2D Materials Enhanced Surface Plasmon Resonance

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Surface plasmon resonance (SPR) device based on attenuated total internal reflection (so called Kretschmann configuration) constitutes one of the most important applications of plasmonics. The configuration usually consists of a thin film of plasmonic material (Au and Ag are the two most commonly used materials) deposited on top of a glass prism. When a beam of P-polarized light of certain wavelength is incident at an appropriate angle larger than the critical angle of the prism, it will excite the surface plasmon (SP) in the metal film. As a result, most optical energy of the incident beam is transferred to the surface plasmon wave in the metal film, thereby the intensity of the reflected beam will be significantly diminished. The condition of exciting the SP is extremely sensitive to the surrounding environment of the metal film. The adsorption of a small number of molecules on the surface of the metal film will remarkably alter the resonant condition of SPR which will induce a notable change of the intensity of the reflected light, and hence the adsorption of the molecules are detected. This has been extensively exploited for sensitive detection of bio- and chemical molecules, with reported detection sensitivity as low as 10^{-18} M.

Although traditional SPR devices have found wide applications in many areas, they have some limitations. The analyte molecules must bind well to Au or Ag. This excludes a vast range of molecules that do not have strong affinity with Au or Ag. Here we propose to add an atomically thin film of two-dimensional (2D) materials (such as graphene, transitional metal dichalcogenides like MoS_2 etc) on the surface of the metal film as a mediate medium (Figure 1). This will significantly enhance the functionality of SPR. Many analyte molecules that cannot directly bind to Au or Ag now can attach to the surface of 2D materials and become detectable. There are significant advantages of using 2D materials as the mediate film. Firstly, 2D materials have atomically thin thickness (less than 1 nm) and atomically smooth surface that will not compromise the plasmonic properties of the SPR device; secondly there are a vast pool (over hundreds) of 2D materials of all kinds of varieties (metal, semiconductor, insulator, magnetic, ferroelectric etc) to choose from, which will substantially extend the scope of the detectable analytes. This offers unprecedented opportunities to advance the SPR technology, making it a powerful platform for ultrasensitive molecular detection.[1] Our group has developed a highly effective Au-assisted exfoliation technique that can exfoliate extraordinarily large-size (of cm^2 scale) monolayer crystals of 2D materials directly on top of Au film.[2] This will give our devices significant advantages over those reported in the literature. Previous technologies usually deposit 2D materials on top of the metal surface through wet transfer methods that would introduce contamination and defects. The directly exfoliated film is clean, smooth, with minimum defects, and making intimate contact with the underlying metal surface, therefore it will significantly enhance the performance of the SPR devices in contrast to the devices demonstrated in the literature. In addition to molecular sensing, the project will also provide opportunities to investigate the fundamental properties of 2D materials, such as the refractive index, which are central to the development of optoelectronic devices of 2D materials.

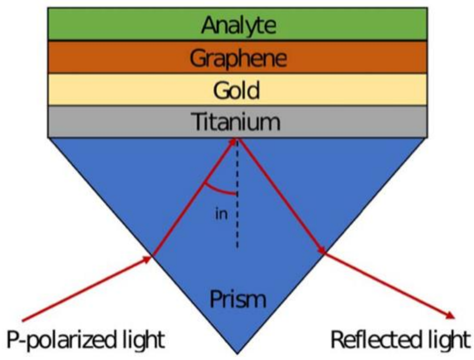

Figure 1 Schematic of 2D materials-enhanced SPR device

1. Yuan et al, Two-dimensional nanomaterials as enhanced surface plasmon resonance sensing platforms: Design perspectives and illustrative applications. *Biosensors and Bioelectronics* 241, 115672 (2023).
2. Velický et al, Mechanism of Gold-Assisted Exfoliation of Centimeter-Sized Transition-Metal Dichalcogenide Monolayers. *ACS Nano* 12, 10463–10472 (2018).