Microstructures located on flat substrates contaminated with small bosses: Backscattering and substrate effects

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Abstract

The influence of the optical properties of the substrate in the backscattering of Micron-sized structures supporting sub-micron defects is analyzed by means of a parameter based on integrated backscattering calculations. This analysis is performed for two different configurations (defect on the microstructure or on the substrate), considering both dielectric and metallic substrates.

1 Introduction

During the last decades, researchers on light scattering by surfaces have focused on the electromagnetic problem of particles on substrates. Their results have generated non-invasive light scattering techniques for particle sizing with applications in different fields. In previous works[1-2], the authors have extensively studied light scattering by particles on substrates from both numerical and experimental points of view.
Among the types of far-field scattering measurements the backscattering detection has proved itself very sensitive to small variations in the geometry and/or optical properties of scattering systems with structures comparable to the incident wavelength[3-4].

In a recent work [1], we described how a small defect located on a micron-sized cylinder on a substrate changes the backscattered intensity. Also, we showed that an integration of the backscattered intensity over either the positive or negative quadrant (corresponding to the defect side or the opposite one, respectively) yields to a parameter, s_{br}, (see ref.[1]) sensitive not only to the existence of the defect but also to its size and location on the microstructure. These results were obtained for a homogeneous system, where substrate, cylinder and defect were supposed perfect conductors. Later on, another work was presented showing results for more realistic systems: dielectric or metallic defect on a metallic cylinder located on a metallic substrate[2] . Also, other geometries, where the small defect was in the substrate nearby the cylinder, were considered. Those works suggests the measurement of s_{br} as an experimental technique for monitoring, sizing and characterization of small defects adhered to microstructures. From a practical point of view, detection and sizing of very small defects on microstructures located over substrates by some reliable and non-invasive method could be useful in quality control technology and in nano-scale monitoring processes. In this context, the objective of this work is to study the sensitivity of this technique to the optical properties of the substrate in two configurations: A) defect on cylinder and B) defect on substrate nearby the cylinder. This abstract is organized as follows: Section 2 is devoted to describe the geometry and the numerical method proposed to solve the problem. Section 3 is devoted to show the main results and their corresponding discussion. Finally Section 4 summarizes the main conclusions of this research.

2 Scattering Geometry and Numerical Method

The scattering geometry is similar to that described in a previous work[1], i.e a cylindrical metallic microstructure of diameter $D=l$ located on a flat conducting substrate, and supporting a much smaller defect. Its shape will be assumed cylindrical with diameter $d=0.1l$. Two situations will be analyzed: Configuration A) The defect is located on the cylinder and its position is given by the angle j, which is considered always in the right side, $j>0$, with no loss of generality. Configuration B) The defect is located on the substrate nearby the cylinder. In principle, we want to show the differences, if any, appearing between these two configurations in order to extract the most important conclusions leading to a possible distinction between them. This could give more insight in the solution of the inverse problem.

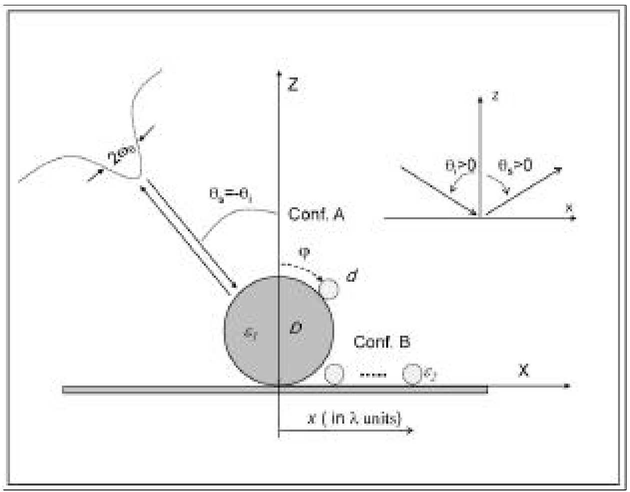

Figure 1: Scattering geometry.

The scattered field in each medium is obtained by numerically solving the Maxwell's integral equations using the Extinction Theorem formulation applied to the 2-D geometry for multiple connected domains [5].

3 Results

3.1 Configuration A

Figure 2 shows a comparison of s_{br} for different dielectric and metallic substrates, as a function of the angular position of the defect on the main cylinder. An interesting result that can be observed in Fig.2 is that $|s_{br}+|$ increases as we increase e, being maximum for the case of metals. An opposite behavior appears for $|s_{br}-|$.

It can also be seen that s_{br} is more sensitive to e, when $e \in [1.2,4]$ and it saturates for big values of e, tending to the metal case. Another difference in $s_{br}+$, is that the maxima and minima shift to the right as we increase e, tending to the metal case for big values of e. The main difference between dielectric and metallic substrate in this configuration is that for the dielectric case, sb- is not close to zero and therefore it is more difficult to predict the side of the cylinder where there is a defect.

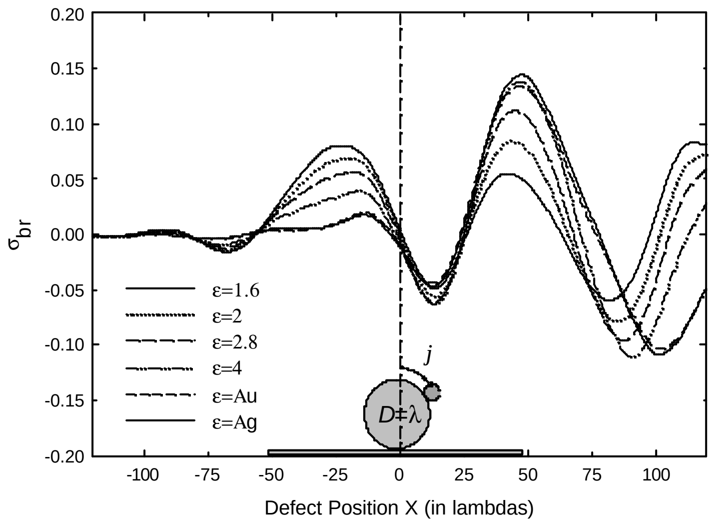

Figure 2: $s_{br}^{\pm}$ as a function of the defect angular position j for a silver cylinder of $D=?$ with a silver defect of $d=0.1\lambda$ and located on different types of substrate (e).

3.2 Configuration B

Figure 3. shows the evolution of s_{br} for different dielectric and metallic substrates, as a function of the position x, of the defect in the substrate. The shadowed area represents defect positions "under" the cylinder, not considered in the calculations. In this configuration, s_{br} is still more sensitive for dielectric substrates than metallic substrates. In fact, silver and gold substrates give almost the same values of s_{br}.

An interesting feature of s_{br} in this configuration is that, s_{br} is always positive for dielectric substrates whereas is always negative for metallic substrates. As it happened in configuration A, s_b- present bigger values for the case of dielectric substrate, but this time this is not critical, as s_b^- is always smaller than s_b^+.

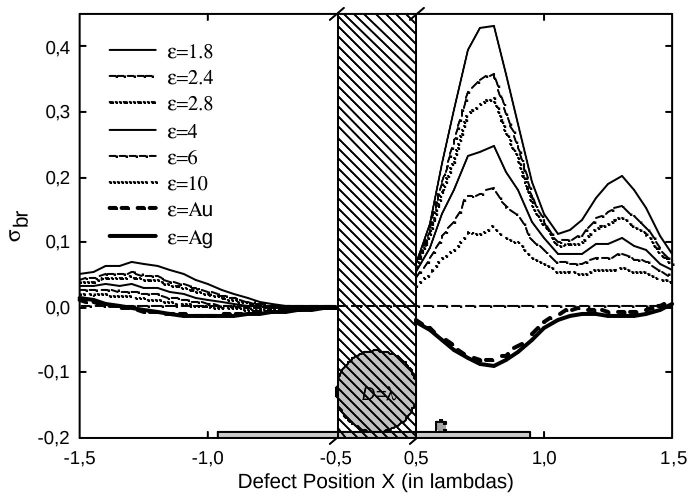

Figure 3: $s_{br}^{\pm}$ for a silver cylinder of $D=?$ with a silver defect $d=0.1\lambda$ and located on different types of substrate (e). Defect position x ranging from $0.5?$ *to* $1.5?$

4 Conclusions

In this work, the influence of the optical properties of the substrate in the sensitivity of the parameter s_{br} has been analyzed for two different configurations: A) defect on cylinder and B) defect on substrate nearby the cylinder. In both cases, s_{b}- present bigger values for the case of dielectric substrate. s_{br} also present an opposite behavior in configurations A and B for different types of substrate. In configuration A, metallic substrates allow an easier detection and characterization of a defect. In configuration B, s_{br} is more sensitive if the substrate is dielectric, giving very high values of s_{br} (up to 0.6) for small values of e.

Finally, if we focus on the inverse problem, information about the optical properties of the substrate could be obtained in both configurations by studying the maximum value of $s_{br.}$

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