Localized surface plasmon resonance sensor based on hetero-core structured fiber optic

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Abstract

Localized surface plasmon resonance (LSPR) sensor is constructed by immobilizing gold nanoparticles (AuNPs) on the surface of hetero-core structured fiber optic and characterized as a refractive index sensor. According to increasing of dipping time of the aminated sensing part in the AuNPs suspension, the propagating light intensity near 545nm decreased. According to increasing of the sensor length, in addition, the propagating light intensity at 540nm decreased. The sensor showed that the propagating loss at 545nm increased according to increasing of ethanol concentration in water, derived from the refractive index increase of the mixture.

Keywords: Hetero-core structured fiber optic; Localized surface plasmon resonance; Gold nanoparticle; Refractive index; Ethanol

1. Main text

Fiber optic chemical sensors have many advantages such as small size, low cost, resistance to electromagnetic noise and long-distance transmission of signals [1]. In fiber optic chemical and/or biological sensors, evanescent field is utilized, and many types of fiber optic such as unclad fiber optic, tapered fiber optic are reported [2,3]. In these sensors, the glass surface is modified with dye molecules and metal thin film [4,5]. In particular, localized

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surface plasmon resonance (LSPR) sensor that is fabricated by immobilizing gold nanoparticles (AuNPs) on the glass surface has wide application in the field of chemistry, molecular biology and analytical instruments [6,7,8].

In this study, LSPR sensor based on hetero-core structured fiber optic and its application to measure ethanol concentration are reported.

2. Experimental setup

AuNPs used in this experiment were prepared by reduction of HAuCl₄ with K₃C₆H₅O₇ in boiling water for 20min [9]. The average of the diameter of the prepared AuNPs was 31nm. The fabrication of hetero-core structured fiber optic and the principle of the generation of the evanescent field at the sensing part were described previously [10]. The fiber optic to fabricate hetero-core fiber optic are used in conventional telecommunication, and the diameters of cladding of multimode fiber (MMF) and singlemode fiber (SMF) were 125μm, respectively. The length of the inserted SMF was 2cm. The hetero-core part was treated with 3-aminopropylixyhoxysilane to make the fiber surface positive.

The schematic diagrams of the measurement system and the sensor structure are illustrated in Fig.1. The positively charged surface was immersed in AuNPs suspension, and the propagating loss was measured to monitor the adsorption process of AuNPs on the fiber surface. The characterization of LSPR sensor for refractive index measurement was performed by immersing in ethanol/water mixture and measuring the propagating light intensity.

3. Results and Discussion

As shown in Fig.1, the propagating light in the core of the MMF leaks into the cladding of the inserted SMF at the fusion-splicing junction because of the difference of the core diameter, resulting in the generation of cladding mode waves on the surface of SMF. When the total reflection takes places at the interface of cladding/surroundings of the SMF, evanescent wave generates. When AuNPs are immobilized on the surface of the SMF, they absorb the evanescent wave, resulting in decreasing the reflection light. Therefore, the propagating loss takes place.

The performances of this sensor depend on the amounts of AuNPs on the surface, which depend on the immersing period in the AuNPs suspension and the sensor length. Fig.2 shows the dependence of the sensor length to the propagating loss in the adsorption process at 545nm. As the sensing part was treated with 3-aminopropylixyhoxysilane, the surface charged positively. On the other hand, AuNPs prepared by using citrate reduction method covered with negative ions. Therefore negatively charged AuNPs adsorbed on the sensor part via electrostatic interaction. The propagating light intensity decreased with the passage of time from the start of immersion. According to increasing of the sensor length, the loss increased. It was shown that 30min of the immersion of the sensor part reached to the adsorption equilibrium.

![Fig. 1. Schematic diagram of the measurement system and the LSPR sensor based on hetero-core structured fiber optic.](image-url)
Fig. 2. Timecourse of the propagating loss on the adsorption process of AuNPs on the hetero-core fiber optic surface in various sensor length.

Fig. 3. Differential loss spectra of AuNPs-immobilized hetero-core structured fiber optic (sensor length, 6.4mm) at various ethanol concentration. The propagating loss peak near 545nm was observed. According to alternating of ethanol concentration, the refractive index of the mixture changes. This figure shows that the LSPR sensor was fabricated by immobilizing AuNPs on the surface of hetero-core structured fiber optic.

In this experiments, it is recognized that the degree of the loss change at 545nm depends on the sensor length when the adsorption of AuNPs on the sensor surface reached to the adsorption equilibrium. Fig.4(a) shows the correlation between the propagating loss at the peak wavelength and ethanol concentration in various sensor length. According to increasing of ethanol concentration till about 80%, the propagating loss at 545nm in all sensors increased, and over 80%, the loss decreased. The refractive indices of water/ethanol mixture has a maximum at about 80% [3]. It was shown that the sensor response reflects the variation of the refractive indices of water/ethanol mixture. Fig.4(b) shows the sensitivity dependence of the sensor on the sensor length. The sensitivity in this experiments was estimated as slope of the regression line in the range of 0 – 20% ethanol concentration. According to increasing of the sensor length, the slope of the regression line increased. This means that the sensitivity was enhanced by lengthening the sensor. And the sensitivity would reach a saturation with about 15mm.
Conclusions

In this study, LSPR sensor based on hetero-core structured fiber optic was fabricated by immobilizing AuNPs on the surface and characterized. It took about 30min to reach to the adsorption equilibrium between the aminated glass surface and AuNPs. The loss spectra of the fiber optic LASP sensor at various ethanol concentration were measured and analyzed. It was shown that the propagating light intensity at 545nm altered in response to the refractive index change of ethanol/water mixture. In this LSPR sensor, the sensitivity was enhanced by lengthening the sensing part.

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References