矽基片上積體抗諧振反射光波導 (ARROW) 化學與生化感測器之設計與研製 3/3
(Si-Based Integrated ARROW-type Waveguide Chemical and Biochemical Sensors 3/3)

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主持人：黃遠東　教授
交通大學電子工程系所
e-mail: huangyt@cc.nctu.edu.tw
http://iol.ee.nctu.edu.tw/

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一、摘要

本計畫的目的在研發積體光學抗諧振反射光波導 (ARROW) 元件，利用其表面衰減波 (evanescent wave) 吸收或折射係數變化的原理，應用在化學與生化感測器上，並配合微小機電系統 (MEMS) 的發展，利用光纖通訊之波長區分多工技術 (WDM)，來製作微小化的多工感測系統。除了設計B型抗諧振反射光波導 (ARROW-B) 以偵測水中低濃度 (10^{-5}) 的有機污染外，並研究以高折射率覆蓋層 (high-index overlay) 來提高表面衰減波感測元件的感測度與感測因子，同時也針對運用雙抗諧振反射光波導之感測元件加以探討。

Abstract

The purpose of this project is to develop chemical and biochemical sensors based on optical absorptiometry or refractiometry of evanescent waves in the integrated antiresonant reflecting optical waveguides (ARROW's). With microelectro-mechanical techniques developed recently, optical sensors can be miniaturized and integrated with WDM systems to become a multi-processing sensor system. In addition to the development of an ARROW-B surface plasmon resonance (SPR) chemical sensor, we have also studied the feasibility of using a high-index overlay to improve the sensitivity and the sensor factors of ARROW evanescent-wave sensors. Moreover, sensors based on multi-core dual ARROW's are also been investigated and discussed.

二、緣由與目的

化學與生化感測器 (chemical and biochemical sensors) 在醫學工程、生化、環保自動化製程等領域都有廣泛、重要的應用，而隨著微小機電系統 (microelectro-mechanical systems, MEMS) 的發展，感測系統也朝向微小化的目標前進，結合積體光學與成熟的積體電路技術製成的積體光波導感測器不但質輕、體積小，大量製造時的穩定度高，又能與光纖耦合以達到遙感探測的目的，在應用與製作上都比傳統感測元件具有更大潛力。

抗諧振反射光波導 (antiresonant reflecting optical waveguides, ARROW's) 為近年新開發的元件，其應用在感測上的優點包括：與光纖的耦合效率高、單模傳輸、

可製作在高折射率的基片上和低傳輸損耗等。由於抗諧振反射光波導元件具有如上的優點，我們可利用其表面衰減波吸收或折射係數變化的原理，應用在化學與生化感測器上，並配合微小機電系統 (MEMS) 的發展，利用光纖通訊之波長區分多工技術 (WDM)，來開發、製作微小化的感測元件，並整合成多工感測系統。

三、結果與討論

第一年我們設計了一種B型抗諧振反射光波導 (ARROW-B) 表面電漿子共振 (surface plasma resonance, SPR) 化學感測元件，利用輸出光能量的變化，可偵測水中低濃度(10^{-5}) 的有機污染。

第二、三年度則探討抗諧振反射光波導表面衰減波感測元件，設計以高折射率覆蓋層於抗諧振反射光波導衰減波感測元件上（結構如圖一所示），以增加吸收區域的能量比例，提高其感測度，圖二為未加高折射率覆蓋層之感測元件的感測率對導波層膜厚的關係圖，而圖三則為加上高折射率覆蓋層的結果，由兩圖之比較可以看出，感測率可藉由加上高折射率覆蓋層來大幅提升。圖四顯示感測率與元件尺寸的關係，感測效果最佳的元件長度約為40 mm。

此外，為提高感測元件元件與單模光纖的耦合效率，我們也針對雙抗諧振反射光波導加以探討。若以底層的抗諧振反射光波導作為輸入耦合，藉由耦合區將光波耦合至上層抗諧振反射光波導進行感測，並加上高折射率覆蓋層來提高感測率（結構如圖五所示），如此設計能同時兼顧高感測率與高輸入耦合效率，使得元件尺寸能進一步縮短。以圖六所示之設計實例，將整個感測元件的長度控制在20 mm左右感測率即可達到接近1的水準。

本計畫研究成果已陸續發表在學術期刊、國際會議，有些已獲得專利或正申請中，詳細內容可參考下列之參考文獻。

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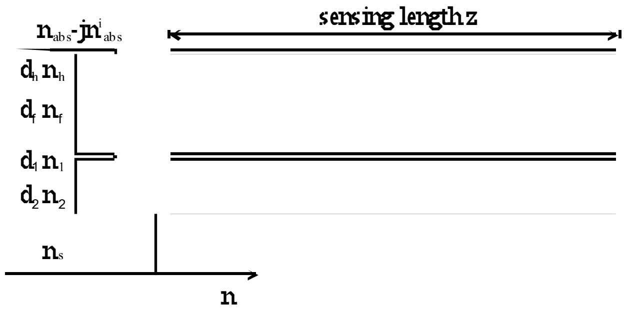

Fig. 1 A quasi-single mode ARROW evanescent-wave sensor with a high-index overlay.

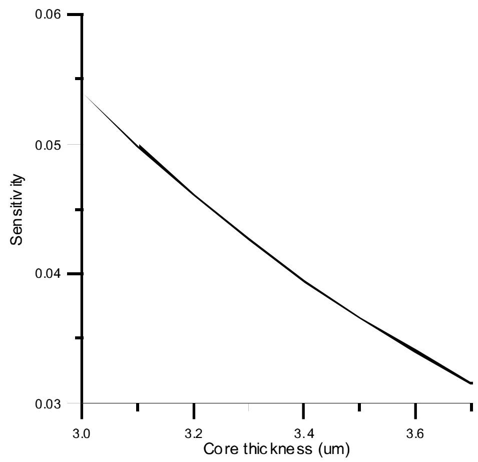

Fig. 2 Sensitivity of a quasi-single mode ARROW sensor.

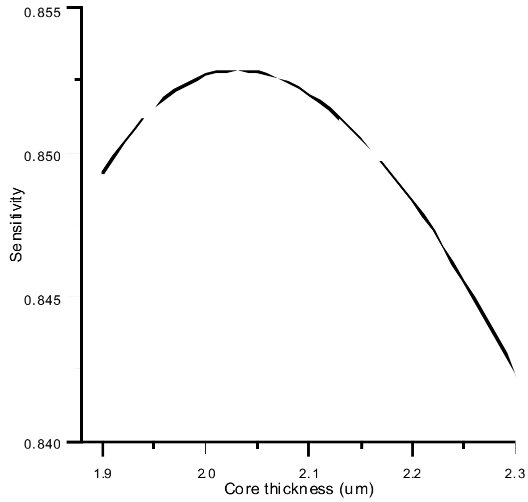

Fig. 3 Sensitivity of a quasi-single mode ARROW sensor with a high-index overlay..

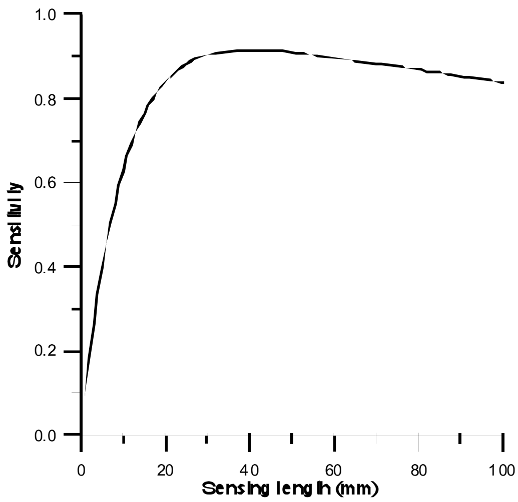

Fig. 4 Sensitivity of a quasi-single mode ARROW with a high-index overlay for different sensing length.

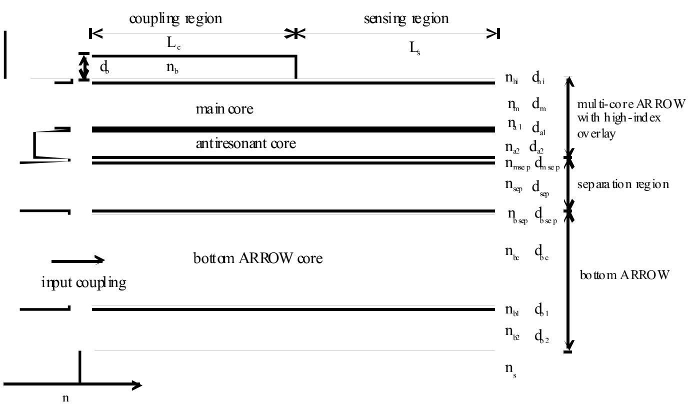

Fig. 5 A multi-core dual ARROW with a high-index overlay for different sensing length.

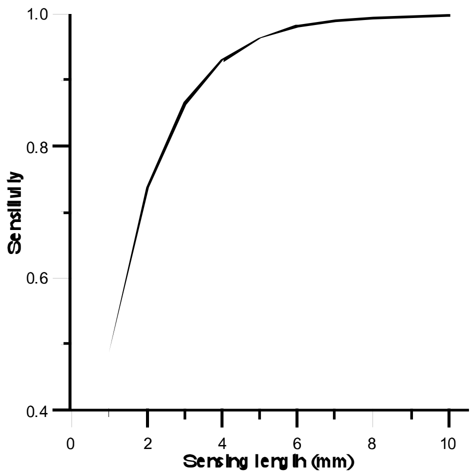

Fig. 6 Sensitivity of a multi-core dual ARROW with a high-index overlay for different sensing length.