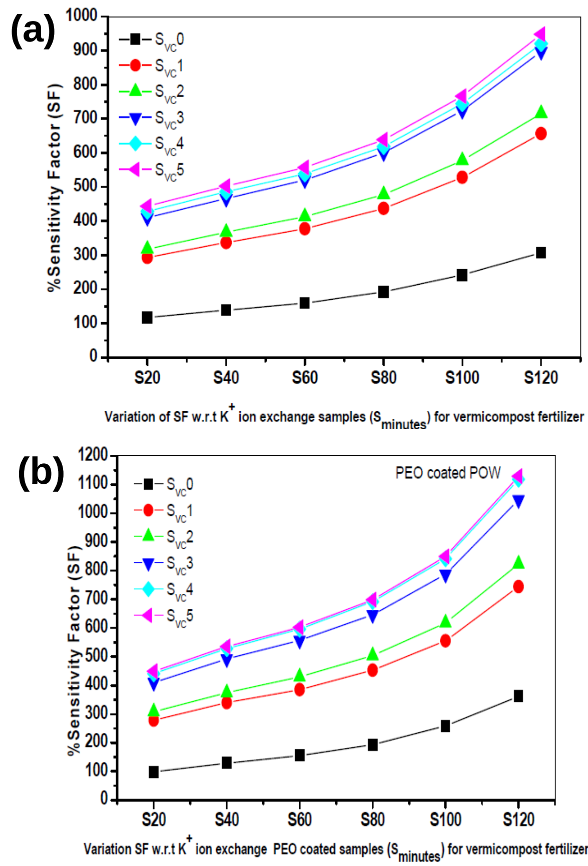

Fig. 5. Variation of sensitivity factor for K^+ ion exchange with and without PEO Coated sample for Red Sandy loam soil modified with x wt% of Vermi-Compost fertilizer (x = 1, 2, 3, 4, 5).

It is clear that the soil sensing performance of red sandy loam soil modified with vermi-compost fertilizer is considerably higher as compared to urea modified soil sample. From the experimental observation it is seen that the interaction of the evanescent field with the cover medium that defines the basis for guided wave optical sensing of biological agents binding to the surface of an optical waveguide. Waveguides have been extensively used for bio-sensing applications [**13, 17, 20, 22-25**]. Detection within the evanescent field allows for enhanced sensitivity of detection, while minimizing non-specific interactions associated with complex biological samples such as fertilizer. This manuscript is a comprehensive summary of the physical and optical properties of planar optical waveguides and elaborates on waveguide-fictionalization for use in soil element analysis.

Conclusion

It is reveal that the soil sensing performance of red sandy loam soil modified with Vermi-Compost fertilizer is considerably higher sensitivity factor as compared to Urea modified soil. It shows the highest value of SF ~1100 at S_{120} ± 10 min obtained for soil modified with 5wt% Vermi-Compost fertilize modified red sandy loam soil whereas the SF for 5wt% urea modified soil is ~ 900. It is concluded that the K^+ ion exchanged PEO coated planar optical waveguide is better sensor for soil character sensing application.

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