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CHANGES IN ELECTROMAGNETIC WAVE POLARIZATION RESULTING FROM ITS REFLECTION AT A UNIAXIAL PLASMONIC METASURFACE ON TOP OF A DIELECTRIC LAYER

Subject and Purpose. *The analysis of the electromagnetic waves' polarizational transformations that may accompany their reflection from a metasurface is of considerable scientific and practical interest from the point of possibilities for improving characteristics of nanoelectronic and optical devices, and creating novel types of these. This work has been aimed at finding the conditions for efficient conversion of a p-polarized electromagnetic wave incident upon a uniaxial plasmonic metasurface at the boundary of a dielectric layer, into a wave of s-polarization.*

Methods and Methodology. *The effects of conversion of p-polarized electromagnetic waves incident upon a uniaxial plasmonic metasurface, into s-polarized waves were explored through numerical modeling. The approach has allowed determining the wave frequencies and thicknesses of the dielectric layer best suitable for ensuring full conversion.*

Results. *The presence of a uniaxial plasmonic metasurface on top of a dielectric layer can provide for full conversion of an incident p-polarized electromagnetic wave into a wave of s-polarization. As has been established, the effect takes place if the plane of incidence of the p-polarized wave makes an acute angle with the principal axis of the plasmonic metasurface. Another finding is that the full conversion is possible for a variety of permittivity values of the dielectric layer.*

Conclusions. *The uniaxial plasmonic metasurface placed on a dielectric layer is characterized by unique reflective properties. It can have a noticeable impact on polarization of the p-polarized waves incident upon the layer. Dielectric layers provided with uniaxial metasurfaces can be used for creating optical and nanoelectronic devices of new types.*

Keywords: *p-polarized electromagnetic waves, uniaxial plasmonic metasurface, polarization conversion, reflectionless propagation.*

Introduction

The polarization effects arising from reflection of electromagnetic waves that propagate through various kinds of solid-state structures are of importance both for the study of physical properties of solids and for various technical applications. Control over electromagnetic wave polarization can be effectuated in the case of their propagation through solid-state

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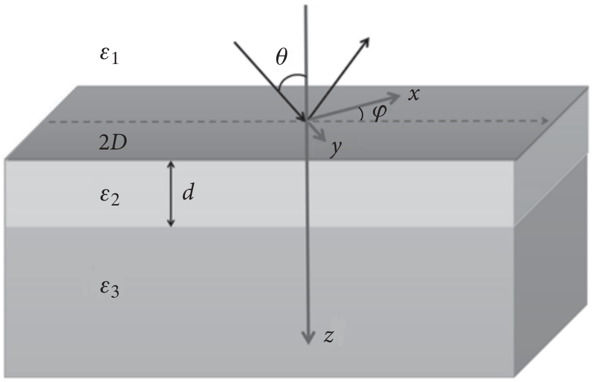

Fig. 1. Geometry of the problem

structures containing either ordinary substances [1, 2] or metamaterials [3]. The latter are of particular interest as they may have a number of unique properties [4].

In the present work, we have investigated the polarization effects arising when p-polarized electromagnetic waves get reflected from a uniaxial plasmonic metasurface lying on top of a dielectric layer [5—7]. As has been shown, the electromagnetic wave reflected from the uniaxial plasmonic metasurface represents a sum of waves of p- and s-polarizations. The conditions have been identified under which an incident p-polarized wave is converted into a s-polarized one upon reflection. To estimate the degree of p- to s conversion which results from reflection at the metasurface, we use the conversion coefficient equal to the ratio of the reflection coefficient of the s-polarized wave to the total reflection coefficient of the wave composed as a sum of the p- and s-polarized waves.

1. Problem statement

The geometry of the problem is clear from Fig. 1. The uniaxial plasmonic metasurface lies on the plane $z = 0$. Actually, it represents a two-dimensional array of conductive ellipsoids [5—7]. The $z < 0$ domain is occupied by a dielectric of permittivity ε_1; the layer ($0 < z < d$) is characterized by dielectric permittivity ε_2, and for $z > d$ the value is ε_3. The electric field vector of the p-polarized electromagnetic wave lies within a plane that makes up an angle φ with the principal symmetry axis of the plasmonic metasurface. We will consider an electromagnetic wave of angular frequency ω, which is incident on the metasurface at an angle θ.

The electromagnetic properties of the uniaxial plasmonic metasurface are described in terms of an effective conductivity tensor. The components of that diagonal tensor, normalized by $c/4\pi$, can be expressed as [5—7]

$$\sigma_{\|,\perp} = \sigma^{\infty}_{\|,\perp} + i\frac{\omega A_{\|,\perp}}{\omega^2 - \Omega^2_{\|,\perp} + i\omega\gamma_{\|,\perp}} = \sigma'_{\|,\perp} + i\sigma''_{\|,\perp}. \quad (1)$$

The "$\|$" and "$\perp$" indices here correspond, respectively, to principal axis orientations along and across the plasmonic metasurface; $\Omega_{\|,\perp}$ and $\gamma_{\|,\perp}$ represent the resonant frequencies and half-widths of the lines; $A_{\|}$ and $A_{\perp}$ denote, respectively, the parallel and the cross magnitude of the oscillator force, and $\sigma^{\infty}_{\|,\perp}$ stand for respective background conductivities. The $\sigma'_{\|,\perp}$ and $\sigma''_{\|,\perp}$ magnitudes represent the real and the imaginary parts of the corresponding conductivity tensor components. Similar as in paper [5], we have assumed $\sigma^{\infty}_{\|,\perp} = 0.2i$; $A_{\|,\perp} = 0.2$; $\gamma_{\|,\perp} = 0.02$; $\Omega_{\|} = 1.0$, and $\Omega_{\perp} = 1.2$.

In a coordinate frame making an angle φ with the principal axis of the plasmonic metasurface (we have assumed the incidence plane of the electromagnetic wave to be identical with the XZ plane) the conductivity tensor of the plasmonic metasurface can be represented as [5–7]:

$$\sigma_{\varphi} = \begin{pmatrix} \sigma_{xx} & \sigma_{xy} \\ \sigma_{yx} & \sigma_{yy} \end{pmatrix}, \quad (2)$$

with

$$\sigma_{xx} = \sigma_{\|}\cos^2\varphi + \sigma_{\perp}\sin^2\varphi; \quad (3)$$

$$\sigma_{yy} = \sigma_{\|}\sin^2\varphi + \sigma_{\perp}\cos^2\varphi; \quad (4)$$

$$\sigma_{xy} = \sigma_{yx} = (\sigma_{\perp} - \sigma_{\|})\sin\varphi\cos\varphi. \quad (5)$$

The existence of non-zero off-diagonal components of the conductivity tensor Eqs. (2)—(5) in the cases $\varphi \neq 0$ and $\varphi \neq 90°$ leads to appearance of mixed p- and s-polarized electromagnetic waves. As a result, when a p-polarized wave happens to be incident on the plasmonic metasurface, the reflected and the transmitted waves possess all the field components and, generally, demonstrate an elliptical polarization. Within the frame that we have selected, the field of a p-polarized electromagnetic wave has the components $\vec{E}_p = \{E_x, 0, E_z\}$ and $\vec{H}_p = \{0, H_y, 0\}$. As for

s-polarized electromagnetic waves, they consist of $\vec{E}_s = \{0, E_y, 0\}$ and $\vec{H}_s = \{H_x, 0, H_z\}$.

The wave vectors of the electromagnetic fields in each of the media involved have the components $\vec{k}_j = (k_x, 0, k_{zj}),\quad j = 1,2,3.$ The longitudinal wave number equals $k_x = \frac{\omega}{c}\sqrt{\varepsilon_1}\sin\theta,$ hence the transverse wave numbers are $k_{zj} = \sqrt{\frac{\omega^2}{c^2}\varepsilon_j - k_x^2}.$

To find the reflection coefficient of a p-polarized electromagnetic wave reflected from the plasmonic metasurface, we will compose non-zero tangential components of the electromagnetic fields in each material-filled domain of the solid-state structure under consideration. The $\exp i(k_x x - \omega t)$ multiplier is the same for all the domains, so it may be omitted from now on. The index 'p' will refer to p-polarized waves, while the 's', in its turn, to s-polarized waves. So, for the field components existing in different regions of the structure we can write

Region 1 ($z < 0$)

$$H_{y1}^p(z) = e^{ik_{z1}z} + r_{pp}e^{-ik_{z1}z},$$

$$E_{x1}^p(z) = \frac{ck_{z1}}{\omega\varepsilon_1}(e^{ik_{z1}z} - r_{pp}e^{-ik_{z1}z}),$$

$$E_{y1}^s(z) = r_{ps}e^{-ik_{z1}z},$$

$$H_{x1}^s(z) = \frac{ck_{z1}}{\omega}r_{ps}e^{-ik_{z1}z}.$$

Region 2 ($0 < z < d$)

$$H_{y2}^p(z) = H_{p2}^+ e^{ik_{z2}z} + H_{p2}^- e^{-ik_{z2}z},$$

$$E_{x2}^p(z) = \frac{ck_{z2}}{\omega\varepsilon_2}(H_{p2}^+ e^{ik_{z2}z} - H_{p2}^- e^{-ik_{z2}z}),$$

$$E_{y2}^s(z) = E_{s2}^+ e^{ik_{z2}z} + E_{s2}^- e^{-ik_{z2}z},$$

$$H_{x2}^s(z) = -\frac{ck_{z2}}{\omega}(E_{s2}^+ e^{ik_{z2}z} - E_{s2}^- e^{-ik_{z2}z}).$$

Region 3 ($z > d$)

$$H_{y3}^p(z) = t_{pp}e^{ik_{z3}(z-d)},$$

$$E_{y3}^p(z) = \frac{ck_{z3}}{\omega\varepsilon_3}t_{pp}e^{ik_{z3}(z-d)},$$

$$E_{y3}^s(z) = t_{ps}e^{ik_{z3}(z-d)},$$

$$H_{x3}^s(z) = -\frac{ck_{z3}}{\omega}t_{ps}e^{ik_{z3}(z-d)}.$$

Here r_{pp} and r_{ps} are amplitudes of the p- and s-polarized waves, respectively, diverging from the metasurface deep into the environment of permittivity ε_1. The t_{pp} and t_{ps} magnitudes are respective amplitudes of the p- and s-polarized waves transmitted into the medium of dielectric permittivity ε_3. The magnitudes H_{p2}^+ and E_{s2}^+ are amplitudes of the forward, while H_{p2}^- and E_{s2}^- of the backward p- and s-polarized waves in the region with a dielectric constant ε_2.

These amplitudes, of both p- and s-polarized waves, can be evaluated through making account of the boundary conditions at the interfaces $z = 0$ and $z = d$. For $z = 0$ we have

$$E_{x1}^p(0) = E_{x2}^p(0) = E_x(0),$$

$$E_{y1}^s(0) = E_{y2}^s(0) = E_y(0),$$

$$H_{y2}^p(0) - H_{y1}^p(0) = -\frac{4\pi}{c}(\sigma_{xx}E_x(0) + \sigma_{xy}E_y(0)),$$

$$H_{x2}^s(0) - H_{x1}^s(0) = \frac{4\pi}{c}(\sigma_{yx}E_x(0) + \sigma_{yy}E_y(0)).$$

Within the plane $z = d$ all tangential electromagnetic field components are continuous.

The reflection coefficient of a p-polarized electromagnetic wave at the plasmonic metasurface is defined by the expression

$$R_p = |r_{pp}|^2 + |r_{ps}|^2, \tag{6}$$

where

$$r_{pp} = \frac{P_- S - Q}{P_+ S - Q}; \tag{7}$$

$$r_{ps} = -2\sigma_{yx}\frac{r_1 r_2}{P_+ S - Q}, \tag{8}$$

with $P_\pm = \frac{\varepsilon_3}{k_3}\cos(k_2\delta) - i\frac{\varepsilon_2}{k_2}\sin(k_2\delta) \pm (\frac{\varepsilon_1}{k_1} \pm \sigma_{xx})r_1,$
$S = (k_1 + \sigma_{yy})r_2 + k_3\cos(k_2\delta) - ik_2\sin(k_2\delta),$
$Q = \sigma_{xy}^2 r_1 r_2,\;\; r_1 = \cos(k_2\delta) - i\frac{k_2\varepsilon_3}{k_3\varepsilon_2}\sin(k_2\delta),$
and $r_2 = \cos(k_2\delta) - i\frac{k_3}{k_2}\sin(k_2\delta).$

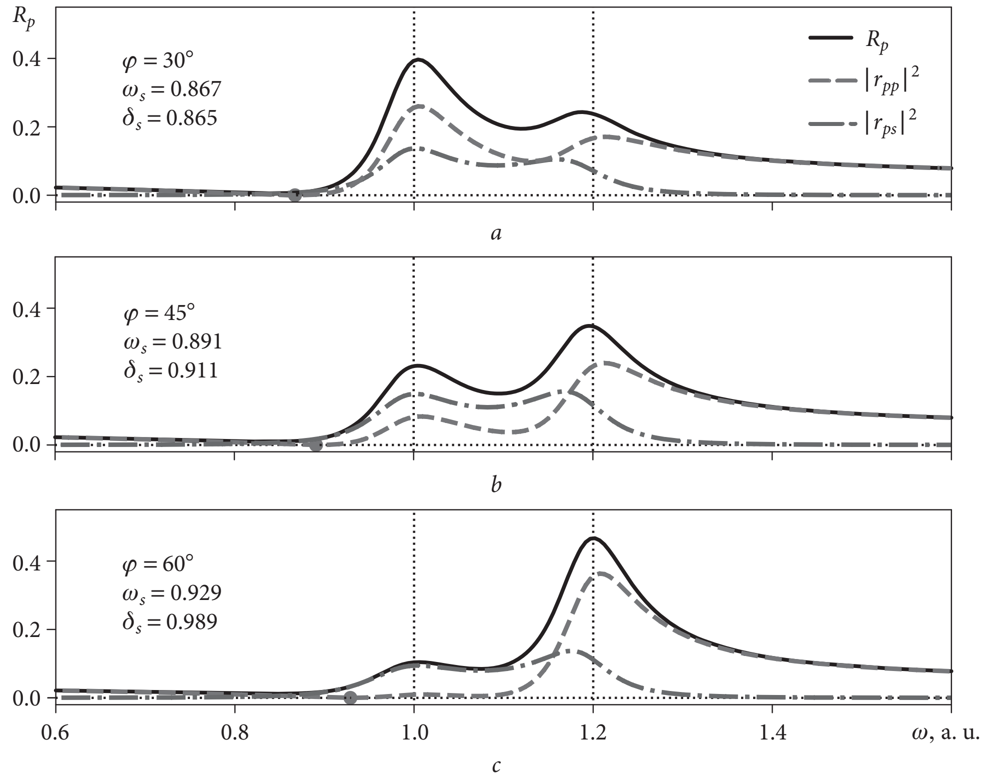

Fig. 2. The ω dependences of $R_p(\omega, \delta_s)$, $|r_{pp}(\omega, \delta_s)|^2$, and $|r_{ps}(\omega, \delta_s)|^2$ (with $\varepsilon_2 = 1.8$, $\theta = 45°$) plotted for a set of values of φ : (*a*) $\varphi = 30°$; (*b*) $\varphi = 45°$, and (*c*) $\varphi = 60°$

In the above definitions, we have used dimensionless values like $k_j = ck_{zj}/\omega$ and $\delta = d\omega/c$.

2. Conversion of *p*- to *s*-polarized wave as a result of reflection from the metasurface

As can be seen from Eq. (5), in cases where the plane of incidence of a *p*-polarized wave is either parallel to the symmetry axis of the plasmonic metasurface (i.e., $\varphi = 0°$), or perpendicular to it ($\varphi = 90°$), the coefficient r_{ps} becomes $r_{ps} = 0$, hence the *s*-polarized reflected wave vanishes. Otherwise $r_{ps} \neq 0$, and there are two reflected waves of both *p*- and *s*-polarizations. To evaluate the conversion ratio of a *p*-polarized into a *s*-polarized wave, we can use the value η_p known as the polarization conversion coefficient for the incident *p*-polarized wave,

$$\eta_p = \frac{|r_{ps}|^2}{|r_{pp}|^2 + |r_{ps}|^2} = \frac{|r_{ps}|^2}{R_p}. \tag{9}$$

The correspondent numerical calculations were performed under the assumption of $\varepsilon_1 = 1$ and $\varepsilon_3 = 4$. If there is no plasmonic metasurface at the boundary of the dielectric layer, then the condition is met $\varepsilon_2^2 = \varepsilon_1\varepsilon_3$, provided that $\varepsilon_2 = 2$. In this case an effect of non-reflective propagation of electromagnetic waves through the dielectric layer can be observed ($R_p = 0$), should its thickness satisfy the criterion $d\sqrt{\varepsilon_2} = \lambda/4$, where $\lambda = 2\pi c/\omega$ is the wavelength [8]. Note that in the case $\varepsilon_2^2 > \varepsilon_1\varepsilon_3$ the effect of non-reflective propagation through the dielectric layer is only possible with oblique incidence of electromagnetic waves within a certain interval of incidence angles θ. With $\varepsilon_2^2 < \varepsilon_1\varepsilon_3$ the effect of non-reflective electromagnetic wave propagation through the dielectric layer is not observable.

The presence of a plasmonic metasurface may greatly change the conditions for non-reflective propagation of *p*-polarized electromagnetic waves with plane of incidence orientations $\varphi = 0°$ and $\varphi = 90°$. We are also interested in investigating another effect associated with changes in the polarization of an incident electromagnetic wave of *p*-polarization undergoing reflection from a plasmonic metasurface,

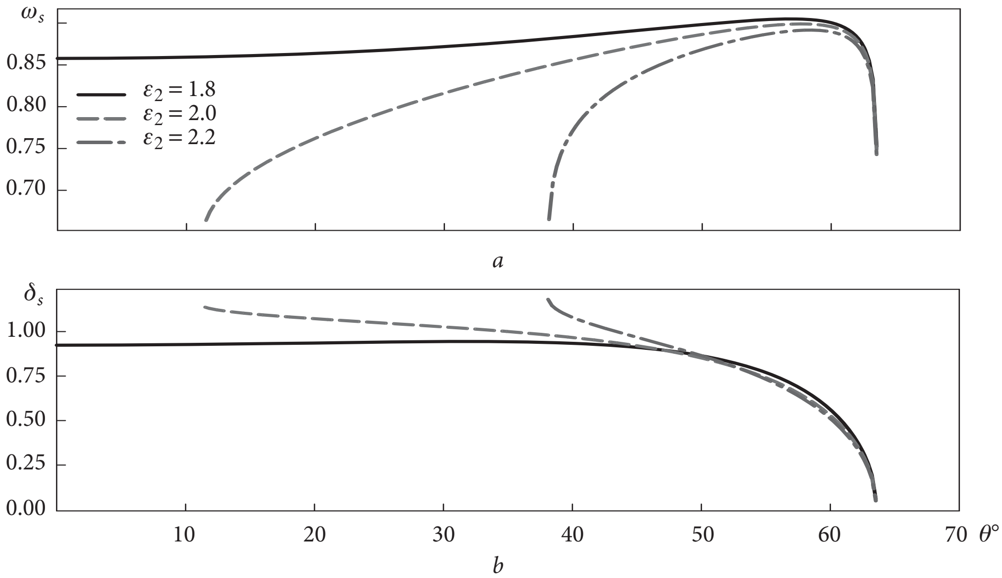

Fig. 3. Relation between angular dependences of $\omega_s(\theta)$ (a) and $\delta_s(\theta)$ (b) with $\varphi = 45°$ plotted for three different values of ε_2

namely for plane of incidence orientations $\varphi \neq 0°$ and $\varphi \neq 90°$. As can be seen from Eq. (8), under such conditions a p-polarized electromagnetic wave incident on the plasmonic metasurface always gives rise to a reflected s-polarized wave, i.e. ($r_{ps} \neq 0$). At the same time, in some cases the amplitude of the reflected p-polarized wave can turn to zero, $r_{pp} = 0$. With fixed magnitudes of the angles φ and θ the condition $r_{pp} = 0$ can be true only for some values of ω and δ, denoted $\omega = \omega_s$ and $\delta = \delta_s$. In this case $R_p = |r_{ps}|^2$ and $\eta_p = 1$. As a result, the electromagnetic wave reflected from the plasmonic metasurface involves an s-polarized component alone. The values ω_s and δ_s have been calculated for a variety of ε_2, θ and φ parameters. Figure 2 presents frequency dependences of $R_p(\omega,\delta_s)$, $|r_{pp}(\omega,\delta_s)|^2$, and $|r_{ps}(\omega,\delta_s)|^2$ for $\varepsilon_2 = 1.8$ and $\theta = 45°$, and three different values of φ. For each of these, δ_s was assumed to be a measure of the dielectric layer thickness. Calculated values of ω_s and δ_s corresponding to each of the selected magnitudes of φ are shown in Fig. 2, where the ω_s's are marked on the horizontal axes as bold full circles. It should be noted that a growth of δ is accompanied by increases of both ω_s and δ_s. Moreover, it is possible to see from Fig. 2(c) that in the case of $\varphi = 60°$ the [squared] reflection coefficient $|r_{pp}(\omega, \delta_s)|^2$ of the p-polarized electromagnetic wave remains low over a wide range of frequencies $\omega < 1.1$. In this case the reflected electromagnetic wave is quasi-s-polarized.

The relations for $\omega_s(\theta)$ and $\delta_s(\theta)$ (with $\varphi = 45°$) are represented graphically in Fig. 3 for three different values of ε_2. It seems evident that the magnitudes depend heavily on the quantity of ε_2. If $\varepsilon_2 = 1.8$, and hence $(\varepsilon_2^2 < \varepsilon_1\varepsilon_3)$, the effect of p-polarized electromagnetic wave conversion into an s-polarized one exists in the cases of both normal ($\theta = 0$) and oblique ($\theta \neq 0$) incidence of electromagnetic waves on the plasmonic metasurface. When $\varepsilon_2 = 2.0$ (and $\varepsilon_2^2 = \varepsilon_1\varepsilon_3$) the effect can be seen only in the case of oblique incidence of the electromagnetic waves. As ε_2 increases further ($\varepsilon_2 = 2.2$ and $\varepsilon_2^2 > \varepsilon_1\varepsilon_3$), the range of angles over which the r_{pp} coefficient equals zero becomes significantly more narrow. Thus, the presence of a plasmonic metasurface on top of the dielectric layer leads to conversion of an incident p-polarized electromagnetic wave into a reflected wave of s-polarization. This effect can be implemented over a wide range of incidence angles of the p-polarized electromagnetic wave for different values of the layer's dielectric permittivity.

It should be emphasized that full conversion of a p-polarized electromagnetic wave into a reflected wave of s-polarization occurs only for certain fixed values of ω_s and δ_s which may prove unsuitable for a lot of technical applications. Therefore, of greater interest might be the frequencies $\omega = \omega_m$ and thicknesses $\delta = \delta_m$ with which the reflection coefficient $|r_{pp}(\omega_m, \delta_m)|^2$ of the p-polarized electromagnetic

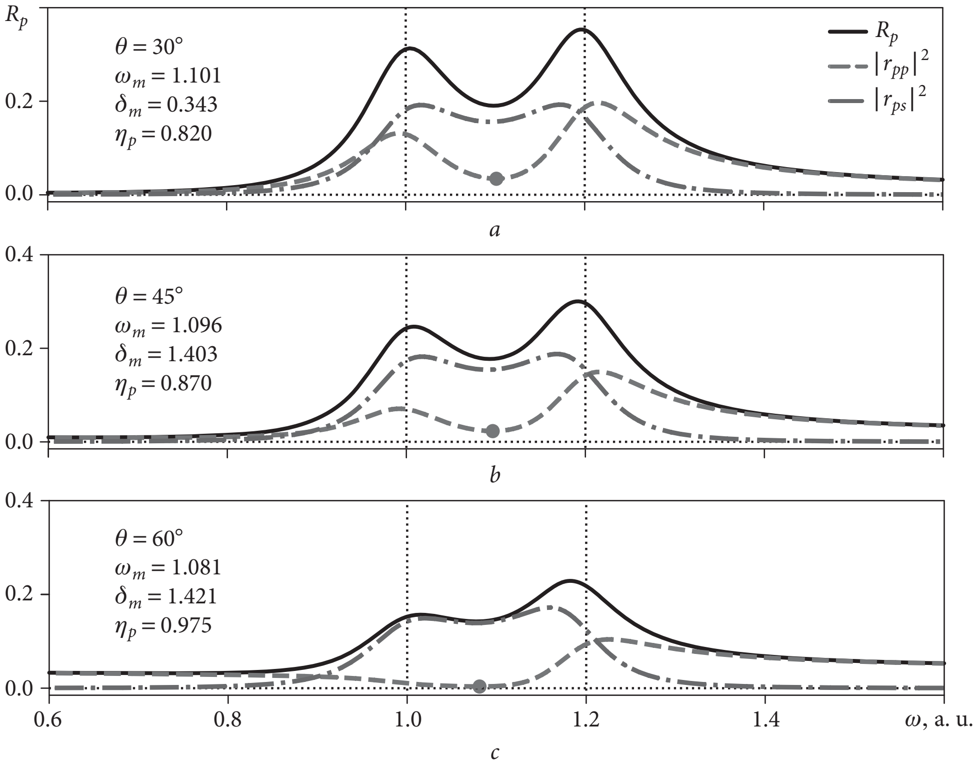

Fig. 4. Frequency dependences of $R_p(\omega, \delta_m)$, $|r_{pp}(\omega, \delta_m)|^2$, and $|r_{ps}(\omega, \delta_m)|^2$ (with $\varepsilon_2 = 1.8$, $\varphi = 45°$) for (*a*) $\theta = 30°$; (*b*) $\theta = 45°$, and (*c*) $\theta = 60°$

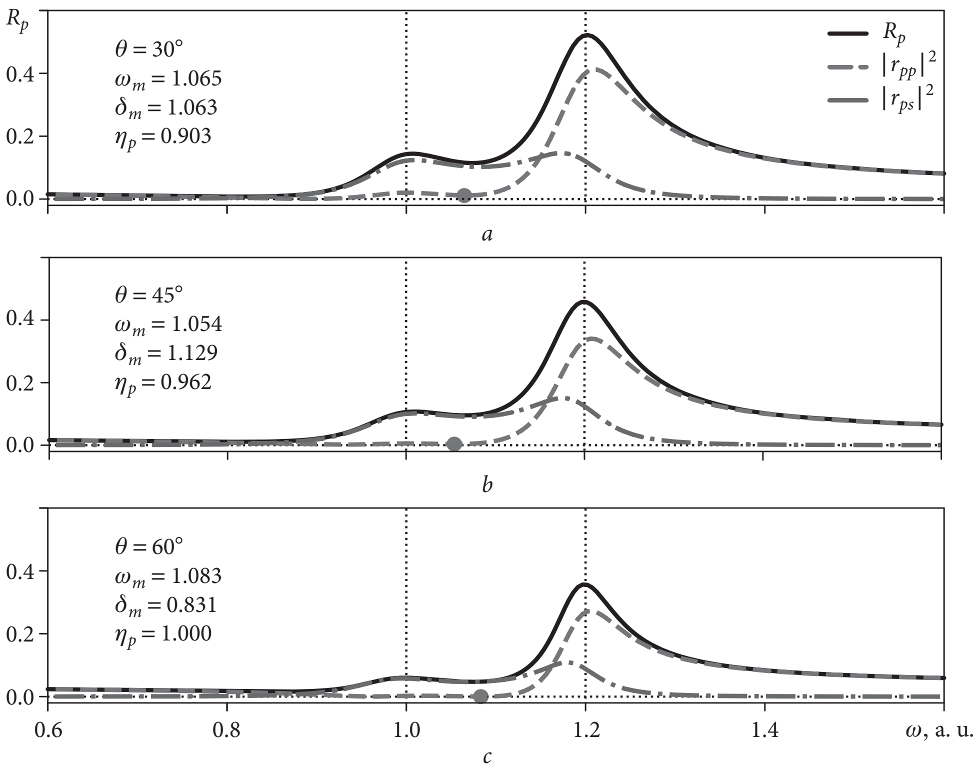

Fig. 5. Frequency dependences of $R_p(\omega, \delta_m)$, $|r_{pp}(\omega, \delta_m)|^2$, and $|r_{ps}(\omega, \delta_m)|^2$ (with $\varepsilon_2 = 1.8$, $\varphi = 60°$) for (*a*) $\theta = 30°$, (*b*) $\theta = 45°$, (*c*) $\theta = 60°$

wave is minimized. With this in mind we have calculated minimum values of the reflection coefficient $|r_{pp}(\omega_m, \delta_m)|^2$ for a variety of magnitudes of θ and φ over the frequency interval $\Omega_{\|} < \omega < \Omega_{\perp}$. Clearly, in such cases the value of $\eta_p(\omega_m, \delta_m)$ should reach its maximum. We considered situations, with $\varphi = 45°$ and $\varphi = 60°$, under which η_p reaches its highest values.

In Fig. 4 the frequency dependences of $R_p(\omega, \delta_m)$, $|r_{pp}(\omega, \delta_m)|^2$, and $|r_{ps}(\omega, \delta_m)|^2$ are presented for $\varepsilon_2 = 1.8$, $\varphi = 45°$ and three different values of the parameter θ. Calculated magnitudes of the related ω_m, δ_m and $\eta_p(\omega_m, \delta_m)$ are also given, with ω_m's marked as bold full circles (see Fig. 4). As can be seen, with an increase in θ the value of $|r_{pp}(\omega, \delta_m)|^2$ decreases, while $\eta_p(\omega_m, \delta_m)$ goes up. The amount of correlation between the two values gets higher with $\varphi = 60°$. The correspondent frequency dependences of $R_p(\omega, \delta_m)$, $|r_{pp}(\omega, \delta_m)|^2$ and $|r_{ps}(\omega, \delta_m)|^2$ (with $\varepsilon_2 = 1.8$ again) are given in Fig. 5.

From the Fig. 5 we can deduce that when $\varphi = 60°$ values $\eta_p(\omega_m, \delta_m)$ are much larger, then in case $\varphi = 45°$. This conclusion hold true for the angle of incidence $\theta = 30°$. By increasing angle of incidence θ value of $\eta_p(\omega_m, \delta_m)$ escalates rapidly and when it reaches $\varphi = 60°$ reflected from the plasmonic metasurfaces wave will be s-polarized, hence $\eta_p(\omega_m, \delta_m) = 1$. And it's important to note that $\eta_p \approx 1$ in a wide range of frequencies.

It should be pointed out that by increasing ε_2 we have not been able to seriously alter $\eta_p(\omega_m, \delta_m)$ with $\varphi = 60°$ and $\theta = 60°$, the value remaining close to ($\eta_p(\omega_m, \delta_m) \approx 1$). At the same time, with $\varphi = 60°$ and $\theta = 45°$ the magnitude of $\eta_p(\omega_m, \delta_m)$ dropped down as ε_2 were increased. For example, $\eta_p(\omega_m, \delta_m) \approx 0.92$ with $\varepsilon_2 = 2.0$ and $\eta_p(\omega_m, \delta_m) \approx 0.86$ with $\varepsilon_2 = 2.2$.

Conclusions

A uniaxial plasmonic metasurface sitting on top of a dielectric layer may demonstrate unique reflective properties. It can effectively change the polarization of incident p-polarized waves in case their plane of incidence is at an angle $\varphi \neq 0°$ or $\varphi \neq 90°$ with the principal axis of the metasurface. The frequencies ω_s and thicknesses δ_s of the dielectric layer have been found for which full conversion of a p-polarized electromagnetic wave into a reflected s-polarized wave can be observed (i.e., $r_{pp} = 0$). In addition, we have analyzed the dependence which the full conversion conditions may demonstrate against the dielectric layer permittivity.

We have also calculated the frequencies ω_m and dielectric layer thicknesses δ_m for which the polarization conversion coefficient $\eta_p(\omega_m, \delta_m)$ reaches its maximum value inside the frequency interval $\Omega_{\perp} < \omega < \Omega_{\|}$ and the amplitude of a p-polarized reflected wave becomes minimal.

By applying the plasmonic metasurface as a practical wave reflector we can obtain either a reflected 'pure' s-polarized electromagnetic wave ($\omega = \omega_s$, $\delta = \delta_s$) or, in the case of $\omega = \omega_m$ and $\delta = \delta_m$, a 'quasi' s-polarized one.

The results can be used for improving polarizational characteristics of the existing nanoelectronic and optical devices. In addition, they offer technical solutions for creating new types of optoelectronic equipment.

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ЗМІНА ПОЛЯРИЗАЦІЇ ЕЛЕКТРОМАГНІТНИХ ХВИЛЬ
ПРИ ЇХНЬОМУ ВІДДЗЕРКАЛЕННІ ВІД ОДНОВІСНОЇ ПЛАЗМОННОЇ МЕТАПОВЕРХНІ,
ЩО ЗНАХОДИТЬСЯ НА МЕЖІ ДІЕЛЕКТРИЧНОГО ШАРУ

Предмет і мета роботи. Дослідження ефекту трансформації поляризації електромагнітних хвиль при їхньому відбитті від метаповерхні має значний науковий і практичний інтерес для покращення характеристик пристроїв наноелектроніки й оптики та створення їхніх нових типів. Метою роботи є знаходження умов повної трансформації *p*-поляризованої електромагнітної хвилі, що падає на одновісну плазмонну метаповерхню, у відбиту хвилю *s*-поляризації.

Методи та методологія. Для дослідження ефекту повної трансформації поляризації електромагнітних хвиль при їхньому відбитті від одновісної плазмонної метаповерхні, що лежить на діелектричному шарі, використовувалося числове моделювання. За його допомогою визначено частоти електромагнітних хвиль і товщини діелектричного шару, що є необхідними для повної трансформації поляризації *p*-поляризованих хвиль.

Результати. Показано, що за наявності на діелектричному шарі одновісної плазмонної метаповерхні на ній відбувається повна трансформація *p*-поляризованої електромагнітної хвилі, що падає, у відбиту *s*-поляризовану електромагнітну хвилю. Встановлено, що для цього ефекту необхідно, аби площина падіння *p*-поляризованої електромагнітної хвилі складала гострий кут відносно головної осі плазмонної метаповерхні. Знайдено, що повна трансформація поляризації *p*-поляризованої електромагнітної хвилі, що падає, може мати місце для різних величин діелектричної проникності шару.

Висновки. Одновісна плазмонна метаповерхня, що лежить на діелектричному шарі, має унікальні відбивні властивості. Вона може ефективно впливати на поляризацію електромагнітної хвилі, що падає на неї. Діелектричні шари з одновісними плазмонними метаповерхнями можуть використовуватися для створення нових типів пристроїв оптики та наноелектроніки.

Ключові слова: *p-поляризовані електромагнітні хвилі, одновісна плазмонна метаповерхня, поляризаційне перетворення, безвідбивне проходження.*