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Original research article

Detection of high energetic alpha particle radiation through metal clad planar waveguide based sensor

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A R T I C L E I N F O

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A B S T R A C T

In present communication, the dispersion characteristic, electromagnetic field distribution and performance parameter of a metal clad planer waveguide sensor for detection of high energetic alpha particle radiation is simulate and studied. Using the boundary matching technique, the modal equation and other necessary formulae of proposed waveguide are derived. It is observed that the dispersion characteristics of waveguide have their usual shape in presence of alpha particle radiation. The cutoff film thickness of waveguide decreases with increase of the dose of alpha particle radiation. The TE mode analysis of proposed waveguide based sensor shows the sensitivity, detection accuracy and overall performance are 153.33°/RIU, 5.75 and 1916.67 RIU^{-1}, respectively. Our analysis also shows that the obtained detection accuracy and overall performance of proposed waveguide for TE mode analysis are sufficiently large comparison to the TM mode analysis.

1. Introduction

High energetic particle radiation in environment becomes a serious issue across the world due to its potential hazards to human health and to the global ecosystem. These energetic radiations are also responsible for failure events of electronic devices working in harsh environments. In this regard, the measurement and control of radiation are an important issue in many areas such as cancer treatment, static eliminator, smoke detector, spacecraft power, pacemaker battery, remote sensing stations, coast guard buoys, seismic and oceanographic devices, oil well equipment, heating devices etc. and much attention have paid on the development of suitable radiation sensors [1]. The basic function of these sensors is to provide continuous detection and quantification for reliable monitoring of high energy radiation. In recent years, researchers have reported on the passage of highly ionizing charged particles through Si based devices. Comparative to other radiation particles, alpha particles are large and powerful that can be emitted by impurities in electronic packaging materials. They reported about the generation and recombination of charge particle in silicon dioxide (SiO_2) due to ionizing radiation [2]. The alpha particle radiation on the surface of SiO_2 film creates enough hole and electron on the film cause a soft error which are neither permanent nor associated any physical defects [3]. Due to their high energy status the alpha particle quickly gives energy to any nearby particle leading them to rapidly reach into equilibrium and disappear within the film or medium. Considering the rapid disappearance of alpha particle in the SiO_2 film layer, in present paper the detection of high energetic alpha particles are targeted. The bombardments of alpha particles on SiO_2 layer have profound effects on the microstructure configuration. Since, the crystalline SiO_2 film have cubic unit shell, therefore it hold back the detail information and hamper the second –neighbour shell [4]. The various sensing principles and detection methods of alpha particle are reviewed a group of

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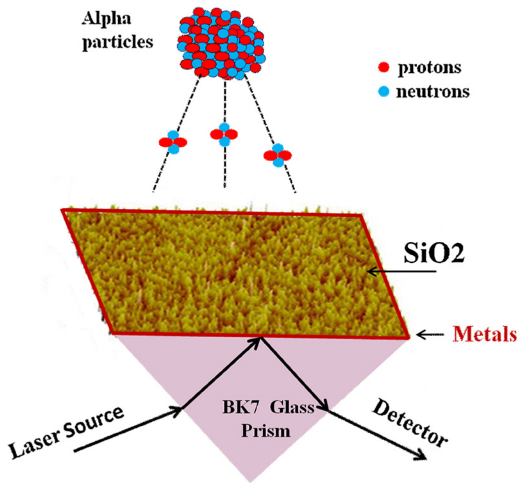

Fig. 1. Schematic diagram of proposed planar waveguide based sensor.

researchers [5]. This high energy radiation can also be identify by planar optical waveguide, because such radiation change in property of waveguide film like density, the optical index or the amount of built in stress etc. [6,7]. The researchers in this field have addressed the impact of radiation in optical waveguide based sensor [8,9] but still very few literatures are available in this field [10].

However, the effect of highly ionizing alpha charged particles on the surface of SiO_2 film based three layer planar waveguide sensor is reported by a group of researchers [11]. Since, SiO_2 is an important dielectric element of optical waveguide based sensor [12] and is also recognised as a suitable candidate for nuclear and space applications due to its accurate electronic stopping power [13], therefore in present communication a SiO_2 film based metal clad planar optical waveguide sensor is proposed to detect the high energetic alpha particles. Unlike to three layer planer waveguide based sensor the metal clad planar waveguide based sensor consist of four layers. Although the sensing principle of both three layer and four layers waveguides are same but the additional metal layer between the substrate and waveguide film increases the overall performance of metal clad waveguide based sensor [14]. Hence, the basic aim of this paper is to estimate the performance of a SiO_2 film based metal clad planar waveguide sensor for detection of high energetic alpha particle radiation.

2. Theoretical background

The proposed four layer metal clad optical waveguide consists of a thin silver film sandwiched between BK7 glass substrate and SiO_2 dielectric waveguide film as shown in Fig. 1. In a planar optical waveguide the light is propagated through total internal reflection (TIR). TIR can only be obtained, when incidence angle of light is greater than or equal to the critical angle which is also known as coupling angle. The coupling angle of the light into the waveguide depends on the effective refractive index of the waveguide. So, if there is any change in the guiding or cladding layer refractive index (RI) consequently this will change the effective refractive index of the waveguide and thereby resulting in a change in coupling angle. This change in angle can be interpreted as the sensing signal and it is limited by the penetration depth of evanescent field. Under TIR conditions, there are parts of optical energy still penetrate in the cladding region which is also known as evanescent field. The nature of this evanescent fields are exponentially decay when one move away from the boundary.

However in our proposed metal clad waveguide, a thin silver metallic layer of thickness d_M is coated on a semi-infinite substrate of refractive index n_S. The wavelength dependent refractive index of silver metal is given by [15]:

$$n_M(\lambda) = 1 - \frac{\lambda^2\lambda_C}{\lambda_P^2(\lambda_C + i\lambda)} \tag{1}$$

where, λ_P is the plasma wavelength and λ_c is the collision wavelength having values $\lambda_P = 1.4541 \times 10^{-7}$m and $\lambda_c = 1.7614 \times 10^{-5}$m.

The metal layer is shielded by a SiO_2 layer of refractive index n_F and thickness d_F. Finally the SiO_2 layer is surrounded by a semi-

Table 1
The variation of refractive indexin SiO_2 layer at 1580 nm wavelength with 2.3 MeV alpha particles dose.

Dose of alpha particles	No of alpha particles per cm^2	Refractive index of SiO_2
0	0	1.4500
1	1×10^{15}	1.4526
2	5×10^{15}	1.4546