A High Potential Optical Method for Sensitive and Selective Detection of Essential Elements

Yap Wing Fen[a,b,*], Wan Mohd Ebtisyam Mustaqim Mohd Danial[a], Silvan Saleviter[a], Afiq Azri Zainudin[a], Nur Alia Sheh Omar[b]

[a]*Department of Physics, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*

[b]*Institute of Advanced Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
**Corresponding Author's Email: yapwingfen@upm.edu.my*

Abstract: An optical sensor based on surface plasmon resonance (SPR) phenomenon has been emerged for sensing a variety of analytes, including essential elements. It has numerous advantages, which include very high sensitivity, simple sample preparation, low cost, fast measurement capability, no requirement for reference solution, high reproducibility, ability to monitor kinetic behaviour, label-free detection, and nondestructive. The instrument and different developments on active layers or recognition molecules for sensitivity and selectivity improvements were explored. Further investigation in SPR optical sensor technology will expand SPR detection abilities and allow SPR sensing to be used widely including in environmental monitoring as an effective essential elements sensor in the future.

***Keywords*:** Surface plasmon resonance, essential elements, sensitive, optical sensor

INTRODUCTION

Numerous SPR sensing structures for chemical and biochemical sensing have been developing tremendously for the past decades. Since the beginning of 21st century, SPR for sensing essential elements has been started to receive continuously growing attention from scientific community. In this study, the development of SPR for essential elements detection by our research group as well as other research groups all over the world has been explored and discussed.

MATERIALS AND METHODS

Surface plasmon requires a coupler as it does not couple with the outside electromagnetic radiation. The simplest coupler for surface plasmon excitation is the prism coupler. Figure 1 shows the schematic diagram for SPR setup. The Kretschmann configuration is commonly used because it is the most efficient. A metal film was placed directly on the horizontal surface of the film (~50 nm) and the incident beam passed through the film to excite the surface plasmon at the bottom of the film. A lock-in amplifier and chopper were used in the setup to enhance the signal-to-noise-ratio of the measurement, while a filter was used to modulate the intensity of the incident light.

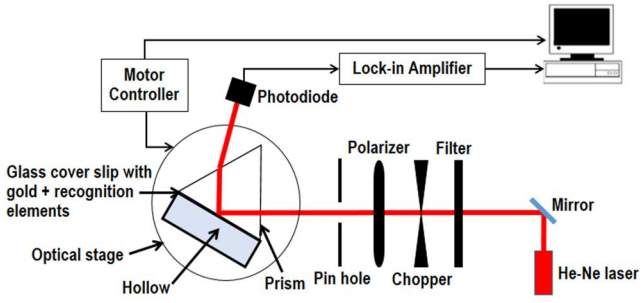

Fig. 1. SPR experimental setup.

RESULTS AND DISCUSSION

The most important finding for sensing essential elements application in SPR is the modification of gold surface with recognition molecules for particular essential elements. Various recognition elements for particular detection is shown in Table 1.

Table 1. Recognition elements in SPR for sensing particular essential elements.

Metal ion	Detection limit/range	Active layers/recognition elements	Reference
Cu^{2+}	1.0 pM - 10 mM	Squarylium dye containing polymeric thin film	1
Zn^{2+}, Ni^{2+}	2.0 μM-1.0 mM	Immobilize methallothionein onto a carboxymethylated dextran matrix	2
Zn^{2+}, Ni^{2+}	10 nM	Immobilize bovine serum albumin onto a carboxymethylated dextran matrix	3
Cu^{2+}, Ni^{2+}	Cu^{2+}: 1.6 nM Ni^{2+}: 41 pM	Cu^{2+}: NH_2 – Gly – Gly – His – COOH Ni^{2+}: NH_2 – $(His)_6$ – COOH	4
Cu^{2+}	0.1 μM-1.0 mM (selective)	2-aminoethane thiolhydrochloride and 6-aminohexane thiolhydrochloride	5
K^{+}	1pM- 10 mM	Calix[4]crown-5 derivatives	6
Cr^{6+}	0.2 mM - 5.0 mM	Gold nanoparticles-chitosan composite	7
Cu^{2+}	7.9 μM - 1.6 mM	MMW chitosan (glutaraldehyde-crosslinked)	8
Cu^{2+}, Zn^{2+}, Mn^{2+}	~8.0 μM-2.0mM	MMW chitosan (glutaraldehyde-crosslinked)	9
Zn^{2+}, Ni^{2+}	Zn^{2+}: 15 μM; Ni^{2+}: 17 μM	polypyrrole-chitosan	10
Ni^{2+}	0.85 nM	N-[5-(3′-maleimidopropylamido)-1-carboxypentyl]iminodiacetic acid (NTA) &polyhistidine	11
Zn^{2+}	1.52 μM	chitosan and chitosan–tetrabutylthiuram disulfide	12
Cu^{2+}	1 μM	5-Chloro-2-[(1E,2E)-3-(4 (dimethylamino)phenyl)allylidene)amino)]phenol	13
Co^{2+}	0.17μM - 1.7 mM	4-(2-pyridylazo) resorcinol-chitosan-graphene oxide	14
K^{+}	25.57 nM	Valinomycin-chitosan-graphene oxide	15

CONCLUSIONS

The evolution of SPR in essential elements sensing have been explored. Various modifications of the metal surface to increase the sensitivity and selectivity were summarized. SPR has a high sensitivity to sense metal ions as low as pM to μM. Fast and label-free essential elements can be measured in real time with small sample consumption. Further research will expand the SPR detection abilities and allow SPR sensing to be used widely as an effective essential elements sensor.

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