別紙様式８

研　究　主　論　文　抄　録

論文題目

Study on Numerical Analysis of Light Enhancement by Means of Noble Metal Films

（貴金属薄膜における光増強の数値計算に関する研究）

熊本大学大学院自然科学研究科　情報電気電子工学専攻　先端情報通信工学講座

（　主任指導　　松島　章　教授　）

論文提出者　　JI, Xiaowei（吉　暁偉）

主論文要旨

The interaction of light with nanostructured metal leads to a number of fascinating phenomena, including plasmon oscillations that can be harnessed for a variety of cutting-edge applications. Plasmon oscillation modes are the collective oscillation of free electrons in metals under incident light. Previously, surface plasmon modes have been used for communication, sensing, nonlinear optics and novel physics studies. Further understanding of the nature of these materials and their optical properties has led to applications in a wide range of fields, such as biological and chemical agent sensing, infrared obscurants and filters, near-field superlenses that can image objects smaller than the conventional lens wavelength limit, and even potential applications in negative-refraction metamaterials. At the heart of the research performed through this fellowship are the study of plasmonics and the coupling of light to surface modes in a metal. The interaction of light with metal is often complicated and useful. In the vast literature on plasmonics, devices that support plasmon oscillations have been engineered for a wide variety of purposes.

In this thesis, we mainly discuss the influence of two thin metal structures on the scattering of electromagnetic waves. They are metal-dielectric composite films and the two-dimensional periodic array of metal disks and circular apertures. We simply study that, when a plane wave is incident on the metal structures, the change of the intensity of the reflection field and the transmission field and the absorption intensity of the

metal structure.

In chapter 2, we present two kinds of metal-dielectric composite film structures, the metal-dielectric-metal sandwich composite film structure and the 2.5 metal-dielectric periods composite film structure. As can be seen from the calculations, by using of multilayer metal-dielectric composite film, the two-way transmission coefficient of light can be strengthened. In other words, these two structures can simultaneously enhance the transmission of the excitation light and the emission light. This can overcome the disadvantage that by using of the single-layer metal film only the transmission of the excitation light can be enhanced. And the results show that, comparing to using a single layer of metal film, using the metal-dielectric-metal sandwich composite film coated on the surface of cover glass of the surface plasmon coupled emission microscopy, the intensity of the excitation field which excites the fluorophore is greatly enhanced, and the intensity of the emitted light of the fluorophore is increased by several thousand times.

In chapter 3, numerical solution is presented for light scattering from two kinds of free-standing periodic arrays, that is, disks made of noble-metal and circular apertures perforated in a thin noble-metal sheet. The shapes of them are complementary to each other, and the circular areas are allocated along two orthogonal coordinates with the same periodicity. Using the generalized boundary conditions of the surface impedance type, we formulate the boundary value problem into a set of integral equations for unknown electric and magnetic current densities defined over the circular area. Numerical solution has been developed to investigate the power distributions of two-dimensional periodic arrays of disks and circular apertures with regard to thin noble-metals. Employment of the method of moments allows us to solve the integral equations and give the expansion coefficients of the current densities, from which we can find reflected, transmitted, and absorbed powers. Dependence of the powers on the array parameters and wavelength is discussed in detail from the viewpoint of grating resonance. Special attention is paid to the extraordinary transmission which occurs in the arrays of apertures of sub-wavelength size by analytical derivation of the quasi-static solutions.

In chapter 4, we apply the composite film to a fluorescence microscope and investigated its effect on fluorescence imaging. First, we calculate the distribution of the excitation field in the object space. Here, the light incident on the composite film is highly focused radially polarized light. The fluorophore in object space is excited and emit light. Then we derive the field intensity distribution of the emitted light in the image space. The results show that, using the metal-dielectric-metal sandwich composite film coated on the surface of cover glass, both the intensity of the excitation field which excites the fluorophore in the object space, and the intensity of the emitted field of the fluorophore in the image space is greatly enhanced.