Evaporated Gold Island Films for Special Optical Applications

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Abstract

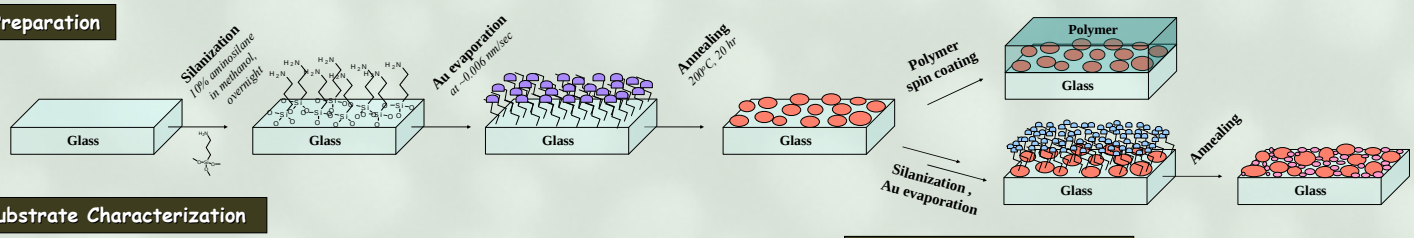
Evaporated gold island films show a localized surface plasmon (SP) resonance, resulting in enhanced light scattering, the appearance of a characteristic absorption band, and enhancement of local electromagnetic fields. These properties have been used in surface-enhanced spectroscopies as well as in chemical and biological sensing. The latter application is based on the sensitivity of the surface plasmon band to changes in the effective refractive index of the contacting medium.

In the present work gold island films (≤7.5 nm nominal thickness) were evaporated on silanized glass substrates. The 3D shape of unannealed and annealed (20 h at 200°C) islands was analyzed using high-resolution SEM and cross-sectional TEM imaging. The sensitivity of gold island films to the refractive index of the contacting medium was measured for island films of different nominal thicknesses.

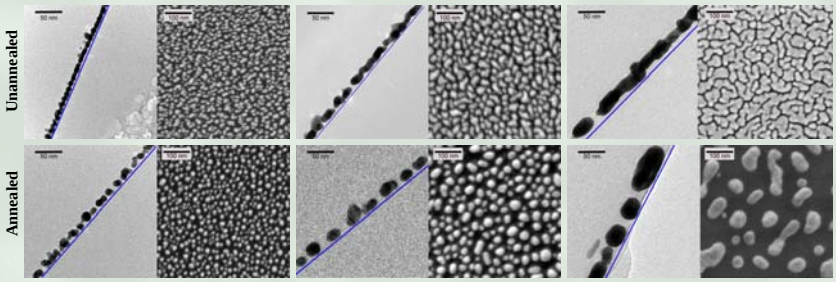
Application of Au island films to gas sensing in the transmission localized surface plasmon resonance (T-LSPR) mode was demonstrated by spin-coating of hydrophobic (polystyrene) and hydrophilic (polystyrene sulfonate) polymers onto 5 nm (nominal thickness) Au island films. Changes in the SP band (intensity, wavelength of maximum absorbance) observed upon exposure to various vapors is attributed to vapor absorption and polymer swelling, effecting change in the refractive index of the islands' environment.

Gold island films with unique morphologies were studied as possible substrates for surface-enhanced Raman scattering (SERS) applications using Rhodamine 6G (R6G) as a marker.

Preparation

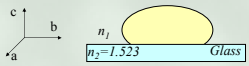


Substrate Characterization

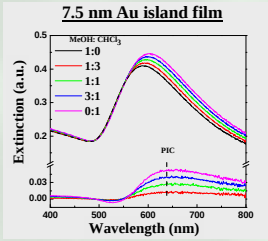


Nominal thickness (nm)	a (nm)	b (nm)	c (nm)
2.5	15±3	13±3	13±2
5	30±7	24±5	22±6
7.5	71±42	43±15	39±8

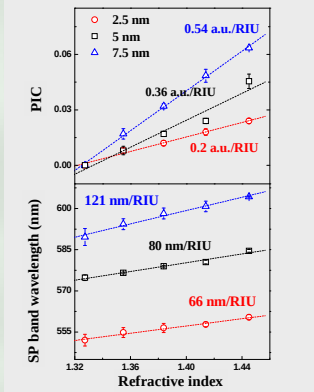
Cross-sectional TEM (left) and HRSEM (right) images



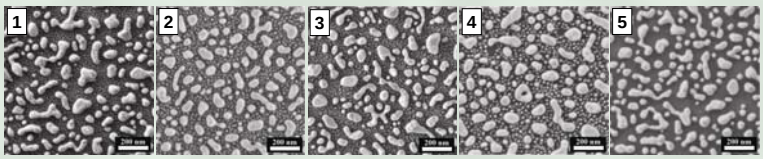
Refractive Index Sensitivity

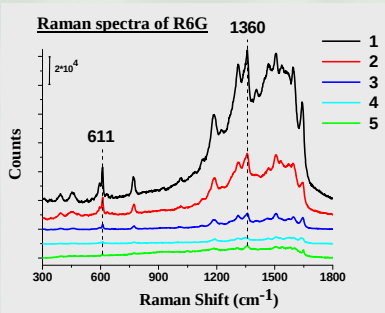


The refractive index sensitivity of annealed gold island films is determined by extinction measurements in mixtures of methanol and chloroform (n_1=1.33 -1.45)



Surface-Enhanced Raman Spectroscopy





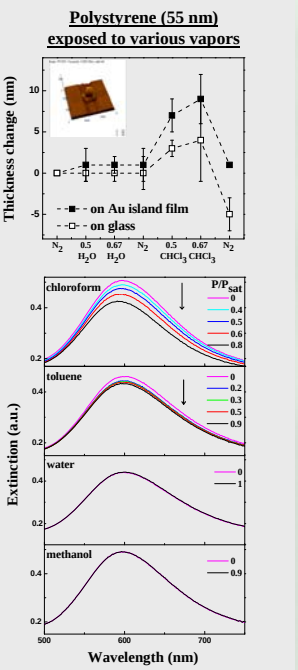
The silane monolayer was prepared using aminopropyl trimethoxysilane. Phodamine 6G (R6G) was adsorbed from 5·10⁻⁵ M solution in ethanol. Raman spectra were measured at λ_{ext} = 633 nm, P = 25 mW, acquisition time = 30 sec.

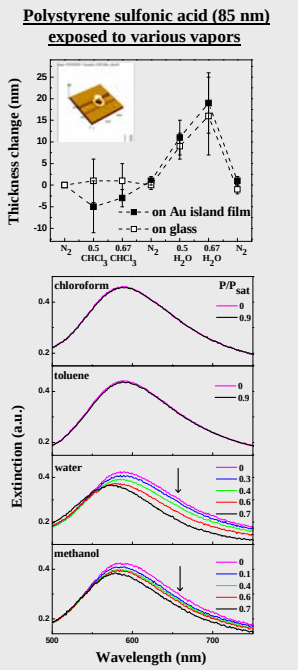
Maximum intensity (counts) of selected R6G Raman peaks

Raman frequency \ Sample	1	2	3	4	5
611	23691	12332	9964	1788	3089
1360	104684	42896	11652	4758	9050

Gas Sensing

T-LSPR transducers were fabricated by spin-coating of polymer layers onto Au island films (5 nm nominal thickness, evaporated on silanized glass and annealed).





Summary

- Evaporated Au island films were studied as possible candidates for T-LSPR sensing and SERS substrates. Upon annealing the islands undergo coalescence and attain an oblate spheroid shape, increasing the average island size and separation between islands and decreasing the relative contact area with the substrate. The refractive index sensitivity increases for higher nominal thicknesses.

- The optical response of polymer-coated T-LSPR transducers is sensitive to vapor analytes. Vapors of good solvents induce polymer swelling and thickness increase, manifested as a characteristic change in the surface plasmon band intensity and wavelength. No response is seen to poor solvent vapors. The response is reversible and fast (~15 sec). Polymer-coated Au island systems are therefore promising transducers for gas sensing in an array configuration (fingerprinting).

- The Raman spectrum of Rhodamine 6G adsorbed on a two-layer hierarchical Au island film was substantially enhanced relative to that obtained with a regular Au island film. Such substrates are therefore promising for surface-enhanced Raman spectroscopy (SERS) and can be optimized by controlling various morphological and interfacial parameters of the hierarchical system.