Wide band transparent metallo-dielectric nanowires at telecommunications wavelengths

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Abstract

Since several decades ago, different systems showing small light scattering efficiency has been proposed [1,2]. More recently, several nanometer sized structures have been studied and, even, experimentally demonstrated [3-7]. Those systems are based on the interaction of the electromagnetic modes in core-shell submicron sized particles. Even with relatively simple geometries, such as spherical or cylindrical core-shell structures, the degrees of freedom provided by size, available *realistic* materials and core-to-shell size ratios, are enough to obtain a global optical response with prescribed properties in a given frequency range.

Optically invisible metamaterial fibers [3], multishell cylindrical cloaking devices [4], metal coated dielectric invisible cylinders [5] or ZnO/Ag nanowire composites [6] have been recently proposed as cylindrical devices showing certain cloaking properties, or combining high transparency -low scattering- with other properties such as high electrical conductivity.

One of the characteristics usually shared by many of the proposed systems is the resonant nature of the effect responsible for the transparency that, along with chromatic dispersion and absorption, lead to a narrowing of the transparency window.

In this work, we analyze in detail the conditions required to obtain small scattering efficiency in a core-shell cylinder for any metal or dielectric combination in the infrared at bands relevant to telecommunications. By the use of a simple model based on the quasi-static approximation with radiative corrections to the polarizability of a core-shell cylinder [8], we obtain general properties required to achieve transparency in realistic structures [9]. We also check our predictions against a more accurate model based on Mie theory for cylinders[10].

We find that, under rather general conditions, metal nanowires with high refractive index coating can show a transparency region which is more robust against fabrication defects (size polydispersity) than metal coated fibers. Also, it is shown that it is possible to obtain up to three orders of magnitude lower scattering efficiency ,compared with raw metal cylinders, in a band as wide as 20% of the central frequency, and with realistic materials (Si coated Ag wires) in the infrared (See figure 1). The transparency condition is also quite robust regarding the angle of incidence and polarization of the incoming signal [9].

It is shown that the near field scattering is extremely weak in the transparency region. Hence, the coupling through evanescent modes among equal cylinders is essentially negligible. Then, a high density assembly of appropriately designed nanowires present a extremely low scattering efficiency [9]. Even the wavefronts are negligibly disturbed in a random and high density assembly of transparent nanowires.

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Figures

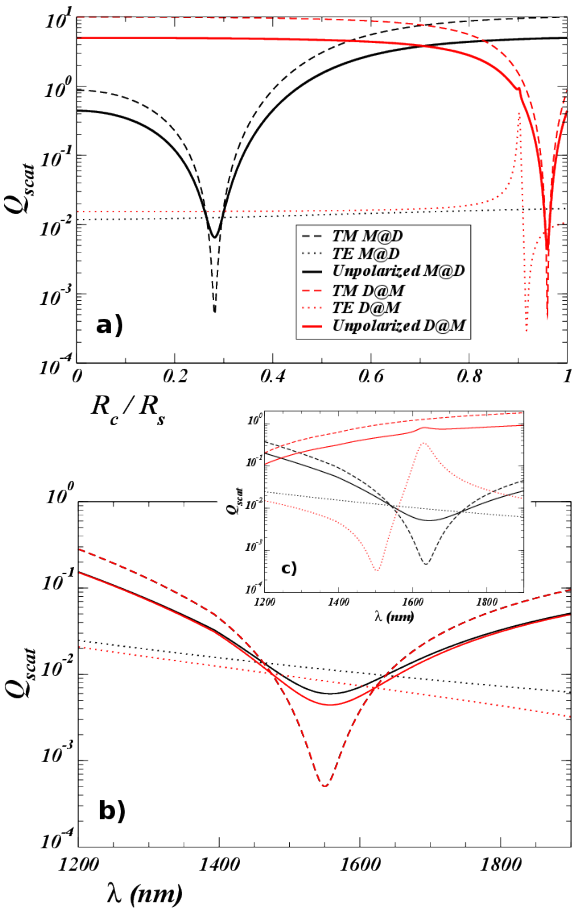

Figure 1: *Approximate scattering efficiency Q_{scat} as obtained from the quasi-static approximation. TM polarization (dashed line), TE polarization (dotted line) and unpolarized (continuous line) radiation is considered for both Ag@Si (black curves) and Si@Ag (red curves) structures. In a) Q_{scat} at a constant wavelength λ=1550 nm is plotted as a function of the core to shell radii ratio. In b), the spectra for the different polarization is presented. The ratio Rc/Rs is fixed in such a way that Q_{scat} is minimized in TM polarization for each structure. In the inset c), the core radius is reduced by 5%.*