EFFECTIVE MEDIA THEORY ADAPTED FOR SCANING NEAR-FIELD OPTICAL MICROSCOPY SIMULATIONS

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Resumen

Optical images acquired by NSOM can be treated by means of theoretical calculations in order to extract all the information they contain, but unfortunately, there is not user friendly analytical expressions to describe transmitted signal under near-field conditions through a sample whose surface exhibits a random roughness having lateral dimensions comparable to the NSOM tip. In this sense, the task of reproducing a refractive index profile of the surface objects from the transmission contrasts requires a great calculation effort to obtain quantitative results [1-2]. In addition, the some characteristics of nanostructured material present other difficulties to perform an accurate estimate of optical contrasts, since some parameters (index profile, size, shape, etc) are not well known often. However, for a structural characterization of dielectric samples we just need to discriminate between the different phases present on the sample surface, as aimed in this work. Therefore, NSOM transmission images could be easily interpreted if we take the next considerations in a 2D-model: (i) the sample is considered a flat surface multilayer with a determined effective refractive index at the surface upper-layer; (ii) a different effective refractive index is considered depending on the tip position (i.e. at each pixel of the image); and finally, (iii) the electromagnetic field distribution in the plane of the probe aperture is approached to a Gaussian spatial distribution with a standard deviation σ ~ 80 nm (i.e., approximately the tip aperture diameter), as illustrated in Fig. 1(a).

It is necessary to point out that according to condition (ii), the effective refractive index is going to depend on the upper-layer of the sample local composition. For this reason, as aforementioned a different refractive index must be considered at each measuring point (at each pixel of the transmission image). Figure 2 (b) and (c) illustrates how the local refractive index is estimated in this work. It is based on the effective medium theory (EMT) which has been successfully applied to several kinds of dielectric materials [3]. This way, the effective dielectric constant ε_{eff} (and therefore the refractive index) for a D-dimensional composite (in this case D=2) comprising inclusions with permittivity ε_{nano} and a filling factor p with respect to the host medium (the upper-layer) with a permittivity ε_{up} is given by [4]:

$$\varepsilon_{eff} = \frac{1}{2(D-1)}\{(Dp-1)\varepsilon_{nano} + (D-1-Dp)\varepsilon_{up} + \sqrt{[(Dp-1)\varepsilon_{nano} + (D-1-Dp)\varepsilon_{up}]^2 + 4(D-1)\varepsilon_{nano}\varepsilon_{up}}\}$$

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Figuras:

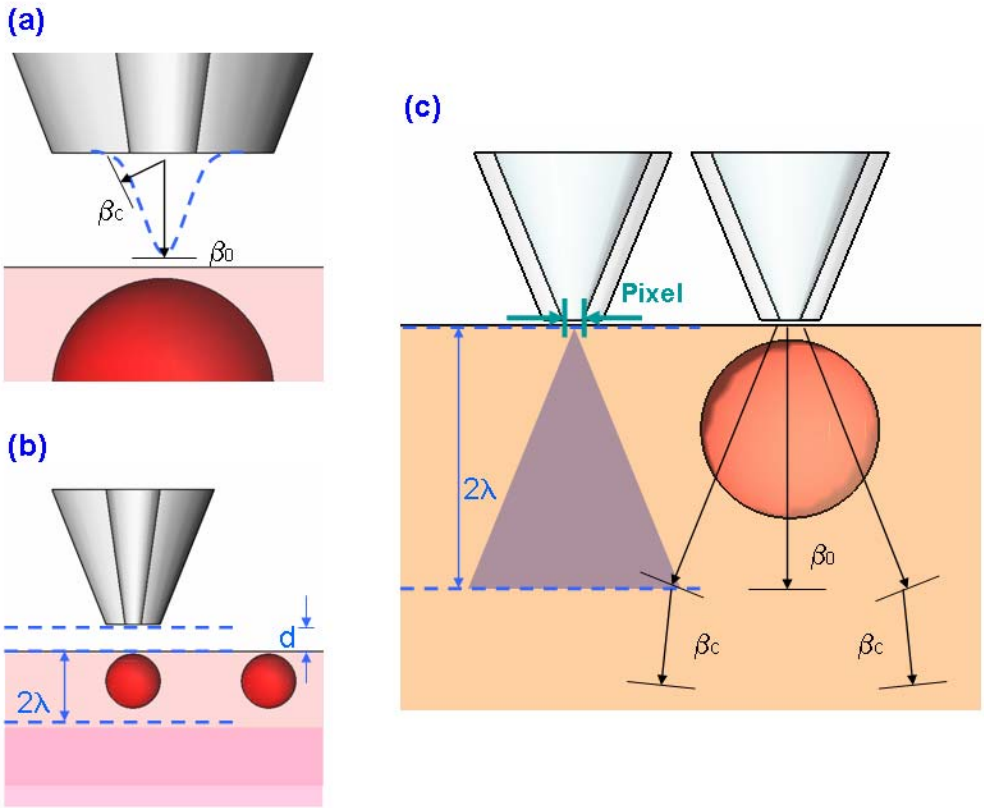

Figure 1. (a) Near-field probe close to the feedback range. The optical intensity on the aperture plane is approached to a Gaussian Field distribution. (b) Scheme of the different layers considered in our two-dimensional simulation. Working at constant gap mode the tip is maintained at a distance "d" of a few nanometers. The sample surface is considered as a flat film (2λ thickness) with an average refractive index, $n_{eff}(x)$, which depends on the tip position. Once the light arrives to the far field is expected to be propagated as in a homogeneous media. (c) 2D-representation of the near-field probe (80 nm) in feedback range close to a scatter object larger than the wavelength. The effective refractive index of the surface are determined according to the cross-section between the excitation light cone and the sample features immersed in the near-field region (propagation distance smaller the 2λ). Therefore, a different effective refractive index, n_{eff}, is expected for each pixel of the NSOM tip scan. Notice, the pictures are not at the correct scale in all dimensions.