Surface Optical Waves at Air/Metal Interfaces: Surface Plasmon Polaritons

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The surface plasmon resonance (SPR) phenomenon has been known for nearly five decades now; since then this method has made great advances in terms of instrumentation development and applications, and it still attracts researchers because of certain subtle issues that could benefit from it mainly detection and analysis of chemical and biochemical substances in different areas including medicine, environmental monitoring, biotechnology and drug and food monitoring. Our interest is focused on the use of this technique for studying thin coating and some application in nanophotonics. In this paper, we discuss the configuration of surface plasmons at air/metal interface by Atenuated total reflection (ATR) technique in the Kretchman configuration, and we present preliminary experimental results on surface plasmons at a Ag/air interface that we obtained in our laboratory.
Keywords: surface plasmons, thin films characterization.

I. INTRODUCTION

The Attenuated total reflection (ATR) is a technique based on light coupling to surfaces and interfaces as well as to waveguides, it has the ability to measure extremely small variations of the optical properties of thin dielectric films.

In this paper, we discuss the principle of ATR, and briefly show how the optical properties of thin coatings are determined; we then introduce our ATR-experimental setup and provide preliminary surface plasmon data that we obtained at an air/Ag interface in the Kretschamn configuration [1]. The experimental results are then compared to theoretical calculations of light reflection based on Fresnel equations.

II. SURFACE PLASMON POLARITONS

Plasmon surface polaritons, or surface plasmons, are traverse magnetic TM waves that propagate along dielectric interfaces, their field amplitudes decay exponentially perpendicular to the interface. One way of introducing surface plasmons, is in the Kretschmann configuration Fig.1, using the fact that the nearly free electron gas in the thin metal film evaporated onto the base of the prism acts as an oscillator that can be driven by the electromagnetic wave impinging upon that interface. Hence we are dealing with the resonant excitation of a coupled state between the plasma oscillation and the photons, that is, “plasmon surface polaritons”.

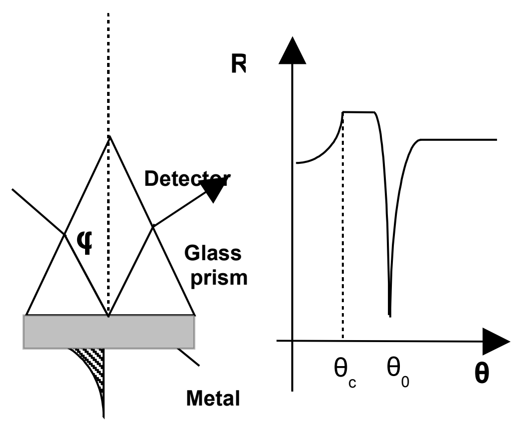

Figure 1: (left) ATR setup for the excitation of surface plasmons in Krtsechmann geometry, a thin metal film is evapolated onto the base of the prism and acts as resonator driven by the photon field, (right) the resonant excitation of the plasmon surface polariton wave is seen in the reflectivity curve as a sharp dip at coupling angle θ_0. θ_c is the critical angle at witch total internal reflection occurs.

The resonance phenomenon can be clearly seen in the ATR scan: below θ_c the reflectivity is very

high because the metal film acts as a mirror with little transmission. Above θ_c for total internal reflection, however, a relatively narrow dip in the reflectivity curve at θ_0 indicates the resonant excitation of such plasmon surface polariton wave at the metal – air interface.

In ATR technique, Fresnel equations simulating the uuuuuuuu of multilayers are used for the determination of the optical properties (thickness and complex refractive index) of the dielectric coating film the metal layer, the obtained theoretical ATR curve is fitted to experimental data to deduce the unknown parameters [2].

1. EXPERIMENTAL SET UP AND RESULTS

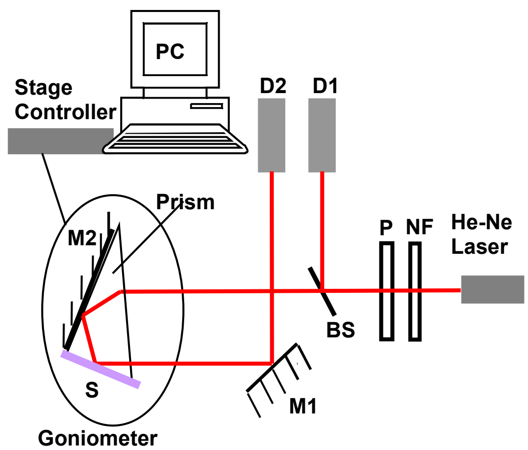

Figure 2: ATR experimental setup for surface plasmons coupling.

The experiment arrangement is depicted in **Fig.2.** A metal film (**S**) (thickness ≈ 50nm) is vacuum evaporated on top of a glass substrate which is deposited on the base of a prism by an index matching oil. We used a BK70 90 prism (equilateral right angle prism). A monochromatic laser light beam From He-Ne laser (632.8 nm) was first passed through a neutral density filter (**NF**) to adjust the laser intensity to 1.2µwatt/cm^2, and then a half wave plate (**P**) to be able to chose TM or TE polarization. After that the beam is split by a beam splitter **BS** into two beams of equal intensities; one of which serves as a reference, the other beam hits the base face of the prism, and it is reflected by the mirror lateral face (**M2**) in order to irradiate the metal film on the film lateral face at an incident angle greater than the critical angle. The intensities of both beams are detected by separate photodetectors (**D1**) and (**D2**). The reflected light beam which emerges from the lateral face of the prism was collected for incidence angles ranging from 40º to 60º. The incidence angle is changed using a controlled goniometer (**G**). Both photodetectors and the goniometer are connected to a computer that manages the experiment using customized software control program.**Figure.4** shows both a preliminary experimental dashed curve and a simulation results that we obtained at an air/Ag interface. The thickness of the metal silver film that we obtained from the Fresnel theoretical fits was 55 nm.

The light beam was transverse magnetic polarized (TM-polarized)

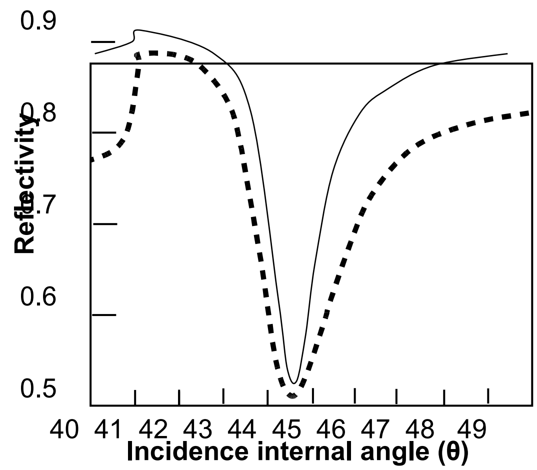

Figure 3: Reflectance of TM polarized light versus angle of incidence (θ) for an air metal interface; dashed curve shows the experimental result while the line represents the theoretical fit.

2. The out look

The results obtained demonstrate the coherence between the theoretical Fresnel reflectivity model and the experimental measurements, a feature which provides an easy tool for characterizing metal and dielectric coatings (thickness, optical proprieties and dielectric constant).

Future work will focus on the improvements of the SPR experiment setup and the study of thin dielectric on metal layers.

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