DESIGN AND REALIZATION OF SET-UP FOR SPR MEASURING METHOD

NÁVRH A REALIZACE ZAŘÍZENÍ PRO MĚŘENÍ METODOU SPR

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Abstract

Given paper describes modification of Gaertner L119 ellipsometer to apply the surface plasmon resonance (SPR) method. Final implementation has been tested on several basic measurements and obtained experimental data were compared with theoretical model.

Abstrakt

Předložená práce se zabývá popisem úprav elipsometru Gaertner L119 k měření metodou excitace povrchových plasmonů (SPR). Výsledná realizace byl prověřena na několika vstupních měřeních a změřené hodnoty byly porovnány s teoretickým modelem.

Key words: surface plasmon resonance, SPR, Gaertner L119

1 INTRODUCTION

The extreme sensitivity of SPR to small changes in refractive index (up to 10^{-8}, [1]) is used primarily in sensors, especially as very sensitive detectors of various substances in biology and chemistry, determining thicknesses of layers adsorbed on metal surface or to study kinetics of chemical reactions [2]. This method can also be used to study layered or periodical nanostructures which occur frequently in microelectronics.

2 THEORY

Surface plasmons are electric charge density oscillations on interface between two media which real parts of permitivity have opposite sign, eg. between metal and isolator. These charge density oscillations are bound to electromagnetic wave, which has it's intensity maximum on interface and decreases exponentially into both media. This electromagnetic wave is polarized parallel to the plane of incidence (p-polarization) and it's propagation constant is given by equation:

$$\beta = k\sqrt{\frac{\varepsilon_m \varepsilon_s}{\varepsilon_m + \varepsilon_s}}, \tag{1}$$

where k is the wave vector in vacuum, ε_m is the permittivity of metal ($\varepsilon_m = \varepsilon_{rm} + i\varepsilon_{im}$) and ε_s is the permittivity of dielectric medium. As may be concluded from this equation the surface plasmon wave may exist only on the interface providing that following condition is satisfied: $\varepsilon_m < -\varepsilon_s$. At optical wavelengths, this condition is fulfilled by several metals of which gold and silver are the most commonly used.

As follows from equation (1) above, the propagation constant of plasmon wave is always higher than that of electromagnetic wave in the dielectric and thus the plasmon cannot be excited directly by an incident optical wave at metal–dielectric interface. Therefore the wave vector of the incident optical wave has to be changed to match that of plasmon wave. This momentum change is commonly achieved using attenuated total reflection in prism couplers or difraction at the surface of gratings (Fig. 1). When surface plasmon wave is induced it manifests itself as significant loss of reflectivity at a specific angle [3].

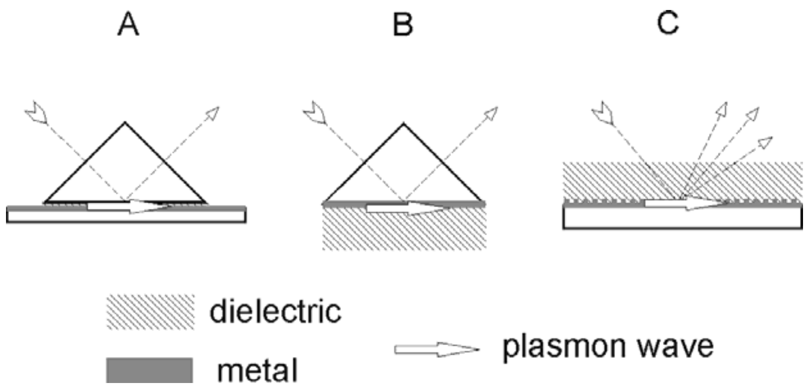

Fig. 1 Possible configurations for exciting surface plasmons:
Otto (A), Kretchmann-Raether (B), metal diffraction grating (C).

3 EXPERIMENTAL SETUP

Apparatus is based on older Gaertner L119 ellipsometer which has been previously modified to fully automatic, computer controlled operation [4]. Simplified scheme of the setup is displayed in Fig. 2A. As a light source serves wavelength selectable HeNe laser, irradiating on wavelengths of 543, 594, 604, 612 and 633 nm, respectively. Before reaching sample the light is polarized by Glan-Thompson prism and part of the light is reflected on beam-splitter to reference detector. Intensity of light reflected from the sample is measured by the other detector attached on traversable arm. Samples with prism coupler are placed on a rotation stage allowing to set incidence angle with precision of one arc second. It is possible to examine solid samples or fluids using flow cell.

Setup is operated by personal computer and whole measuring procedure is fully automatized. Driving software, including graphic interface, was created in LabWindows/CVI (National Instruments Inc.) development environment.

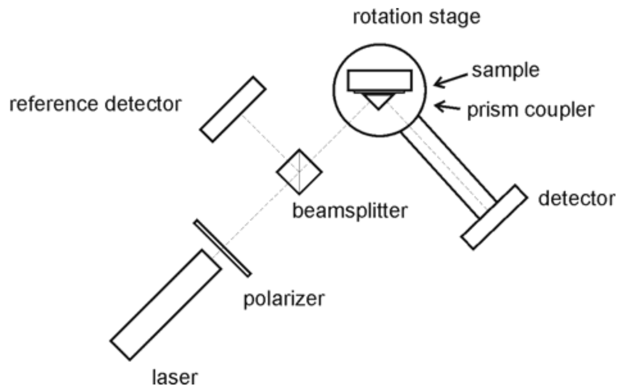

Fig. 2 Scheme of experimental arrangement.

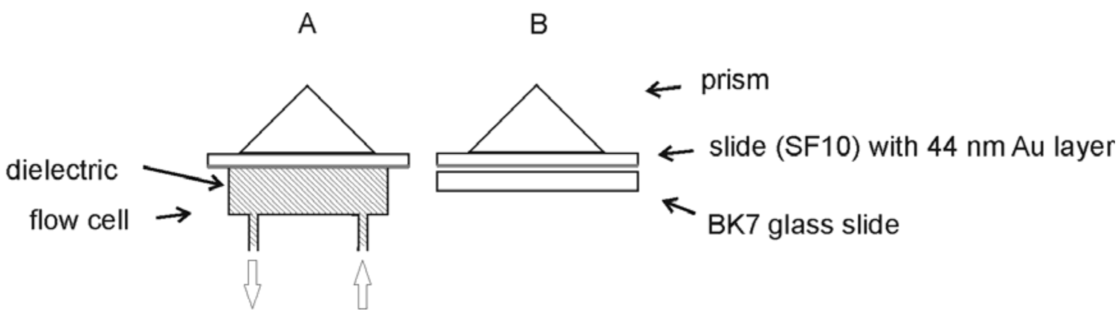

Fig. 3 Scheme of sample arrangement. A) with flow cell, B) solid samples.

Volume LIV (2008), No.1
p. 23-26, ISSN 1802-5420

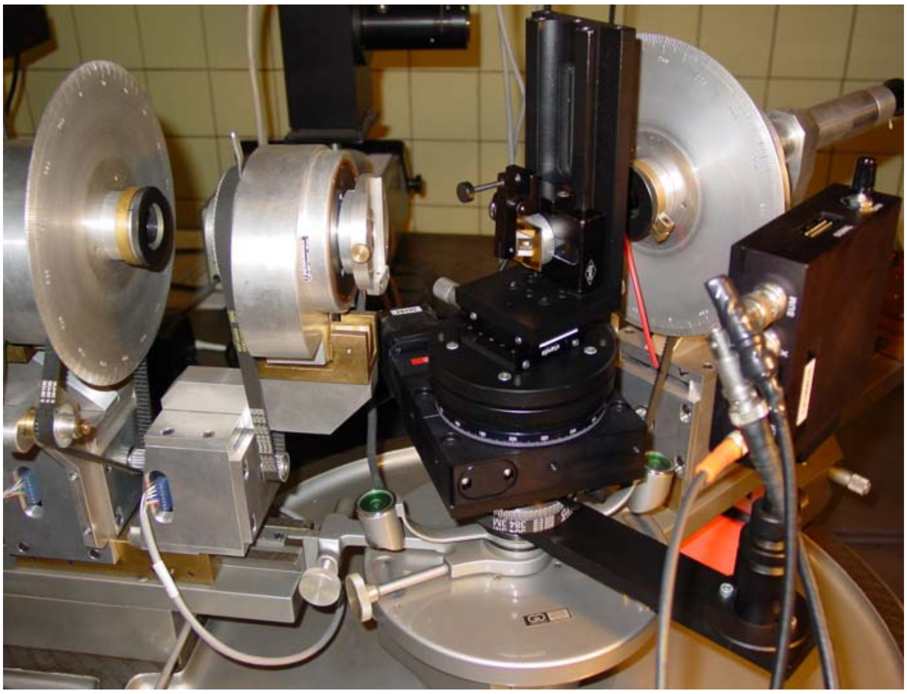

Fig. 4 Detail of experimental setup. In the center of picture there is rotation stage with sample, the polarizer is on the left side, the detector is on the right side.

4 RESULTS

Several basic measurements were made to test the setup and obtained experimental data were compared with theoretical model. These measurements were realized on sample-setup displayed in Fig. 3B which consists of right angle prism of BK7 glass, 1 mm thick SF10 glass slide with 44 nm Au layer and the other glass slide made of BK7 glass. Experiments were performed on wavelegths of 543, 594, 604, 612 and 633 nm, respectively. On Fig. 5 there are displayed data taken on 612 and 633 nm wavelengths (dotted line).

Theoretical values of reflectivity (solid line in Fig. 5) were computed using Yeh's 4x4 matrix formalism [5]. To fit experimental data the BFGS Quasi-Newton algorithm was used, which is contained in Matlab optimization toolbox. Variable fitted parameters were the thickness of air gap (between Au layer and bottom glass slide) and deviation of prism base to glass slides. In the plots below measured values are displayed of reflectivity of p-polarized wave versus angle of incidence.

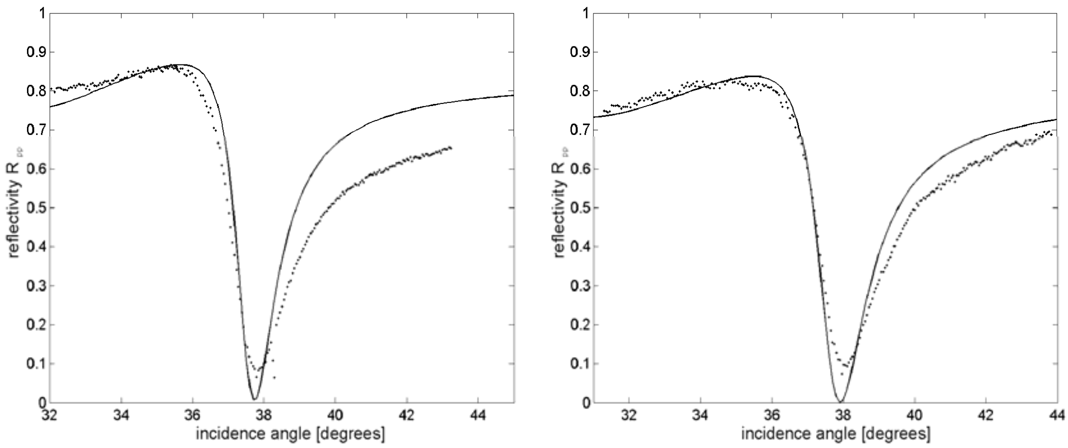

Fig. 5 Measured values of reflectivity of p-polarized wave versus the angle of incidence with the following parameters: left) wavelength 612 nm, deviation of prism 1,3°, air gap thickness 0,7 μm, right) wavelength 633 nm, deviation of prism 1,5°, air gap thickness 0,8 μm.

CONCLUSIONS

Modified Gaertner L119 ellipsometer has been adjusted to enable use of the SPR method. Several basic measurements were made to test the setup and obtained data were compared to the theoretical model. The agreement of experimental data with theory is good and this entry measurements proved that setup is fully functional and prepared for further usage.

Another modification of presented instrument is planned. It should be equipped with electromagnet to allow study of magnetooptic effects.

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RESUMÉ

Článek se zabývá popisem úprav a využitím elipsometru Gaertner L119 k měření metodou SPR. K ověření správné funkce přístroje bylo provedeno několik základních měření a naměřené hodnoty byly porovnány s teorií. Měření byla úspěšná, shoda naměřených hodnot s teoretickým modelem je velmi dobrá. Tato vstupní měření prokázala, že přístroj je plně funkční a připraven k dalšímu využití při studiu kapalných a pevných vzorků.

V další fázi se počítá s rozšířením experimentálních možností zařízení. Přístroj bude vybaven elektromagnetem, který umožní měření magnetooptických jevů.