DEPENDENCE OF PLASMONIC PROPERTIES OF LATTICES OF NANOPARTICLES ON THEIR ORIENTATION. MICROELLIPSOMETRIC INVESTIGATIONS.

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Abstract

Microellipsometry was used to reveal plasmonic properties of an ordered lattices of nanoparticles depending on the mutual orientation of the plane of incidence of exciting light and own vectors of the lattice. Although Rayleigh anomalies for differently oriented lattice are different, they are reflected at energies beside of experimental range. In spite of this fact, registered positions of plasmonic resonances are different and obtained behaviour is not standard birefringence.

1 Experimental

Plasmonic structures of gold nanodiscs ordered in square lattices were prepared by electron-beam lithography [1]. Electron-microscopic image of one of the structures with the period of 150 nm is shown in Figure 1.

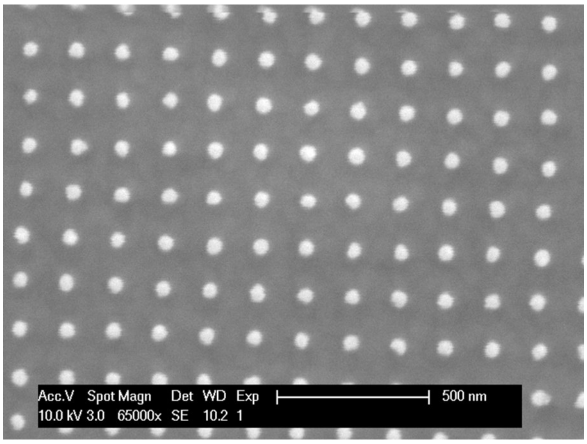

Figure 1 *Image of the lattice of nanodiscs.*

Imaging ellipsometer nanofilm_ep4 from Accurion GmbH with spatial resolution on the micrometer range was used for the investigation of these structures. Measurements were made with the plane of incidence oriented either along the side of squares of the lattice or along the diagonal of squares.

2 Results and Discussion

It was shown [1] that interparticle interactions in lattices result in effective birefringence of a layer of nanoparticles depending on the angle of incidence. The optical axes of this birefringence are fixed by the geometry – along (X) and perpendicular (Y) to the plane of incidence in the surface plane and perpendicular to the surface (Z). Independence of the X- and Y- effective components of the birefringence can be proven by simple symmetrical considerations [1]. However, this effective birefringence behaves contrary to the standard crystal birefringence. Another symmetrical consideration demonstrates that the rotation of the plane of incidence relative to the lattice and its arrangement along the diagonal of the square lattice leads to the planar optical axes again directed along and perpendicular to the plane of incidence and their components of the birefringence are independent again. In the case of crystal birefringence, the optical axes would be fixed by the lattice, not by the plane of incidence, and by rotation of the plane of incidence by 45° the Jones matrix [19] of the reflection would be nondiagonal and components of the dielectric functions along planar axes are mixed in the strongest way in such a geometry.

Ellipsometry provides two so-called ellipsometric angles Ψ and Δ bearing amplitude and phase information [2]. It is demonstrated [3] that the spectral behaviour of the angle Ψ of a system with a layer with resonances in relation to the spectrum of the angle Y of the system without this layer reflects resonances by the extremums allowing easily assign separated extremums to resonances of different components of the fielectric function of the birefringent layer.

Spectra of the angle Ψ for different angles of incidence measured for two noticed mutual orientations of the plane of incidence and the lattice are shown in Figure 2.

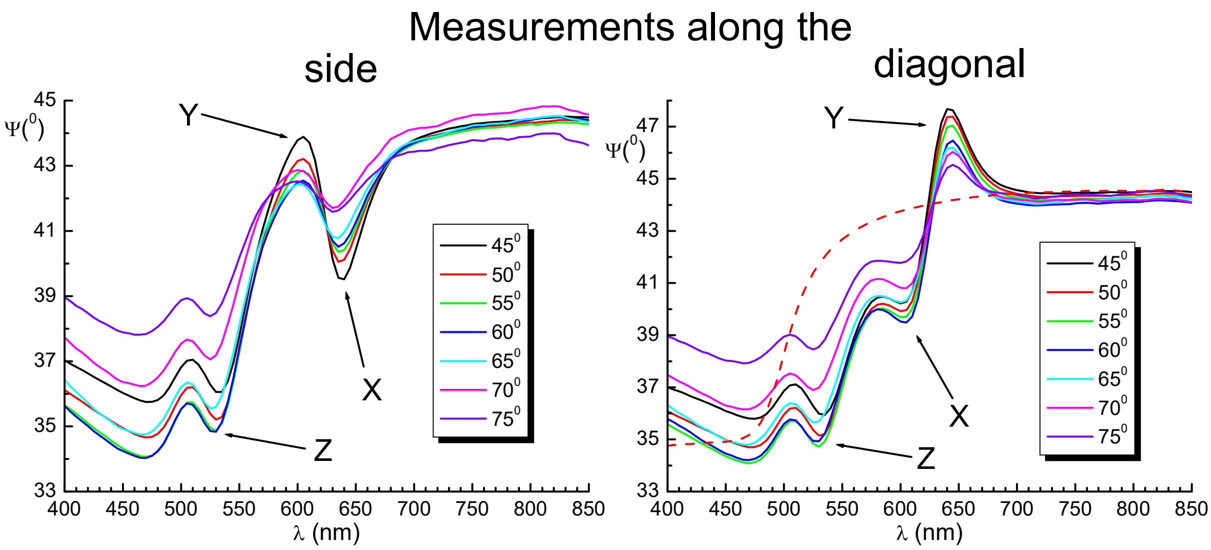

Figure 2 *Spectra of ellipsometric angle Ψ measured at different angles of incidence for two mutual orientations of the square lattice and the plane of incidence, the directions of which are indicated. The dashed line demonstrates the spectrum for a clean substrate, i.e. without lattice of nanoparticles.*

The analysis [3] further indicates that the minima in the spectra are connected to resonances of the X- and Z-components of the dielectric tensor while maxima are related to the resonance of the Y-component. All those features are indicated in Figure 2 and are clearly different at the two different orientations of the plane of incidence.

Previous results [1] demonstrated that standard treatment of ellipsometric results for considered plasmonic structures is incorrect. Application of standard models of Effective-Medium Approximation for layers of nanoparticles is incorrect too [4]. Direct assignment of features in ellipsometric spectra to resonances of the components of dielectric functions of deposited birefringent layer [3] is convenient but qualitative tool. Thus, as correct account of the polarizability renormalization of a single nanoparticle deposited on a layered surface inside of an ordered structure of nanoparticles, as appropriate construction of parametrized effective dielectric functions of the layer of nanoparticles are necessary for the analysis of ellipsometric results.

In spite of Rayleigh anomalies for both orientations of the lattice are rather far from the experimental spectral range and the approach developed in [1] gives only minor changes of the values of the components of the effective dielectric functions for both orientations, different positions of plasmonic resonances for different orientations are clearly visible. So, this question demands additional investigations.

3 Conclusions

Ellipsometry clearly reveals plasmonic resonances of the lattice of nanoparticles and demonstrates that their position depends on the mutual orientation of the plane of incidence of the exciting light and own vectors of the lattice. The reason of so clear difference demands further investigation.

4 References

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