NEAR FIELD ABSORPTION OF RESONATING NANOSIZED GOLD PARTICLES

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ABSTRACT

Thermal transfer at the nanoscale is crucial for robust and novel nanomanufacturing applications. The mechanisms by which heat can be transported to and from nano-sized mechanical systems are currently comprehended through solutions to Maxwell's equations; analytically this is a complex and weighty task [1]. Equally, optical and thermal phenomena that occur in the nanoscale regime are challenging. In order to gain a clearer understanding of absorption by nanosized particles on or near substrates we have studied the effect of particles size (10-80 nm in diameter) and the effect of a probe (gold, silver or silicon). To assess the scale and importance of these interactions, and to increase the depth of knowledge of nanoscale physics, we have performed numerical analysis of the optical absorption of nanoparticles. The results presented are a portion of the theoretical framework of nanoscale interactions and fusing [2,3] which is currently being experimentally verified.

The absorption of resonating particles of different sizes, between 10 and 80 nm, are modeled. The extinction cross sections, radiant flux scattered and absorbed by the particle and the extinction efficiency can be used to determine resonance wavelengths [4]. Using the dipole approximation, one can determine the extinction cross-section resonance [5,6], which can be used as a litmus test for the accuracy of the results. The particles, which are gold and situated above a glass and a thick metallic film, are modeled in three dimensions. Light is assumed to be linearly polarized and incident upon the glass at 45°, which allows total internal reflection. These conditions produce transverse magnetic waves at a resonance wavelength of gold [5,7]. In addition to particle size, the simulations also examined the effect of introducing an atomic force microscope (AFM) probe near or in contact with these excited particles, and monitoring the effect on the temperature of the particles (modeled particles are 10 nm in diameter, and the tip materials are silicon, gold and silver). The choice of modeling an AFM probe with the particles was designed to mimic our experimental settings.

We use the Electromagnetics Module of the finite element program COMSOL Multiphysics to model the absorption of energy by particles. The construct of the model is based on the mesh density, the geometry of the system, the frequency dependent index of refraction and the boundary conditions. The electric and magnetic fields are determined at each mode within the system at each point in time. The results of these fields are exported to a program that integrates the field over a subdomain area. From this information, the Poynting vector can be extracted. The Poynting vector allows one to determine the electric field within the metal, and gives the field intensity of the surface plasmons at the metal's surface. Through the equations describing energy time derivative of the electric and magnetic fields (power), one can relate properties of energy via Poynting's theorem [6] From this information, one can determine the enhancement of the electric field with in the particle [8].

$$\left|\frac{E(a)}{E_o}\right|^2$$

When this energy is localized within a particle, it is considered absorption. This is the value we call 'relative absorption.'

RESULTS

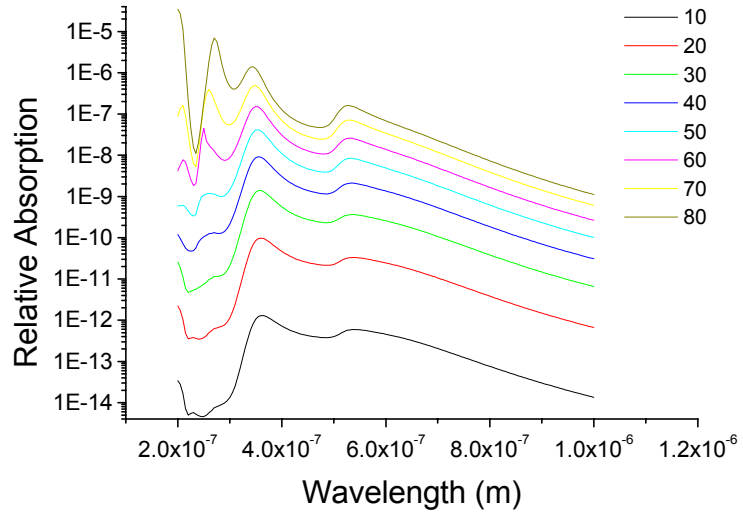

Figure 1: Spectral absorption of surface plasmon waves by gold particles, 10-80 nm in diameter. The numbers in inset corresponds to particle diameters, in nm.

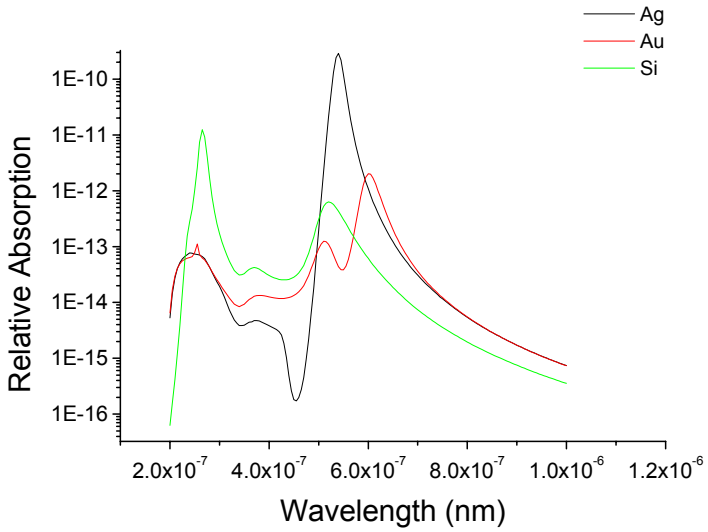

Figure 2: Spectral absorption of surface plasmon waves by gold particles, with a gold, silver or silicon probe 10 nm above the particle. Particles are 10 nm in diameter.

The first portion of the study is to characterize the behavior of gold spheres, with diameters of 10-80 nm, when they experience SPR. The results show that an increase in absorption accompanies an increase in diameter size- these can be seen in *Figure 1*. In the visible wavelengths, the particles do not experience a shift in resonance in size: the resonance occurs consistently at 520 nm. While this is expected, the results did demonstrate unique resonance shifts in the non-visible range. There are several possible reasons for this shift in resonance, and as these pertain to all the results, they will be reviewed in depth in the poster.

Figure 2 shows the absorption of a 10 nm particle for wavelengths ranging from 200-1000 nm. The figure compares a gold probe, a silver probe and a silicon probe 10 nm in distance above the particle.

The geometries chosen mimic AFM settings. This choice is to determine how the particles would behave when subjected to current imaging techniques. The gold and silver probes had dramatic effects on the absorption of the particle. Both metals had caused no resonance shift and no significant change in magnitude at the shorter wavelengths, as compared to an isolated particle. However gold probe had shifted the secondary peak from 520 nm to 600 nm, and doubled the magnitude of the absorption. The silver probe shifted the absorption of the secondary peak from 520 nm to 540 nm, and tripled the magnitude of absorption, as compared to an isolated particle.

The presence of the silicon probe as a non-metal can be considered as the 'neutral' test. The presence of the silicon probe was different from an isolated 10 nm particle; the resonance went from 250 nm to 265 nm, and tripled the magnitude of absorption. There was, however, no appreciable change in the magnitude of absorption, nor any resonance shift for the secondary peak at the 520 nm.

These results indicate that nanoparticles targeted by a realistic AFM probe can be selectively excited relative to isolated nanoparticles. The results also suggest that the material of the probe can manipulate the magnitude and wavelength of peak resonance.

CONCLUSIONS

The most fascinating aspect of the nanoscale is that the solutions are neither obvious nor explained by current theory. The results above have shown that the absorption of energy by nanosized gold particles is affected by geometrical and material considerations. The results can be considered as a portion of a 'map' for directed self assembly. The map will ultimately allow one to choose conditions that provide selective heating.

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