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NANOSCALE CHARACTERISATION OF ULTRATHIN GOLD FILMS DEPOSITED ON SILICA WITH ORGANOSILANE ADHESION LAYERS

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Fabrication of thin metallic films on dielectric or semiconductor substrates is central to the plasmonics research field. Here, gold is the most used material, but due to its chemical inertness typically require an adhesion promoter to bind to the substrate. Metals such as Ti and Cr are often used for this purpose. However, they are known to degrade the plasmonic response of the metallic layer [1]. In this study, we investigate the adhesion mechanism between gold and SiO_2 substrates, using Ti, Cr and organosilanes as adhesion layers [2, 3]. In particular, surface roughness, grain size, grain orientation and interdiffusion of the adhesion material into the gold film are analysed. Transmission and scanning electron microscopy, transmission Kikuchi diffraction and electron energy-loss spectroscopy (EELS) are used to understand and compare the morphology, microstructure and chemistry of the different thin film interfaces.

[1] Habteyes et. al., American Chemical Society Nano, 6 (2012) 5702-5709.
[2] Leandro et. al., Applied Materials & Interfaces, 7 (2015) 5797-5802.
[3] Sukham et. al., Applied Materials & Interfaces, 9 (2017) 25049-25056.

Keywords: adhesion layer, metal thin film, microstructure

Nanoscale Characterisation of ultrathin gold films deposited on silica with organosilanes adhesion layers

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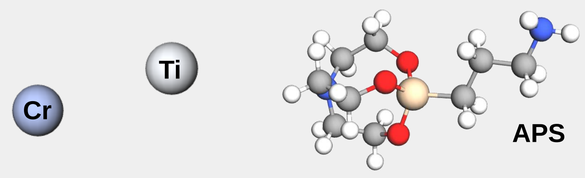


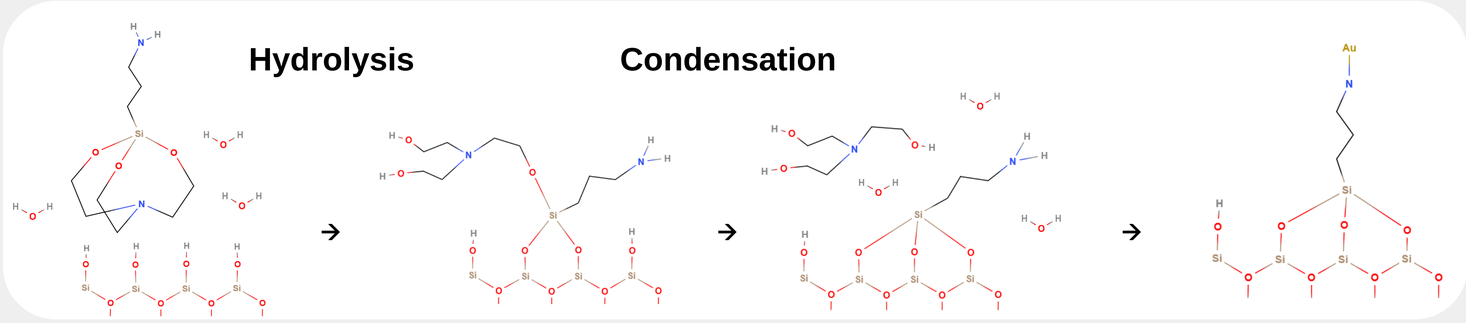
Motivation and background

In the field of plasmonic and microelectronic devices, the fabrication of noble metal thin films on dielectric or semiconductor substrates requires an adhesive intermediate layer that guarantees the stability of the structure. The most common materials for this purpose are metallic adhesion layers Cr or Ti. However, they deteriorate the optical characteristics of ultra-thin and ultra-smooth films for plasmonic waveguides and hyperbolic metamaterials. Here, we investigate the adhesion mechanism between gold and silicon oxide substrates, comparing the classical Cr and Ti adhesion layers with silane coupling agents, APTMS (3-aminopropyl)trimethoxysilane, MPTMS (3-mercaptopropyl)trimethoxysilane, and APS 3-aminopropylsilatrane, to establish an improved understanding of the structural effects and material properties.

Surface Chemistry

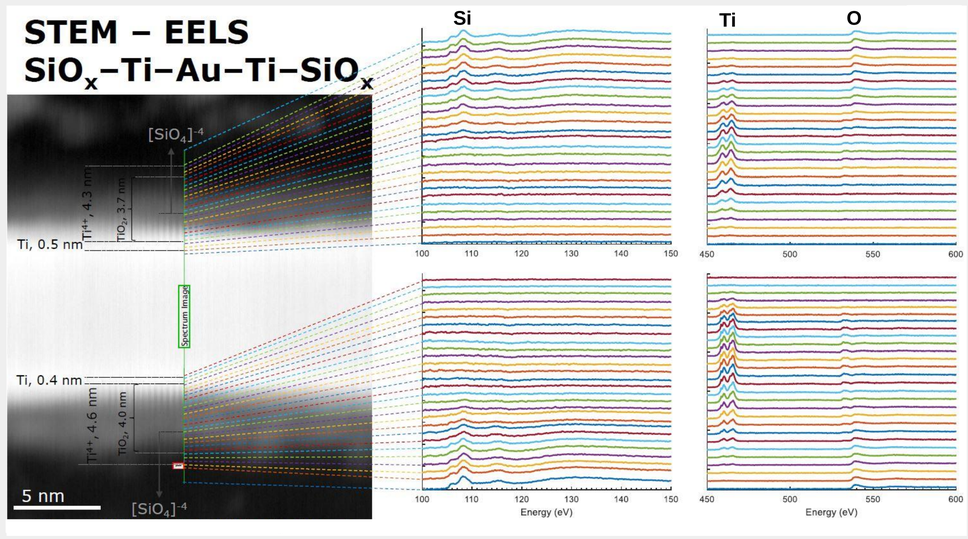
Surface modified silicon oxide substrate with an increased OH-group density for more efficient organosilane coverage, enables an enhanced adhesion for metal thin film structures.

Metals sputtering of Cr and Ti
Organosilane self-assembled monolayers (SAMs) in aq. sol.

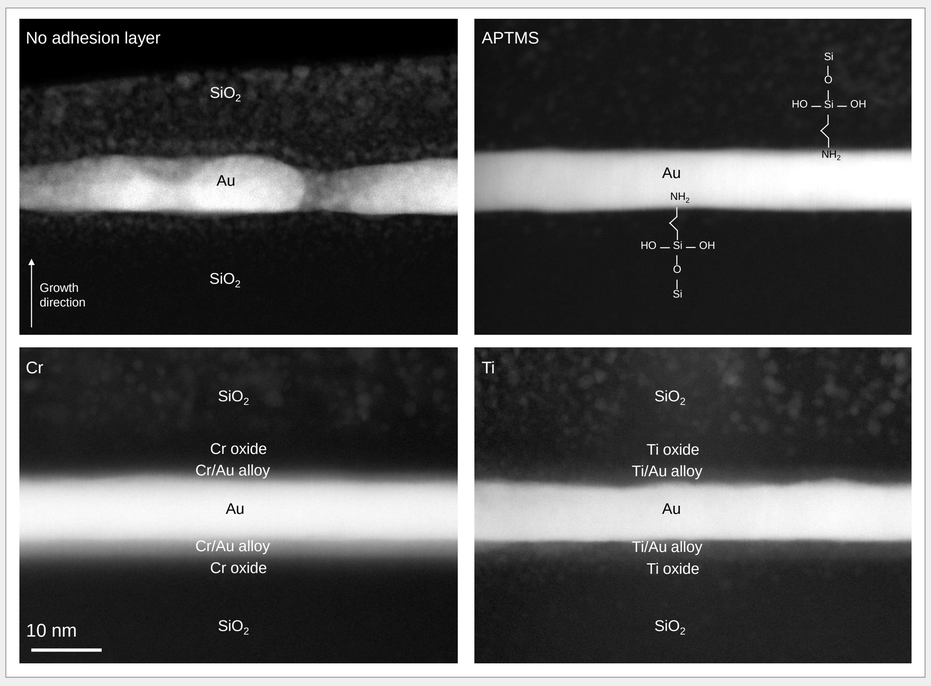


Interface Mechanisms

Electron energy-loss spectroscopy (EELS) scans for chemical characterisation of multi-stacked thin films with various adhesion materials in cross-section. Cr and Ti build thin oxide transition layers and diffusion occurs at the Au thin film edge, while the organic layers provide a continuous, undiminished thin film system.



➢ **ADF STEM imaging** in cross-section geometry

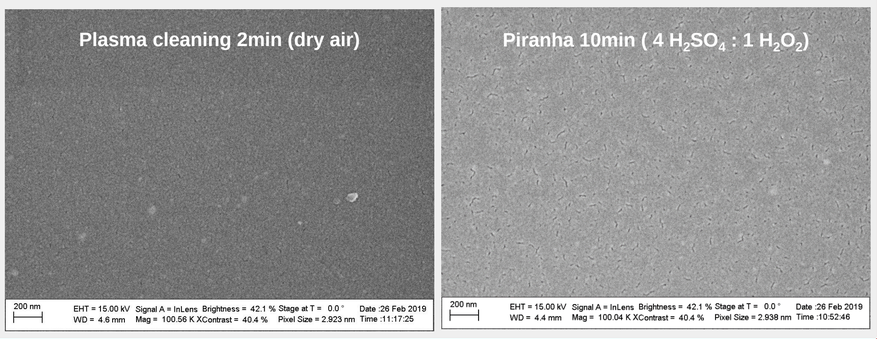


Surface pre-treatment

SEM imaging

Au ultrathin film on APS after Plasma cleaning and Piranha treatment.

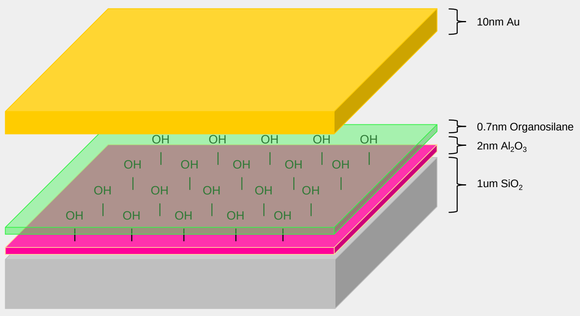
➢ thin film quality
➢ (dis)-continuity



Alumina

Intermediate layer of 2nm Al_2O_3 to increase the **OH-group density** on the sample surface

➢ SiO_2 8 [OH/nm^{-2}]
➢ Al_2O_3 18 [OH/nm^{-2}]



Conclusion and Outlook

We conduct comprehensive studies on effects of adhesion layers on Au thin films and investigate the potential of organic adhesion promoters as an alternative for thin film systems. The results present promising tendencies for the ultrathin film fabrication in terms of coverage, grain size distribution and film quality.

Further High-resolution TEM (HRTEM), transmission Kikuchi diffraction (TKD) and EELS will be used to understand and compare the morphology, microstructure and chemistry of the thin films. After elaboration the most promising fabrication method, additional organosilanes will be investigated with respect to optical and mechanical properties in order to avoid the dampening influences of metallic adhesion layers for more advanced plasmonic applications.

References

[1] Leandro et. al., Applied Materials & Interfaces, 7(2015), p. 5797-5802.
[2] Sukham et. al., Applied Materials & Interfaces, 9(2017), p. 25049-25056.
[3] Habteyes et. al., American Chemical Society Nano 6(2012), p. 5702-5709.
[4] Madsen et. al., American Chemical Society Photonics 4(2017), p. 268-274.