Hyperspectral imaging of surface plasmon resonance effects induced by uncollimated semiconductor radiation

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The inherent surface sensitivity of the surface plasmon resonance (SPR) effect has made it highly attractive for biochemical analysis of processes localized on metal surfaces. Many SPR devices have been developed and made commercially available for that purpose in the past 20 years. However, most of them are relatively bulky and a monolithically integrated SPR microchip, which could be easily combined with specimen processing hardware for a wholly automated analysis, has yet to be demonstrated. We have recently proposed an innovative SPR microstructure comprising a metal coated dielectric layer deposited on top of a photoluminescence (PL) emitting quantum well (QW) wafer [1-2] Nano-scale grating fabricated in the metal layer allows for the extraction of the SPR signal. The entire device, thanks to the built-in light source and the application of a SPR imaging technique, has the potential to become a highly compact SPR biosensor for simultaneous detection of numerous biomolecules.

The functioning of the QW-SPR device is based on the uncollimated, and usually incoherent, emission of QW. Therefore, any given point of the metal-dielectric interface is exposed to the whole range of wavevector spectra and thus, coupling of all the SPR modes supported by the architecture is expected to take place. The multiple SPR coupling along the metal-dielectric interfaces distinguishes our QW-SPR device from other "macro" SPR devices, where only one wavevector is excited at a time.

The device takes advantage of this uncollimated and incoherent emission of the QW microstructure, which results in a spectro-angular far-field SPR response. In addition, our recent results have indicated that the injected in-plane wavevectors could increase the SPs coupling efficiency up to 10^3 times in comparison to indirect SPs injection [2]. To adequately monitor the emitted spectro-angular far-field, we have presented the general idea of an experimental setup required for the collection the 3D measurements of SPR dispersion relations $\hbar\omega(\mathbf{k_x},\mathbf{k_y})$, enabling a much richer picture of surficial biochemical events. Preliminary results have indicated that the proposed methodology would produce simultaneously the equivalent of 10^5 to 10^8 conventional SPR scans achievable with commercial systems [2-3].

In this communication, we present a novel surficial imaging technique, based on the hyperspectral photoluminescence mapping of SPR events (HI-PLM-SPR). We discuss the functioning of the QW-SPR architectures and the HI-PLM-SPR microscopy method. The full far-field spectro-angular responses of various integrated architectures are predicted. The energy transfer between the various diffraction modes are explored and taken advantage of for the design of both efficient and practical SPR microchip. A comparison between experimental and analytical dispersion relation maps $\hbar\omega(\mathbf{k_x},\mathbf{k_y})$ are presented. We then conclude on the tradeoffs of the technologies presented and on how to achieve a useful quasi real-time semiconductor-based SPR spectroscopy.

References

[1] Lepage D., Dubowski J. J., App. Phys. Lett., **91,** 163106 (2007).

[2] Lepage D., Dubowski J. J., Opt. Express **17(12),** 10411-10418 (2009)

[3] Lepage D., Dubowski J. J., Synthesis and Photonics of Nanoscale Materials VII (Proceedings Paper), **vol. 7586, 758607** (2010).

Figures

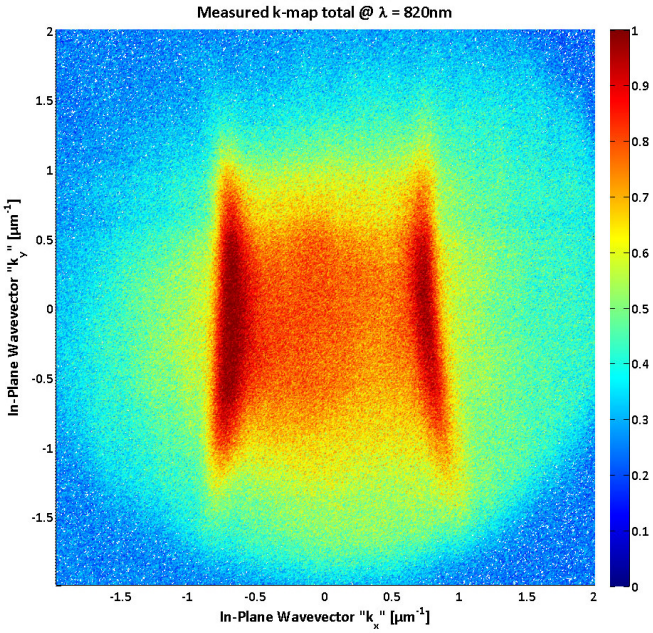

Fig.1: 3D slice of the measured $\mathbf{k_x}$-$\mathbf{k_y}$ mapping for a SiO_2-Au-Photoresist architecture at λ=820nm. All diffraction orders and all polarizations are simultaneously monitored. The non-uniformity from the top left to bottom right is due to geometrical alignment.

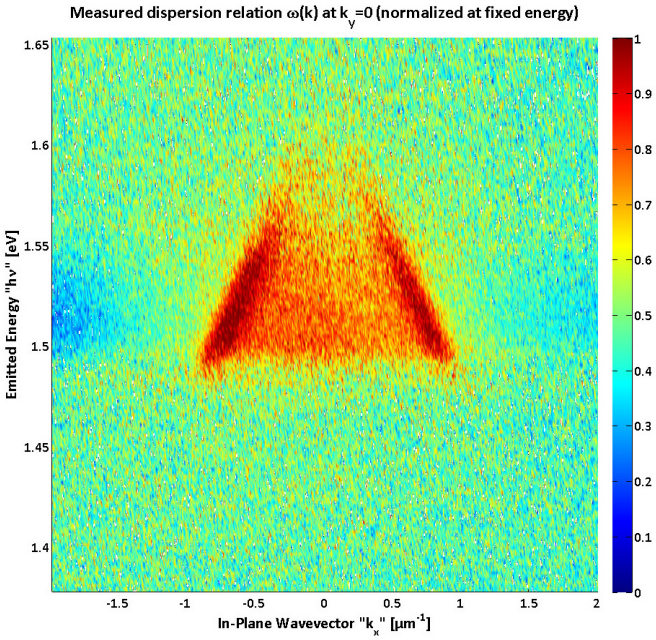

Fig.2: 3D slice of the measured $\boldsymbol{\omega(k_{II})}$ mapping, at $\mathbf{k_y}$=0, for the same acquisition as Fig.1. All diffraction orders and all polarizations are simultaneously monitored. The peaks correspond to SPR effects and are to be tracked in $\hbar\boldsymbol{\omega}(\mathbf{k_x},\mathbf{k_y})$ for a quasi real-time semiconductor-based SPR spectroscopy.