Minimizing Quenching of Plasmonic Sensors caused by Adhesion Layers

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Abstract: Adhesion layers necessary for the robustness of plasmonic sensors are commonly used at dimensions where the electric near-field intensity can be strongly quenched. We have found that by minimizing the layer thickness to roughly 0.5 nm and by additionally controlling the geometric design of the layer, quenching can by reduced by a factor of up to 7.

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1. Introduction

Chromium and Titanium are commonly used metals to improve the adhesion of metals, such as gold or silver, on silicon or oxide substrates. While the influence of the adhesion layer can be neglected for most applications, it strongly affects the near-field response of plasmonic sensors at the plasmon resonance[1, 2].

2. Methods

Nanogap arrays are fabricated via shadow evaporation directly onto the photoresist hydrogen silsesquioxane (HSQ) and after patterning using Extreme Ultraviolet Interference Lithography (EUV-XIL)[3]. Chromium, titanium and gold are evaporated at 60° from the surface normal. A schematic of the obtained nanogap array is illustrated in Fig. 1 and further details of the process are described in the literature[4].

![Fig. 1: Schematic cross section and a SEM image of the nanogap pattern. The thickness a of the adhesion layers is varied between 0 and 7 nm.](image)

3. Results

The plasmon resonance of the samples showed a red-shift of 70 nm that was already observed for the smallest adhesion layer thickness of <1 nm and stayed constant with increasing layer thickness (Fig. 2). Furthermore, the
magnitude of the plasmon resonance strongly reduces with increasing adhesion layer thickness. Subsequent surface enhanced Raman scattering (SERS) experiments revealed a decrease of signal with growing adhesion layer thickness (Fig. 3). Signal quenching becomes severe during the first 3 nm of adhesion layer thickness. Finite Element Method simulations revealed the origin of SERS hotspots and quantitatively allowed for the visualization of quenching the electric near-field intensity (Fig. 4). The quenching of SERS was found to be independent of the gold layer thickness. Additionally the design of the adhesion layer, such that it is not in direct contact with the adhesion material, was found to decrease the effect of quenching by a factor of 2.

![Fig. 3](image-url)

**Fig. 3:** SERS intensity for the 1007 cm⁻¹ peak of a self-assembled benzenethiol monolayer as a function of the different adhesion layer thicknesses.

![Fig. 4](image-url)

**Fig. 4:** Near-field intensity simulations for varying adhesion layer thickness using a 3D surface integral approach with periodic boundary conditions[5].

4. **Conclusions**

The drastic decrease of SERS intensity (up to a factor of 10) for growing adhesion layer thicknesses correlates well with the shift of the plasmon resonance and with the decrease of the plasmon resonance magnitude and electric near-field intensity. Despite the importance of an adhesion layer for the robustness of the sample, these experiments quantitatively demonstrate the necessity to control the shape and minimize the adhesion layer thickness to achieve highest SERS enhancements.

**References**


