Transmission Surface Plasmon Resonance Spectroscopy for Chemical Sensor Application

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ABSTRACT

Transmission surface plasmon resonance spectroscopy (TSPR) has been developed as an advancement over conventional surface plasmon resonance spectroscopy (SPR), addressing the limitations and complexity of conventional SPR setups. In this study, a grating substrate obtained from a DVD-R was coated with gold, enabling a simpler and more accessible experimental TSPR configuration. To enhance the sensitivity and selectivity for arsenate or As(V) detection, UiO-66-NH_2 metal-organic frameworks (MOFs) with high surface area and abundant amine (-NH_2) functional groups were incorporated as the sensing material. UiO-66-NH_2 was deposited onto the gold-coated DVD-R grating substrate by the drop-dry method, enabling effective adsorption and detection of As(V). TSPR signal exhibited a response to the adsorption of As(V) ions on the UiO-66-NH_2 layer with effective detection range of 10-70 mg/mL. This study demonstrates the potential of MOFs-TSPR integration as an efficient and sensitive approach for heavy metal detection in environmental monitoring.

INTRODUCTION

Surface Plasmon Resonance (SPR) is an established, label-free optical technique widely employed for the real-time monitoring of interfacial reactions and biomolecular interactions[1-3], offering high sensitivity and selectivity. While conventional SPR often relies on a prism-based Attenuated Total Reflection (ATR) configuration[1], more accessible and convenient **grating-coupled SPR** methods have emerged[4-5]. A recent evolution is **Transmission Surface Plasmon Resonance (TSPR)**, which simplifies the setup by measuring the enhanced transmission of p-polarized light through a thin metal film coated on a grating substrate[6]. This TSPR configuration offers an attractive, portable platform for in situ sensing. To further enhance sensing capabilities, there is growing interest in integrating TSPR techniques with advanced functional materials. **Metal-Organic Frameworks (MOFs)**, particularly UiO-66-NH_2, are highly promising due to their exceptional porosity, high surface area, and tunable surface chemistry, featuring abundant amine (-NH_2) groups that act as strong coordination sites for heavy metal anions[7]. This study, therefore, introduces a simplified TSPR sensing platform utilizing a cost-effective, **gold-coated DVD-R grating substrate** integrated with a UiO-66-NH_2 layer. This novel **MOFs-TSPR** approach aims to provide an efficient, highly sensitive, and accessible method for the selective detection of the hazardous heavy metal ion, arsenate (As(V)), crucial for environmental monitoring applications.

EXPERIMENT

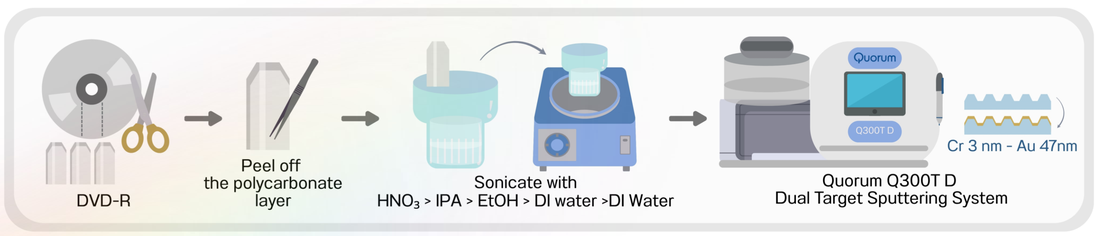


Figure 1 Preparation of grating substrate for TSPR signal measurement.

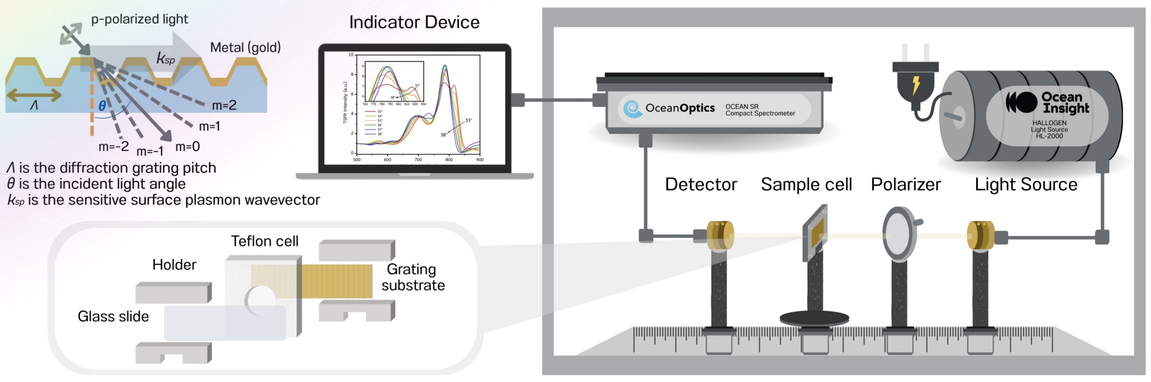


Figure 2 Installation of equipment for measuring TSPR signals.

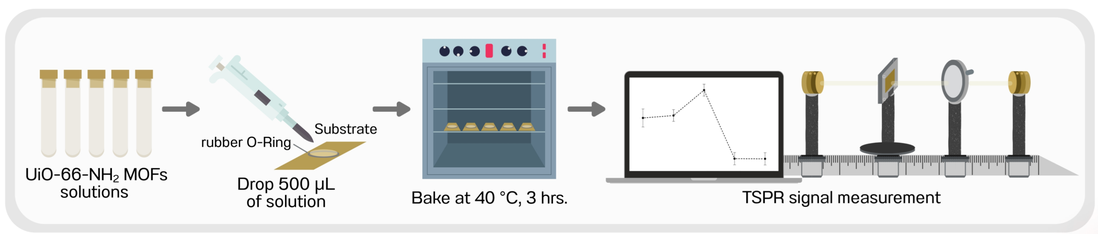


Figure 3 Determination of UiO-66-NH_2 MOFs concentration by drop dry method for measuring As(V).

RESULTS AND DISCUSSION

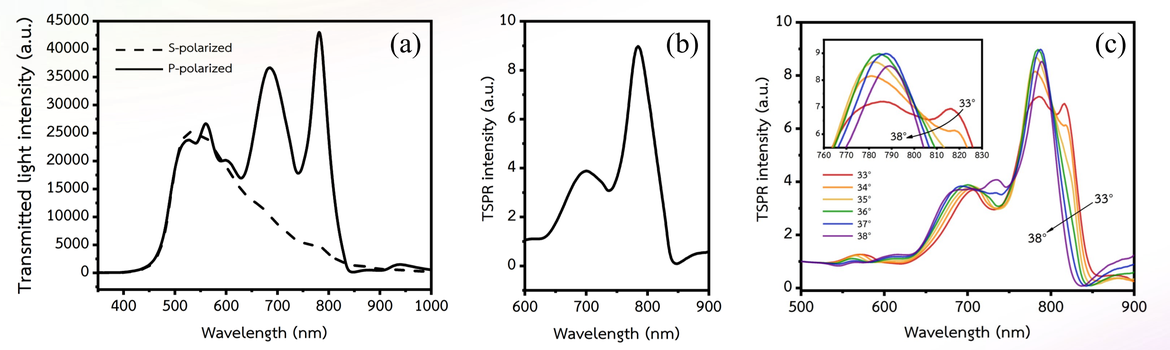


Figure 4 (a) Light intensity signals of the transmittance from P-polarized light and S-polarized light and (b) TSPR spectrum at an incidence angle of 36° and (c) TSPR spectrum at incidence angle 33°-38°.

- The transmittance intensity that can be used to generate the TSPR spectrum is obtained from PoverS, which can reduce the effects of background signals[8].
- The gold peak signal is in the range of 700-800 nm, which is due to the material having subwavelength apertures structure that causes the gold peak to shift to this range, called Extraordinary peak[9].
- The optimum incident angle for measuring the TSPR signal of the change in refractive index affecting the gold peak is 36°.

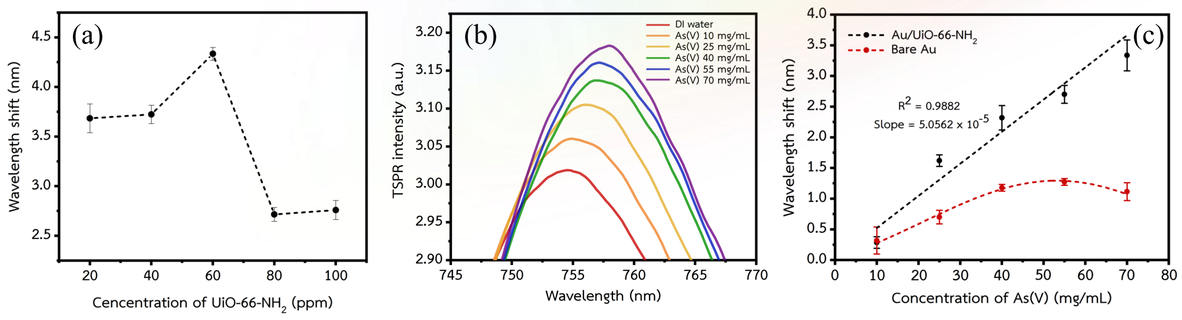


Figure 5 (a) Wavelength shifts with respect to concentration of UiO-66-NH_2 MOFs drop-dried on substrate surface, (b) TSPR signal of As(V) in the concentration range of 10-70 mg/mL and (c) standard calibration curve of As(V).

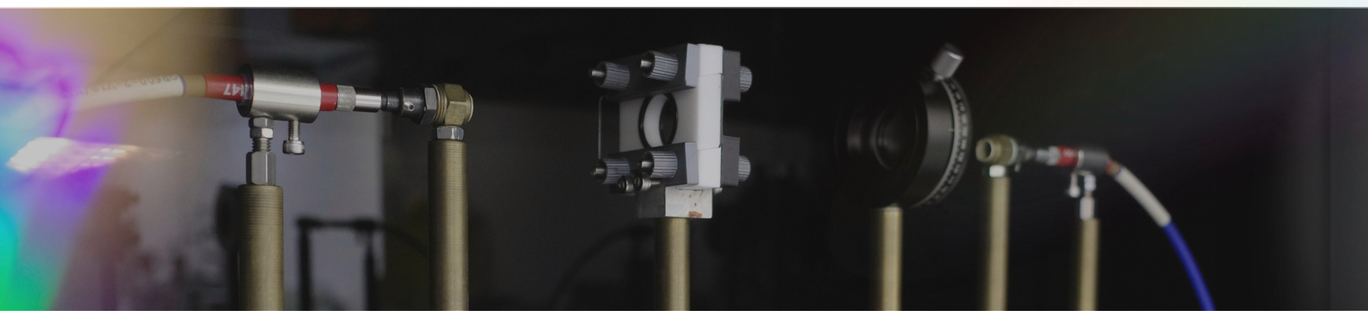
- The optimum UiO-66-NH_2 MOFs concentration was 60 ppm, which gave a high shift value of 4.3 nm.
- The sensitivity of the constructed TSPR system is in the range of 5-100 mg/mL therefore, the concentrations for standard calibration curve determination were selected at 10, 25, 40, 55 and 70 mg/mL.
- The Au/UiO-66-NH_2 substrate showed a good linear relationship ($R^2 = 0.9882$), indicating a higher sensitivity than the bare Au substrate which showed a non-linear relationship.

CONCLUSIONS

- The appropriate incidence angle for studying the change of refractive index in TSPR system is 36°.
- The constructed TSPR system can still detect As(V) at high concentrations.
- The Au/UiO-66-NH_2 substrate showed good linearity ($R^2 = 0.9882$) in the detection of As(V), indicating significantly higher sensitivity than the bare Au substrate.

ACKNOWLEDGEMENT

This work was financially supported by National Nanotechnology Center (NANOTEC), National Science and Technology Development Agency (NSTDA) and Deparment of Chemistry, Faculty of Science, Chiang Mai University.



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