Supercritical angle fluorescence (SAF) and plasmonic enhancement strategies for optical biochip applications

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In this presentation, two different strategies are discussed, which have the potential to produce substantial enhancement of fluorescence in optical biochips for point-of-care applications. Key benefits from these enhancements include lower limits of detection, reduced reagent requirements and improved resolution. The enhancement strategies to be presented are (i) increased light collection efficiency using supercritical angle fluorescence-based structures and (ii) plasmonic enhancement using metal nanoparticles (NPs).

(i) It has been established that excited fluorescent molecules, which are in close proximity to the interface between two dielectric media, emit a large proportion of their radiation into the higher refractive index substrate. The emitted light is highly anisotropic, with a substantial fraction of fluorescence being emitted above the critical angle as supercritical angle fluorescence (SAF). We have applied the SAF principle in highly efficient optical biochip platforms by the appropriate structuring of polymer chips in order to collect the anisotropic SAF emission. In this work, SAF detection was achieved by using a parabolic light collection element which allows diffraction-limited high aperture optics. Because of the nature of the SAF interaction, fluorescence is collected only from molecules which are a short distance ($<\lambda$) from the surface, hence discriminating against bulk fluorescence in the sample solution leading to a reduction in background signal.

(ii) The plasmonic enhancement effect can occur when fluorophores are adjacent to metallic NPs and is the result of the localised surface plasmon resonance (LSPR) at the metal surface. The scale of the enhancement depends on many parameters such as NP size and shape, metal type and NP-fluorophore separation. Characterisation techniques include TEM, AFM, optical decay time and optical fluorescence and absorption. Plasmonic enhancement has been demonstrated in solution and on planar platforms. A range of techniques was employed for nanoparticle production, including nanosphere lithography using polystyrene spheres and the production of colloidal nanospheres and nanoprisms from solution. In each case, NP dimensions were tailored in order to match the metal plasmon resonance wavelength to the fluorophore absorption. For planar biochip platforms, controlled NP-fluorophore separation was achieved using polyelectrolyte layers deposited using a layer-by-layer technique. Enhancements of up to x20 were achieved, the exact value being dependent on the experimental configuration used.

These fluorescence-enhancement strategies are currently being implemented in the development of high sensitivity, multi-analyte biochip platforms for point of care applications for example monitoring of cardiac risk.