Guided Immobilization of Quantum Dots on Gold Nanogratings for Enhanced Surface Plasmon Resonance Biosensing

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I. Introduction

The literature points to a vast array of plasmonic enhancement effects being studied for biosensing applications. Plasmonic biosensors utilise surface plasmon waves to sense the surface adsorption of analytes from a complex sample solution. In this report, we present a surface plasmon resonance (SPR) biosensor (based on the Kretchmann configuration) which incorporates surface nanogratings and guided quantum dot immobilization. The adsorption of fluorophores on plasmonic surfaces is interesting due to two known physical effects associated with the interaction between the fluorophore and the electromagnetic field. The propagating surface plasmon wave generates, along the nanograting structures, high electromagnetic (EM) field intensities that can excite the adsorbed fluorophores to produce a highly directional and polarized emission [1]. Moreover, the presence of fluorophores causes an important change in both the real and imaginary parts of refractive index near the plasmonic surface affecting the excitation and propagation of the plasmon wave [2]. Therefore, there is significant scope in exploring these EM interactions as amplification methods for enhanced SPR [3].

II. Guided Quantum Dots Immobilization on Gold Nanogratings

The enhanced SPR biosensor features nanogratings with differentiated surface chemistry. It allows the binding of the analytes to receptor probes attached to the troughs or the mesas of the nanogratings where SP fields are strongest. The substrate is passivated against non-specific adsorption of proteins. Quantum dots conjugated to a secondary receptor are allowed to be adsorbed on the captured analytes (figure 1). The guided and periodic immobilization of analytes and quantum dots generates an additional optical contrast that perturbs the propagating surface plasmon.

III. Fabrication and Characterization Methods

The electromagnetic field enhancements of surface gold nanogratings are initially studied via rigorous coupled wave analysis method (RCWA). Nanogratings with 250 and 400 nm periods are fabricated by E-beam lithography and metal lift-off (figure 2). The differentiated surface chemistry is applied in a two-step process. Prior of the metal lift-off, a first surface chemistry is applied using a self-assembled monolayer of 16-mercaptohexadecanoic acid activated for the attachment of biomolecular receptor probes. Metal lift-off in acetone/MEK is applied and then followed by the second surface modification by self-assembled poly-ethylene glycol (PEG) to passivate the surface. The surface is then incubated in successive solutions of the primary surface receptor probes (anti-TNF-α), analytes (TNF-α), and quantum dots (CdSe). The characterization of the nano-structured surface is performed by atomic force microscopy (Nanoscope III SPM). The patterned immobilization of the quantum dots and the fluorescence emission are imaged via custom-built near-field scanning optical microscope (NSOM).

IV. Results

The numerical modelling suggests that the localized field enhancement and the concentration of the adsorbed analytes lead to SPR sensitivity enhancement (figure 3). Depending on the excitation wavelength, the field gradient can be tuned to be localised on the grating troughs or mesas. Preliminary characterisations show good surface topography (figure 4), and

differentiated surface chemistry [4]. The on-going work focuses on imaging the emission from surface immobilized quantum dots via NSOM and measuring their interactions with the surface plasmons via SPR imaging. In particular, we seek to evaluate the effect of this approach on the improvement of sensitivity for the detection of small biomolecular analytes.

References:

[1] J.R.Lakowicz, J.Malicka, E.Matveeva, I.Gryczynski, Z.Gryczynski. Plasmonic technology: novel approach to ultrasensitive immunoassays, Clin.Chem., 51, (2005) 1914-1922.

[2] H.Komatsu, M.Miyachi, E.Fujii, D.Citterio, K.Yamada, Y.Sato, K.Kurihara, H.Kawaguchi, K.Suzuki. SPR sensor signal amplification based on dye-doped polymer particles, Science and Technology of Advanced Materials, 7, (2006) 150-155.

[3] O.Stranik, H.M.Mcevoy, C.McDonagh, B.D.MacCraith. Plasmonic enhancement of fluorescence for sensor applications, Sensors and Actuators B-Chemical, 107, (2005) 148-153.

[4] X.D.Hoa, A.G.Kirk, M.Tabrizian. Modelling and Implementation of a Novel SPR Biointerface for Time-Effective Detection of Sepsis Biomarkers, Proc.IEEE Workshop on Computer Architecture for Perception and Sensing (CAMPS 2006), (2006).

Figures:

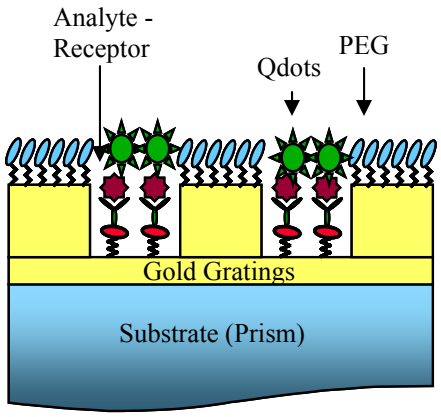

Figure 1: Guided quantum dots immobilization on SPR gold nano-grating surface

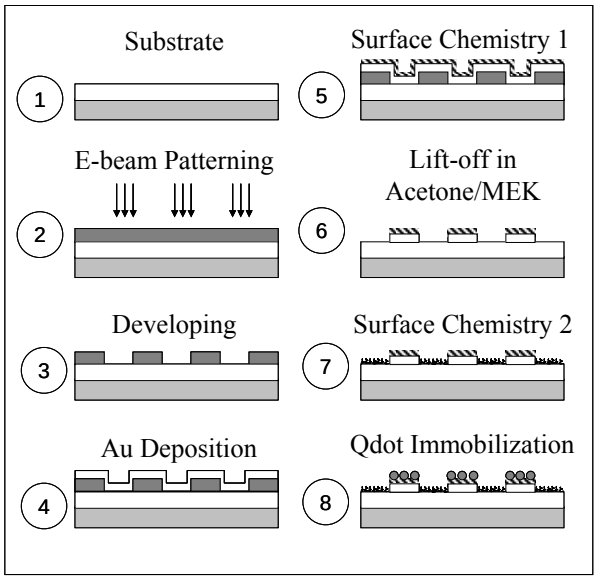

Figure 2: Fabrication of patterned surface via electron-beam lithography and metal lift-off

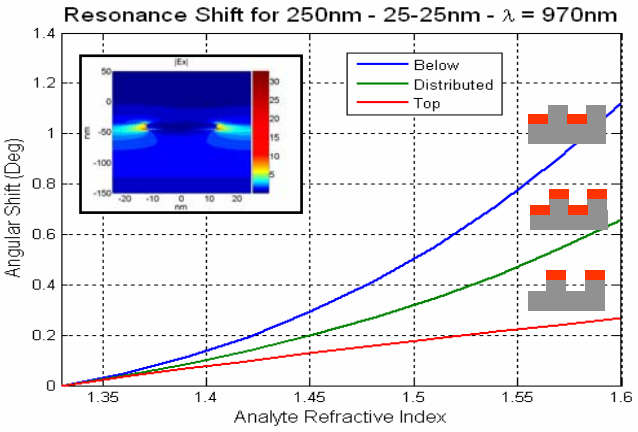

Figure 3: RCWA simulation results for immobilization in the grating troughs (below), mesas (top) and uniformly distributed. (Insert) field distribution

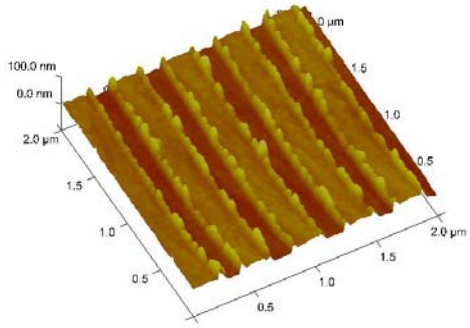

Figure 4: AFM nanograting structures