Transmission of light through arrays of holes in “optically” thin films

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Since the discovery of Extraordinary Optical Transmission (EOT) **[1]**, through optically thick films drilled with arrays of square holes, numerous works have explored different parameter configurations of two-dimensional hole arrays (2DHAs) **[2]**. As regards to geometrical parameters, it has been found that the hole shape can strongly influence both the polarization properties and the intensity of the transmission. On the other hand, in the Ebbesen's configuration **[1]** the metal film is opaque. In this case, the EOT process involves surface modes at each side of the film which couple through the holes **[3]**. Note that continuous metal films (thin enough to be translucent), also present transmission resonances when periodically corrugated. In this configuration, resonant spectral features are related to the surface plasmon polaritons (SPPs) of the thin film, the so called Short Range SPPs (SRs) and Long Range SPPs (LRs) **[4]**.

We present here a recent theoretical study on the optical transmission through square hole arrays drilled in optically thin films **[5]**. We study the effect of diminishing the film thickness, going from optically thick films to films as thin as approximately one “skin depth” (~20nm). The main finding is that EOT peaks are due to the excitation of SR resonances, therefore their spectral position depend strongly on both lattice parameter and metal thickness. On the contrary, LRs do not appreciably contribute to transmission spectra. The figure below shows zero-order transmittance curves as a function of the film thickness, for a structure defined by the parameters given in the figure caption. As we can see in panel (b), both maxima and minima red-shift as the metal thickness decreases. We have also found transmission features appearing close to the SR plasmon polariton energies for small holes (not shown). Any relevant transmission feature seems to be related to the excitation of LR surface plasmons.

References

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Figures

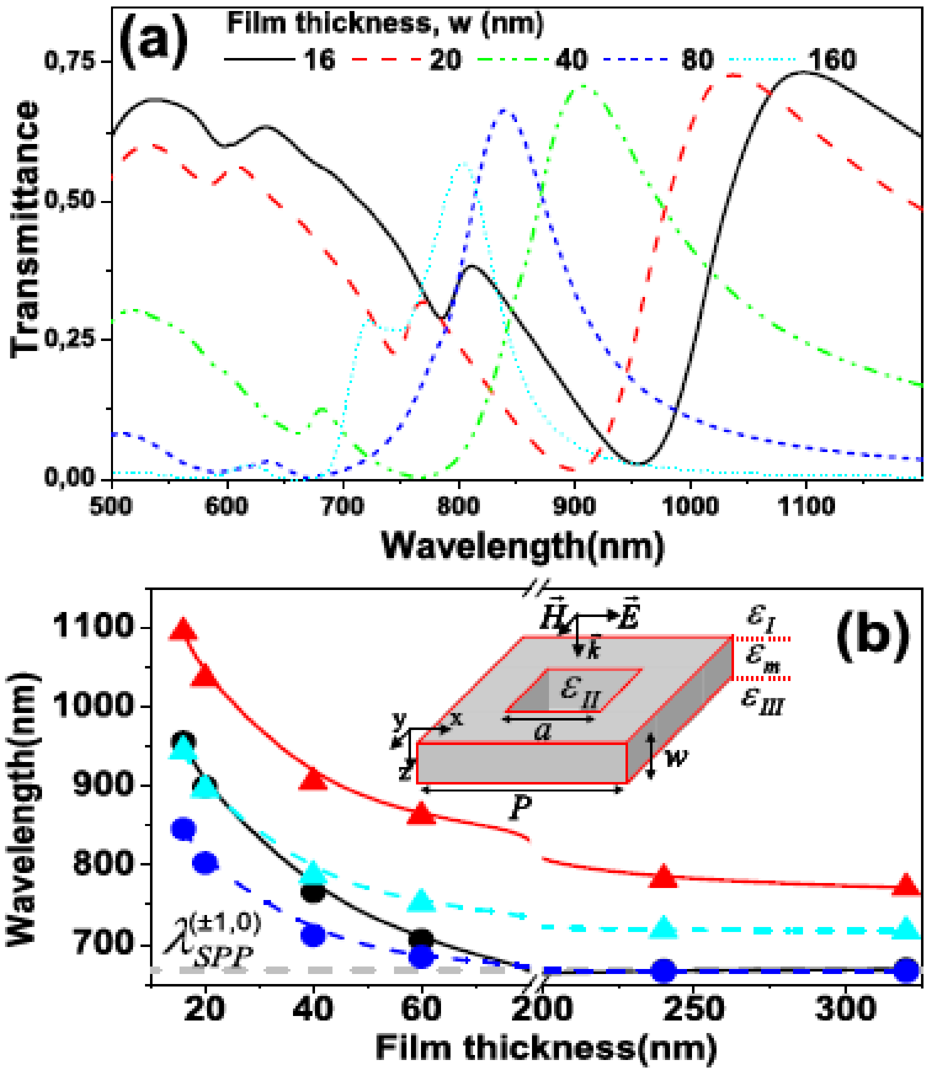

Figure: (a) Zero-order transmittance through 2DHAs in gold, as a function of the film thickness (P= 400nm, a = 160nm). The whole system is embedded in a dielectric medium (ε = 2.25). The spectral position as a function of w for both the EOT maximum (triangular symbols) an the EOT minimum (circular symbols) are shown in panel (b). Dashed lines summarize data obtained from panel (a), while solid lines are used for data taken from the asymmetric configuration where the hole array is placed on a substrate (ε = 2.25), air elsewhere. The horizontal dashed line renders the SPP energy at k=2π/P.