Excerpt from the Proceedings of the 2011 COMSOL Conference in Stuttgart

Simulation of Realistically Shaped Nanoantennas Using COMSOL Multiphysics

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Nanoantennas - nanometer sized gold structures with resonances at optical wavelengths have interesting properties for many tempting applications [1-7]. Although the principle behavior of such antennas can be learned from conventional antennas, concepts for the quantitative evaluation of antennas cannot be simply scaled down for nanoantennas [8]. This is mainly due to the fact that metals behave quite different at optical frequencies. The behavior of such nanoantennas is dominated by surface plasmon resonances and a numerical solution based on Maxwell's equation is necessary. Usually this is done for simplified geometries. However, since the fabrication of such nanoantennas is still at the limit of what is possible today, the fabricated shape still differs significantly from perfect geometries. Furthermore, such structures are very sensitive to small changes in the geometry. Here, we investigate to which extent the deviation in geometry influences the measured results.

We use the RF-module of COMSOL Multiphysics for the calculation of scattering from gold nanoantennas. The antennas investigated here are pairs of metal bars with dimensions in the order of a few tens of nanometers, which are separated by a small gap. We present a method, where the geometries from real fabricated nanoantennas are extracted from SEM images and then a 3D CAD model is built which is finally imported into COMSOL. The dielectric function of gold at optical wavelengths is complex and frequency dependent [9]. In our simulation a plane wave is incident on the metal structure and the scattered fields are investigated. The whole simulation area is surrounded by PMLs to avoid any backscattering into the simulation area.

The behavior of realistically shaped nanoantennas is compared to that of the ideal, perfectly rectangular nanoantennas intended to fabricate.

Figure 1 a) shows an SEM image of a two-arm nanoantenna (scale bar 50 nm). The blue line indicates the contour extrected with image processing techniques. The contour was then imported into a CAD program, where it was extruded in the third dimension. Therefore, the height was taken from AFM measurements. In Figure 1 b) (left side), the resulting CAD structures for realistically shaped geometry is shown. This geometry is compared to the ideal geometry with nominal dimensions Figure 1 b) (right side). Figure 2 shows the scattering cross section from antennas with both ideal and real geometry. In Figure 3 the respective electric field distributions at resonance wavelength are shown. As can be seen, the scattering cross section is significantly smaller for the real geometries. Furthermore, also the near field distribution of the electrical field is strongly influenced and can only be calculated correctly when taking into account the precise shape of the geometry.

From the above presented results it can be seen that there is indeed a significant difference between the behavior of nanoantennas with ideally and realistically shaped geometries. We have shown a possibility how to create a 3D CAD model based on measurement data which we imported into COMSOL. This enables a better prediction and interpretation of measured results.

Reference

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