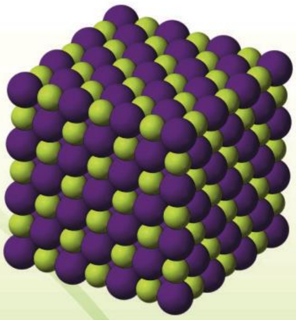

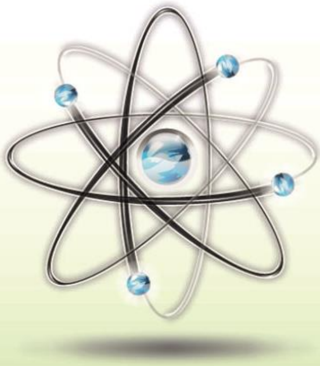

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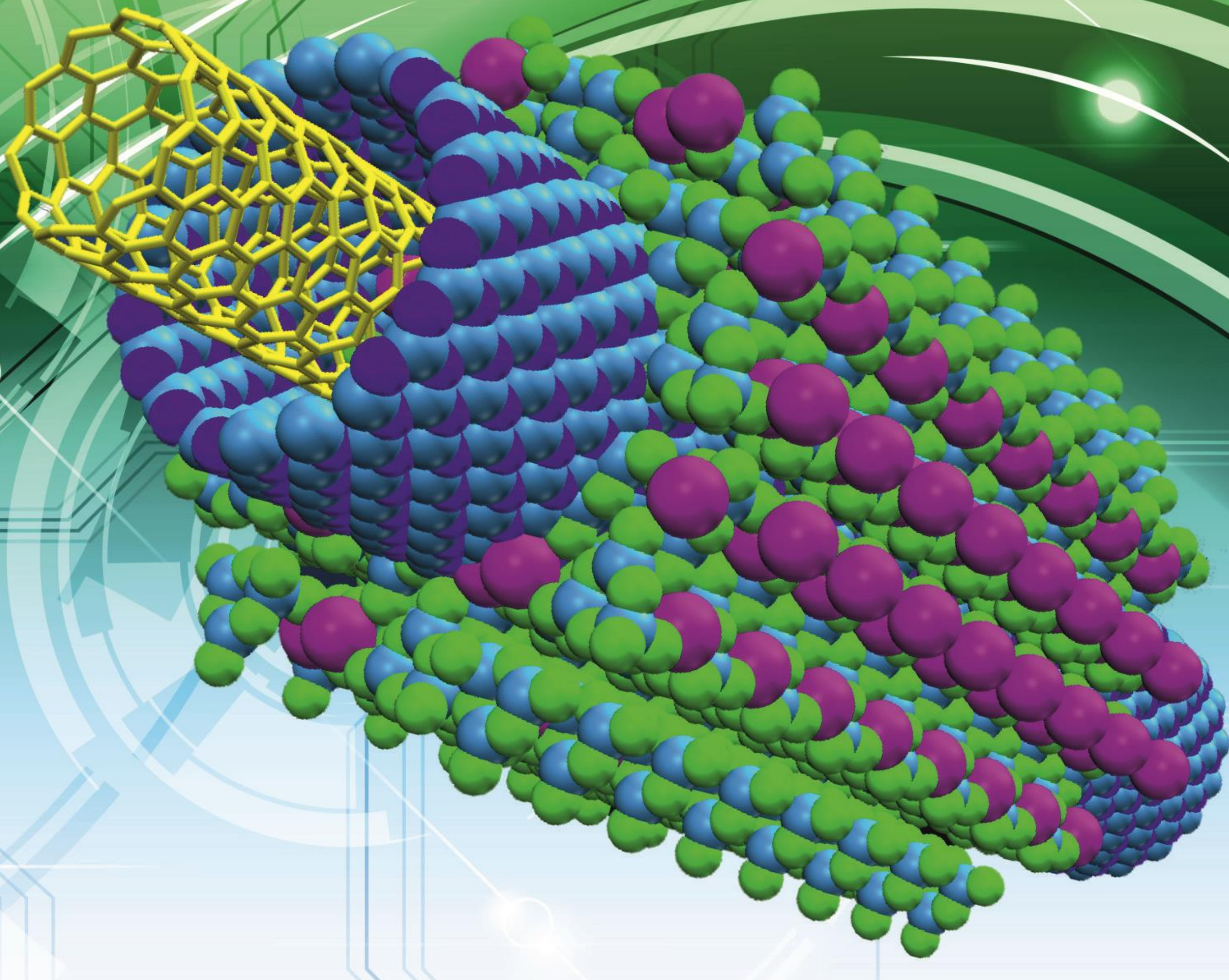

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Учреждение образования
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БЕЛОРУССКО-КИТАЙСКИЙ НАУЧНО-ТЕХНИЧЕСКИЙ СЕМИНАР

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СОДЕРЖАНИЕ

NUMERICAL PARAMETRIC INVESTIGATION OF PHOTONIC CRYSTALS IN BIRD FEATHERS

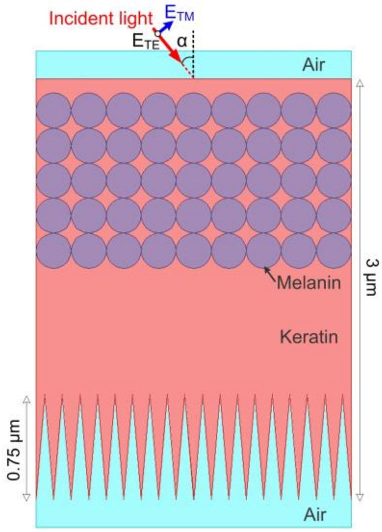
A. Balmakou, S. Khakhomov

Department of Optics, Gomel State University,
Sovetskaya Str. 104, 246019, Gomel, Belarus

Abstract – a nature designed photonic crystals found in bird’s feathers with structural type of coloration are considered in this paper from the point of view of optical applications. We consider that the type of photonic crystals can be implemented for different purposes of sensing of environmental parameters related to temperature, humidity, air pollution etc. The possible sensors of this type have advantages related to low power consumption, self-indicating requires no additional displays, easy to handle.

Introduction. Photonic crystals are mainly met in nature among butterfly wings and birds feathers with structural coloration as well as some species of beetles [1]. The remarkable feature of the nature designed avian photonic crystals is that they are made of only few materials, namely melanin, keratin and air. Despite this very limited range of materials used, the photonic crystals in nature produce full range colors through the mechanism known as structural coloration [2]. Structural coloration results from the interaction of light waves with featured structures having the same order of size as the wavelength of light. The type of coloration is described by thin-film interference, or the scattering from a spongy matrix structure incoherently or coherently.

Theory and modeling. In this section, we will focus on photonic crystals found in feathers of some birds. The photonic crystal of this type is composed of cylindrical solid or hollow melanosomes situated in keratin cortex as it is shown in Fig. 1(a), where closely packed solid melanosomes form square layout. The thickness of the upper keratin layer is 100 nm, diameter of melanosomes D=100 nm, number of layers: 5, inter-layer spacing 150 nm. In Fig. 1(b), closely packed hollow melanosomes are packed into array with the following values: thickness of the upper keratin layer is 200 nm, diameter of melanosomes D = 250 nm, diameter of air holes d = $0.8D$, number of layers: 5, inter-layer spacing 216.5 nm.



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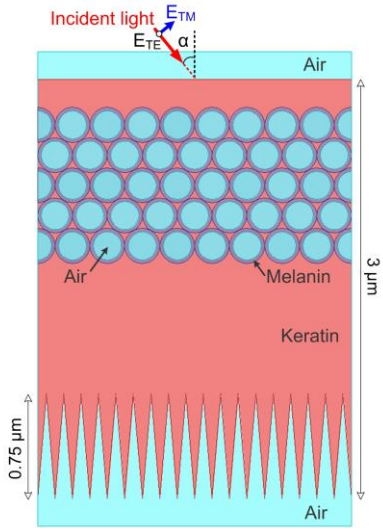

b

Fig. 1. Structure of photonic crystals in structurally colored bird feathers with: (a) solid melanosomes, (b) hollow melanosomes

The wavelength-dependent material parameters for melanin and keratin were as those used in Ref. [3]: the refractive index nonlinearly changes from 1.79+i·1.69 to 1.66+i·1.54 for melanin and from 1.57+i·0.01 to 1.54+i·0 for keratin in the visible spectral range. We have performed a parametric analysis of the two structures depending on the following variables: full keratin layer thickness, thickness of the upper keratin layer (between air and the first row of melanosomes), diameter of melanosomes D, diameter of the air holes d, hollowness d/D, number of layers, inter-layer spacing, angle of incidence, and polarization: TE and TM modes. The parametric analysis reveled the detailed picture of how the mentioned parameters affect the shape of the spectrum of reflectance. For example, the dependence on the number of layers is depicted in Fig. 2. From this figure, one cans see that with increasing the number of layers of melanosomes the reflectance increases too.

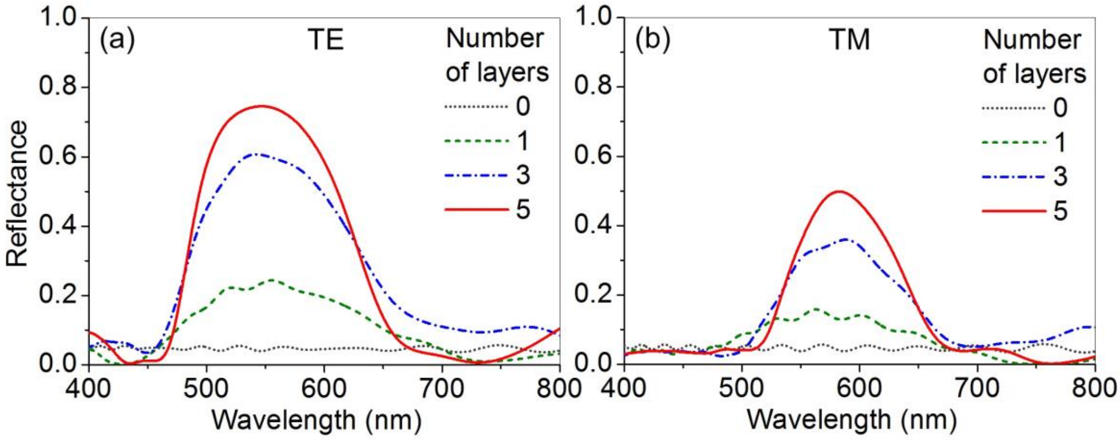

Fig. 2. Reflectance spectra of the hollow photonic crystal in Fig. 2(b) with varying numbers of melanosome layers. (a) TE- and (b) TM-polarized light of incidence

As we can see from Fig. 2, the number of layers do not affect the positioning of the perk wavelength reflectance, but only its height. However, the diameter of melanosomes and air holes influences the peak positioning substantially. This effect can be used for constructing reconfigurable photonic crystals with defined spectral properties.

Conclusion. Full parametric analysis of a photonic crystal found in birds feathers reveals details of the physical mechanism of formation of colors in this type of photonic crystals. We can apply this knowledge to constructing optical sensors, indicators, displays with new types of light reflectors with reconfigurable spectrum and almost zero power consumption.

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RESEARCH ON METAMATERIALS ABSORBER

Shicheng Fan, Yaoliang Song

School of Electronic and Optical Engineering
Nanjing University of Science and Technology,
Nanjing, 210094, China
313104002292@njust.edu.cn, ylsong@njust.edu.cn

Artificial stealth materials have widely applications in areas such as radar target stealth, antenna design and electromagnetic protection etc. However, absorber based on traditional structures for the radar targets stealth application is facing big challenges on absorbing frequency, bandwidth, bulky and poor flexibility and other practical problems. Fractal structures different from the traditional structures, it has self-similarity, can have a fine structures in any small scale , if it can be used in the designing of microwave absorber combined with characteristics of surface fulling curves and will break through existing barriers. Our research aims at these tough problems of designing the artificial broadband radar stealth materials, a new broadband composite structure based on fractal curves and flexible magnetic material are proposed, in which new ideas combine new structure and material. The goal of the project is to research on design methods, theoretical modeling, absorbing mechanism of new broadband absorbing materials, through experiments to verify the feasibility of experiment design method. It will lay a solid theoretical foundation for solving the problems on working frequency, bandwidth, and flexible aspects of design methods of existing absorber. According to this situation, our work mainly focuses on three aspects broadband, miniaturization, and conformal. Based on three aspects we have done the following work.

We have present a broadband polarization insensitive prefect metamaterial absorber based on fractal structures.

Through the combination of fractal and circular structure, the bandwidth is extended without increasing the size of the unit cell. A simple parallel equivalent circuit model has been proposed describing the absorption phenomenon to predict the frequency of absorption of the proposed absorber. The simulated result shows that the absorber's full width half maximum is 18.5 %. With rotational symmetry structures, the absorber is insensitive to the polarization. The incident angles at which the metamaterial absorber can maintain 50 % of the absorbance are up to 50. With the geometrical scalability, the absorber can be extended to any frequencies. This absorber is fabricated and measured at X-band, and the experimental results coincide well with the simulation results.

Multiband absorbers based on ultra-thin multi-layer structures, with different bandwidth characteristics, are presented. The proposed structure is composed of three vertically stacked metal- dielectric layers backed by a metal ground. All the metallic patches are symmetrical T-shape and have different geometrical dimensions, which can be manipulated to design six-band. A simple series equivalent circuit model has been proposed describing the absorption phenomenon to predict the frequency of absorption of the proposed absorber. The designed structures are polarisation-insensitive as well as wide-angle absorptive for both TE and TM polarisations. The 3 dB broadband structure, exhibiting an absorption bandwidth of 40 % at 10 GHz, has been fabricated and the absorption performance has been verified with the simulated response. The proposed absorber has the advantages of ultra-thin thickness, compact size, simpler design, tunable absorption bandwidth and experimental validation, which makes it a promising candidate for many potential applications.

Based on the analysis of the circuit model, we conclude that increasing the resistance of structure can greatly expand the bandwidth. We have present an ultra-wideband flexible absorber by loading chip resistors. Simulated results show that the bandwidth of the proposed absorber with absorptivity more than 90 % is 2.56-10.03 GHz with a relative bandwidth over 118.5 %. Bandwidth is much wider than the existing design. Moreover, the absorption peak remain high with large angles of incidence for both TE and TM polarizations. This absorber has been fabricated and measured, whose measured results coincide well with the simulation results. The fabricated absorber has the advantages of convenient to be carried and flexibility that can easily be conformed to cylindrical and spherical. The proposed absorber also possesses many advantages such as polarization-insensitive, wide-angle, low profile and lightweight that make it easier to apply.

We have present an UHF prefect metamaterial absorber by combining coupling lines and fractal lines with very small unit cell. The proposed absorber consists of surface metal structure and metallic background plane, separated by a dielectric substrate and air. Simulation results show that the absorber has absorption peak at 442MHz with 99.73% absorptivity. The ratio between lattice constant and resonance wavelength is 1/68, significantly less than the existing absorber. According to the absorption mechanism of proposed absorber the design principle is introducing in detail. Moreover, the absorption peaks remain high with large angles of incidence for both TE and TM polarizations. With the geometrical scalability, the absorption peaks can be changed to any frequencies, such as 433 MHz and 5 GHz. The proposed absorber also possesses many advantages such as polarization-insensitive, wide-angle, low profile and lightweight that make it easier to apply. Due to the small ratio, it can be widely used in radiation suppression for microwave relay communication such as mobile communication and wireless network by changing the parameters of structure.

Absorbers can be used in many applications, but they need to be conformal, low profile, and lightweight. Flexible devices have many advantages over their non-flexible counterparts such as much lighter in weight, much smaller in size, much more durable, and outstanding flexible and conformal ability. Flexible MM absorbers which typically fabricated using flexible dielectric layer such as MM film, polyimide layer, and polydimethylsiloxane (PDMS) layer can be easily conformed to the unusual surfaces such as cylindrical, pyramid, and spherical. We have utilized polyimide material and air layer in our design, foam and glue can be used instead of the original thick dielectric layer. All absorbers we proposed possesses many advantages such as low profile, conformal and lightweight that make it easier to apply. At the same time, we conducted experimental measurements on various complex application scenes, for example, the cylindrical RCS reduction effected measurement and RCS reduction of missile model. The actual verified the flexible absorbing body good applicability.

The main research content we have already done is for radar stealth, so the design of the band is in the L (1GHz-2GHz), S (2GHz-4GHz), C (4GHz-8GHz) and X (8GHz-12GHz) band, with the application of the THz is more and more widely, we need to re-examine the design method. Firstly, Circuit's equivalent model needs to be re-researched. Secondly, in THz, many fine structures cannot be realized due to the limitation of processing accuracy, such as multi-level fractal. Third, the size of the absorber corresponding to THz is very small, so the chip resistance cannot be loaded. This is a big difficulty for the design of THz broadband absorbers. According to this situation, our work mainly focuses on three aspects equivalent circuit model proposed, design of surface structure, and research on dielectric layer. Based on three aspects we need to do the following three aspects.

1 Analysis of equivalent circuit models of absorber in THz frequency band. To research the effect of surface structure, dielectric layers dielectric loss and magnetic loss on absorptivity. Research on the equivalent circuit model of double-sided absorber.

2 Research on structural design based on fractal, mainly utilize multi-layer structure to extend the complexity of fractal. Research on how to increase the resistance of the surface structure to increase the absorption bandwidth.

3 Design of metallopolymer polydisperse. It is also necessary to measure the electromagnetic parameters of the metallopolymer polydisperse. Research on periodic cell structures of the novel absorbers from the conventional double PCB to metallopolymer polydisperse and flexible metamaterials.

PHYSICAL AND CHEMICAL REGULARITIES OF THE STRUCTURE AND PROPERTIES OF DOPED CARBON FILMS DEPOSITED FROM THE PLASMA OF PULSED CATHODE-ARC DISCHARGE

D. Piliptsov, A. Rogachev, A. Rudenkov, Xiaohong Jiang, Bing Zhou

International Chinese-Belarusian scientific laboratory by vacuum-plasma technologies

a-C films gain ever-growing popularity in scientific and industrial communities on the dependence of the excellent properties like high hardness, low friction coefficient, high wear resistance, better chemical inertness, biocompatibility and optical transparency in IR region [1]. Various deposition techniques have been used to fabricate a-C films, such as plasma enhanced chemical vapor deposition (PECVD) [2], magnetron sputtering [3], pulsed laser deposition (PLD) [4], and cathode arc evaporation (CAE) [5]. Compared with other methods, CAE is a low temperature deposition method with a better ion ratio and higher ion energy. By CAE method, films with strong sp^3 bonding are easily produced. During deposition, ion bombardment on the substrates improves adhesion between the film and the substrate.Preparation of a-C films using CAE technique, the power supply is operated in direct-current or pulsed mode. Bias voltage is an important parameter for direct-current cathode arc evaporation technique. Pulse frequency is crucial influencing factors for pulsed cathodic arc method. In recent years, the incorporation of metallic elements into the a-C films provides an effective way to improve the properties of the films, such as Ti doping, Cu doping, W doping, Cr doping and etc. [6]. Incorporating metals in a-C films considerably influence their microstructure and lead to significant changes in electrical conductivity, biocompatibility, mechanical, optical and tribological properties. Compared with Ti-doped a-C (a-C:Ti) films containing TiC nanometer grains, copper atoms are not chemically bound with carbon in Copper-doped a-C films (a-C:Ti) [7]. In addition, some researchers also proposed a mechanism for the effect of incorporating metal on the tribological properties of the a-C films, including the relationship between variation of metals-doping and the graphitization of films [8]. It signifies that doping metal (Ti or Cu) is a promising technology improving the structure and mechanical properties of a-C films [9]. a-C films are composed of a sp^2 hybrid graphite phase and a sp^3 hybrid diamond phase. The graphite phase exists in the highly crosslinked network structure of diamond phase, which improves the a-C film by higher hardness, resistivity, thermal conductivity and chemical inertness. Recent data indicate that a-C films show high transparency in a wide wavelength range starting from ultraviolet up to infrared revealing, in turn, high resistivity, low permittivity and high refractive index. Therefore, the studied a-C films can be used as infrared antireflection films, which requires that the film thickness, its structure and optical properties (the refractive index, the extinction coefficient, the optical band gap) are precisely controlled by improved deposition technology. a-C films doped with metals such as W, Au, Pt etc. reveal excellent performance regarding to adhesion, corrosion resistance and residual stress. When choosing an ultimate element, Cu can be regarded as an ideal alternative for Pt and Au, due to its low cost, high stability and excellent electrical conductivity. However, Cu in a-C films cannot form carbide, but only a weak chemical bond between carbon and copper, which, in turn, affects the relative content of the graphite phase and the diamond phase. As it is known, the relative content of the phases influences the film properties, therefore, special methods of using Cu can be applied to get the necessary performance of a film. It is worthwhile to mention that one important feature for a-C films is its facile manipulation of their physical properties, ranging from the mechanical properties to the photoconductivity, by simply controlling the relative ratio of the sp^3 to sp^2 carbons in films. However, the shortcomings of a-C films, involving the large internal stress, low adhesion and thermal stability have hindered their practical applications in engineering. For example, conventional a-C films exhibit limited adhesion to many metallic substrates and high internal compressive stress (up to 10 GPa), as a result, leading to peeling-off of the films from the substrate when the film thickness is more than 1μm. Consequently the development of a-C films with improved adhesive to metallic substrate has become one major topic in engine applications. To reduce internal stress, wear and friction, and to improve adhesion between film and substrate, one of the most efficient methods is metal doped a-C film deposited by introducing metal elements into the system. Unfortunately, the effects of metals implanted on the structure and further on the properties of a-C films are very complex, as the functions of each metal element varies. For example, some metals (e.g. Ag, Cu, etc.) do not chemically bond with carbon and only arranged in the form of nanoparticles within the diamond-like carbon matrices. The other species (e.g. Ti, W, etc.) can be chemically bonded with carbon atoms which results in the formation of the composite film with metal carbide phases. Although the introduction of metallic species can reduce the internal stress of a-C films, which on the other hand will unavoidably change the films' hardness. To our knowledge, no report has been given on the effects of binary metal doped a-C composite films on the structures and properties of a-C films with the aim to improve its surface properties. Consequently, the development of a-C films with simultaneous improved adhesion to substrate, low stress and high hardness has become one major topic in engineering applications. Recently, many stress-demoting strategies have been investigated for a-C films, such as incorporating a small percentage of metal or nonmetal ions in the films, and producing functional films in the form of interlayer or buffer layer between the substrate and a-C films. However, there are still presenting the challenges in the deposition of carbon films with good integrated performance for engineering application. To address these shortcomings, different technological methods are used such as doping different elements or introducing interlayer in the a-C films.

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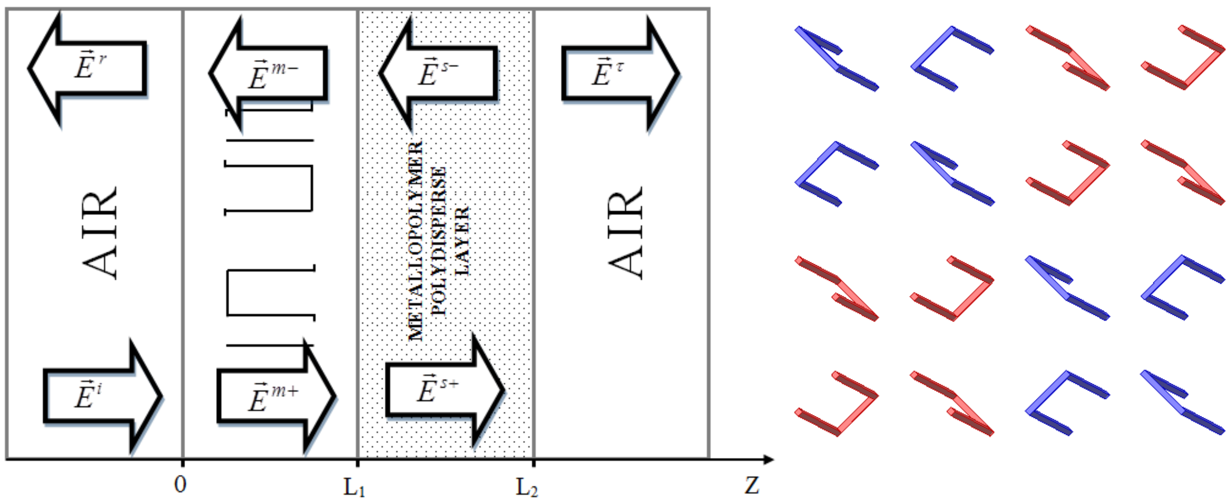
DEVELOPMENT OF A DOUBLE-SIDED "IDEAL" ABSORBER OF MICROWAVE AND THZ WAVES BASED ON METAMATERIALS AND METAL-POLYMERIC POLYDISPERSE LAYERS

I. Semchenko, S. Khakhomov, A. Samofalov, I. Faniayeu

Francisk Skorina Gomel State University, Gomel, Belarus
isemchenko@gsu.by, khakh@gsu.by

In recent years the artificial structures of bianisotropic elements have been actively studied. In such materials, along with the electric anisotropy, there might be magnetic anisotropy, as well as a magnetoelectric coupling. Scientists show particular interest to planar layered structures. Planar layered structures, in which anisotropic materials of various nature (dielectrics, semiconductors, conductors, magnets, liquid crystals, composite materials) are used, have got widespread practical applicability in optoelectronics. Filters that allow to pass or reflect the selected spectral regions; low-reflection coatings; converters of optical radiation controlled by external electric or magnetic field; thin-film magnetic storage devices, the information from which is derived with the help of the magneto-optical Kerr effect; planar waveguide structures and integrated optical elements serving to process optical information and control radiation – all these have been produced on the basis of such structures. But of late layered structures of bianisotropic materials have been widely studied. They might have magnetic anisotropy as well as a magnetoelectric coupling in addition to the electric anisotropy. The magnetoelectric coupling is expressed in the presence of cross terms in the material equations for electric and magnetic fields. In other words, under the influence of the electric field of the incident wave, magnetic moments can be induced in such structures, and vice versa, under the action of the magnetic component of the incident radiation, electric dipole moments in the structure can be induced. Bianisotropic materials are represented by electro- and magneto-optical crystals, liquid crystal, composite and optically active media. In connection with this, the problems, describing the propagation and transformation of electromagnetic waves in layered structures with various types of bianisotropy, are current and topical. Metamaterials are artificial structures consisting of periodic arrays of electrically small elements with arbitrary electromagnetic properties and shape. Varying the properties of such elements, you can adjust the macroscopic parameters of the entire structure.

We plan to develop and create a metamaterial that has low reflection and almost complete absorption of microwave and THz waves during their incidence on a metamaterial from one or both sides. Omega elements of classical or rectangular shape are offered to be used as elements of the metamaterial. Equally significant an electric dipole moment and a magnetic moment are induced in each omega element under the influence of an electromagnetic wave. Therefore, the metamaterial, produced on the basis of optimal omega elements, shows not only dielectric, but also magnetic properties. Near the resonance frequency relative permittivity and relative permeability of the metamaterial are approximately equal. This equality ensures the matching of the input impedance of the metamaterial with the wave impedance of free space, i.e. the absence of a reflected wave. The advantage of optimal omega elements is their equally effective activation by both electric and magnetic fields. In addition, the optimal properties of omega elements are shown not only in external fields, but also in their mutual influence. Therefore, the necessary properties of the metamaterial will be maintained even with a high concentration of elements. Previously, we showed the possibility of significant absorption of electromagnetic radiation using a metamaterial containing omega elements of a rectangular shape, but in this paper, in order to achieve maximum absorption, in addition to omega-structured metamaterials we suggest using a metallopolymer polydisperse layer with significant absorption. As a result of passing through all the layers of such structure (two-or three-layer), including repeated passing through an omega-structured metamaterial, the electromagnetic wave will be completely absorbed, and the wave reflection will not take place. In this absorber, the metamaterial performs two roles: 1) matching the input impedance of the structure with the impedance of free space, which results in the absence of wave reflection at the air-metamaterial boundary; 2) waves absorption in the metamaterial layer, including waves reflected from the boundary "metamaterial - metallopolymer polydisperse layer". The polymer layer, in its turn, has the function of an absorber of electromagnetic waves with a controlled frequency bandwidth of the absorption band (Fig.1).



a b

Fig. 1. a – the structure consisting of a metamaterial containing omega-elements of a rectangular shape, and a metallopolymer polydisperse layer having a significant absorption; b – the geometry of the location of the rectangular omega-shaped inclusions in a metamaterial

We solved the boundary problem for a structure consisting of a metamaterial containing omega-elements of a rectangular shape and a metallopolymer polydisperse layer (Fig. 1), which has a significant absorption and serves as a substrate. An analytical calculation of the transmittance and reflection coefficients of an electromagnetic wave from such a structure is carried out. It is shown that the metamaterial and the absorbing substrate, when used together, lead to a stronger absorption of the transmitted and reflected electromagnetic wave and, consequently, to a decrease in the transmission and reflection coefficients at the resonant frequency.

Optimal parameters of an omega-element of a rectangular shape are calculated. Subsequently, the reflection and transmission coefficients of electromagnetic waves for a two- or three-layer sample containing omega-structured metamaterials and a metallopolymer polydisperse layer will be determined. The scientific novelty is the design of samples based on metamaterials with omega elements and metal-polymer polydisperse layers that have the property of a single- or double-sided "ideal" absorber in the microwave and THz bands. The modeling and production of experimental samples of metamaterials that have the property of an "ideal" absorber are planned.

The application field of the obtained results is the microwave electromagnetics. The results can be used for theoretical and experimental studies of artificial composite media with inclusions of various shapes. The developed technique will allow to predict the behavior of new complex composite materials and to investigate the electromagnetic properties of such media. The studies that have been carried out will allow turning to manufacturing of experimental samples of new artificial metamaterials and the development of theoretical bases of new types of frequency filters, converters of polarization and deflectors of electromagnetic waves on the basis of composite media with inclusions of the various form. The results of the research will also be used in materials science while creating new radio absorbing materials and coatings (as experimental samples) that convert the energy of electromagnetic radiation on mechanisms of multi-level absorption, the use of which will solve urgent problems of electromagnetic safety, electromagnetic compatibility and engineering ecology.

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METALENSES BASED ON THE UNSYMMETRICAL DOUBLE SLITS ARRAY

Hongyan Shao, Jicheng Wang, Zheng-Da Hu, Tian Sang

School of Science, Jiangsu Provincial Research Center of Light Industrial Optoelectronic Engineering and Technology, Jiangnan University, Wuxi 214122, China

Abstract. Metasurface combined with surface Plasmon polaritons (SPPs) has been becoming an indispensable role in ultra-thin devices designing, by which the amplitude, phase and polarization of electromagnetic wave all can be controlled easily. The structures of Babinet-inverted nano-antennas we proposed can provide a series of phase-shifts covering 2π and ensure almost same transmission simultaneously. So the wavefront can be modulated by arraying the unit cell in course. Metalenses with 1D linear array and 2D planar array are designed to show various distributions of optical fileds. And the high signal-to-noise ratio makes them standing out from the traditional counterparts. In addition, these design of metalens will pave an avenue in the practical applications of metasurface in data storages and optical holography.

Metamaterials can realize some non-natural electromagnetic properties such as negative refraction[1] and optical invisibility[2]. However, it is still restricted in respect of the hope-for applications, which is mostly attributed to the challenge of the fabrication of 3D structures at nanoscale. Therefore metasurface has been entering the sight of people as a brand-new and potential research field and been paid the extraordinary degree of interest in recent years owing that it can be considered as the investigation of 2D surfaces in essence. So far, the applications and devices based on it have been investigated extensively and a markedly progress has been gotten in metalenses [3], optical holography [4], anomalous reflection/refraction [5] and optical information processing and propagating [6]. We designed a new geometry nanopatterning composing of two separated nano-voids with a certain angle milled in a thin golden film. We can obtain the blocks with arbitrary phase-shift by changing the angle and the size of the nano-voids for cross-polarized incident light based on the principle of Parancharatnam-Berry (PB) phase modulating. We pick out a series of building blocks with specific phase-shifts ensuring same transmission simultaneously. Then we arrange those selected into chain-like and flat array in course as a focusing lens and the simulation results have displayed the quite high signal-to-noise ratio and the full width at half maximum (FWHM) [7].

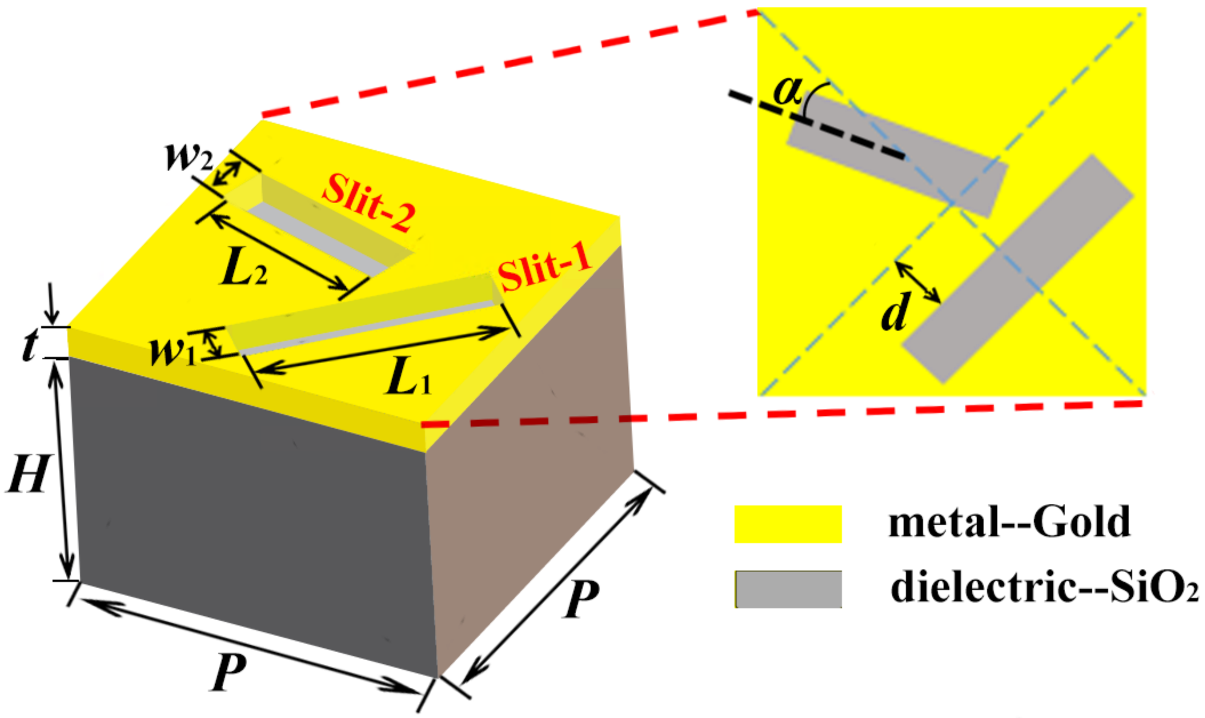

Fig. 1. Schematic of the structure of building unit-cell with two separated nano-voids, slit-1 and slit-2. The sideward inset is the top view of the structure. The distinctions between the selected unit-cell lie in the different w1 (w2 = w1) and α

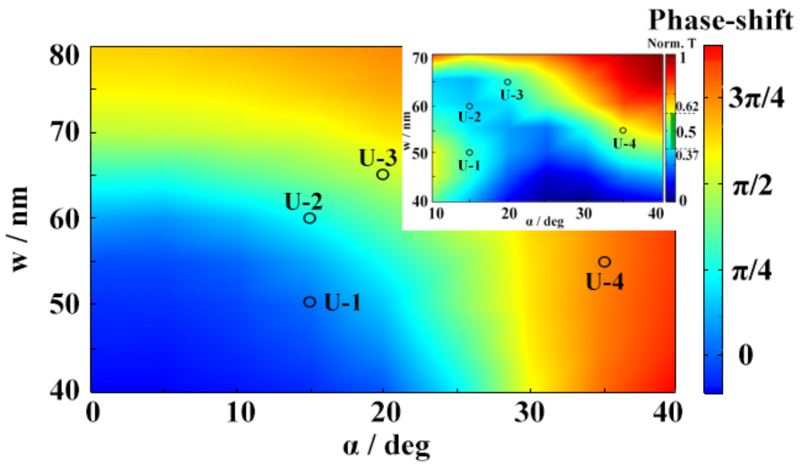

Fig. 2. The simulated results for individual double-slits structure. The colour maps indicate the relative phase-shifts (the main) and the normalized transmission (the inset) as the function of the width w (y axis) and splitting angle α (x axis) of the Slit-2 for cross-polarized electric field with wavelength λ=632.8nm. The small circles indicate the unit-cells we picked, U-1 to U-4, and their relative phase-shifts are 0, π/4, π/2, and 3π/4, respectively

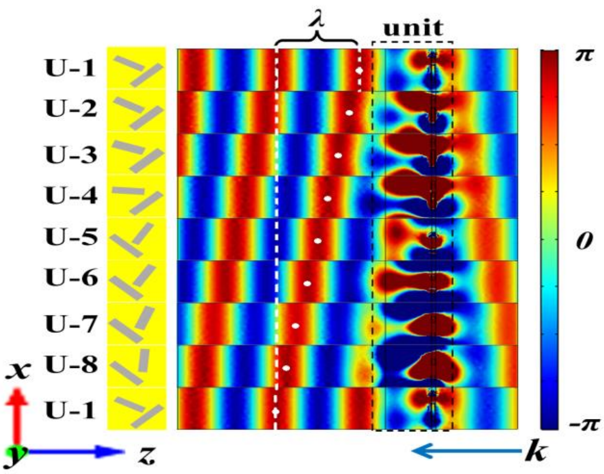

Fig. 3. The simulated results of all selected unit-cell.
The U-5 to U-8 are obtained by rotating 90° for U-1 to U-4, respectively. So they can create relative phase-shifts π, 5π/4, 3π/2, and 7π/4 for cross-polarized light. The pseudo-color fields map indicates the phase distribution of transmitting light scattered from each unit-cell

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TRANSMITTED-TYPE GUIDED-MODE RESONANCE SENSOR USING COUPLED GRATINGS

La Wang, Tian Sang, Zheng-Da Hu, Jicheng Wang

School of Science, Jiangsu Provincial Research Center of Light Industrial Optoelectronic Engineering and Technology, Jiangnan University, Wuxi 214122, China
sangt@jiangnan.edu.cn

Abstract. Transmitted-type guided-mode resonance (GMR) sensor based on the coupled gratings (CGs) and the corresponding Fabry-Pérot-like (FP-like) model for evaluating the resonance peaks are presented. The estimated locations of the FP-like resonance obtained by this theoretical model are well agreed with those of the exact results. Good sensing properties of the CGs sensor can be maintained, regardless of whether the two grating membranes are laterally aligned or not. The sensitivity of the CGs sensor is immune to the variation of the refractive index (RI) of the substrate, and it can be improved by selecting higher order FP-like mode.

Optical device based on the guided-mode resonance (GMR) effect has been a growing field of interest due to its narrowband spectral filtering property and low sideband. Optical sensors based on the GMR effect are of increasing importance due to their simple structures with versatile sensing characteristics. Various GMR designs based on 1D and 2D periodic structures have been proposed to improve the performance for sensing applications, examples of present-day uses include optical pressure sensor [1], multiwavelength GMR sensor [2, 3], intensity-resolved GMR sensors[4], and polymer GMR sensor[5].

We proposed a transmitted-type sensor based on the GMR transmission filter using the coupled gratings (CGs). This kind of sensor consists of two identical grating membranes with a gap for analyte, and a Fabry-Pérot-like (FP-like) model is proposed to analyze the tunable transmission characteristics of the CGs sensor. It is shown that a narrow FP-like channel with high transmissivity occurs in the opaque background of the CGs, and its location is shifted linearly with the variation of the RI of the gaseous analyte. Good sensing properties are immune to the lateral shift and the refractive index (RI) of the substrate. The stronger couplings between the two grating membranes can be used to improve the sensitivity. By selecting higher order FP-like mode such as m = 4, the sensitivity of the CGs sensor can be improved to 748 nm/RIU with the FOM of 374[6].

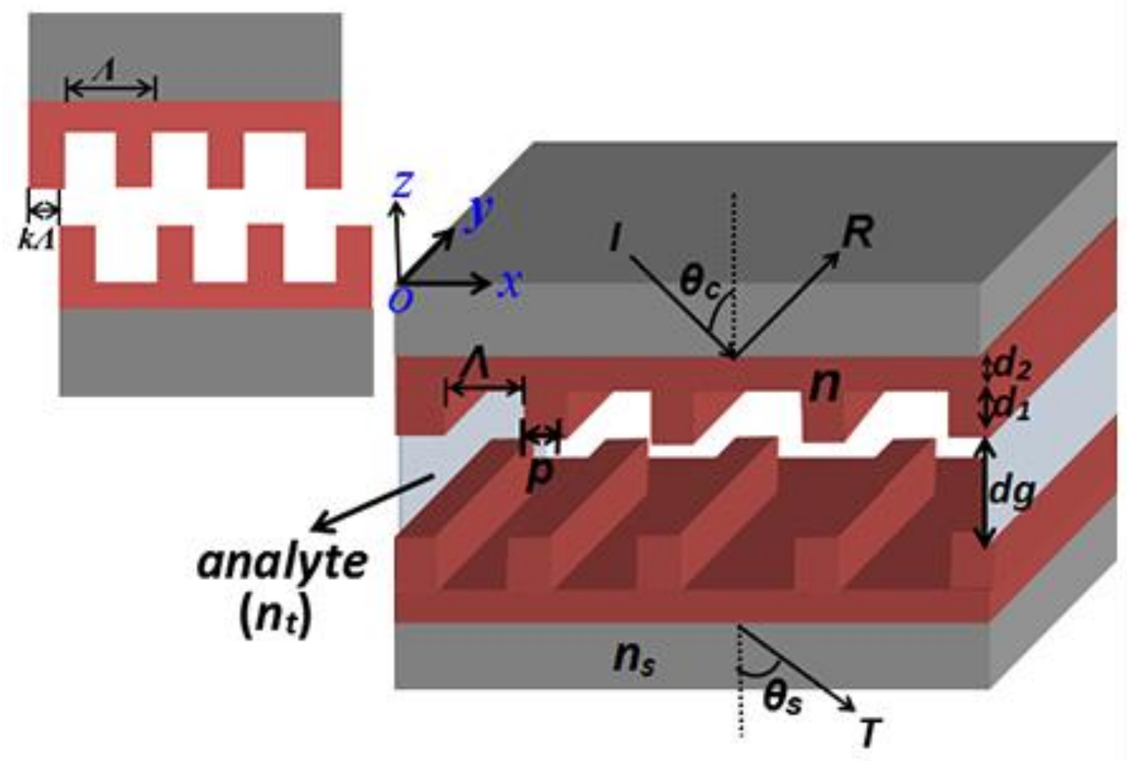

Fig. 1. Schematic diagram of the CGs sensor under the TE-polarized plane wave illumination, k=0 corresponds to the aligned condition

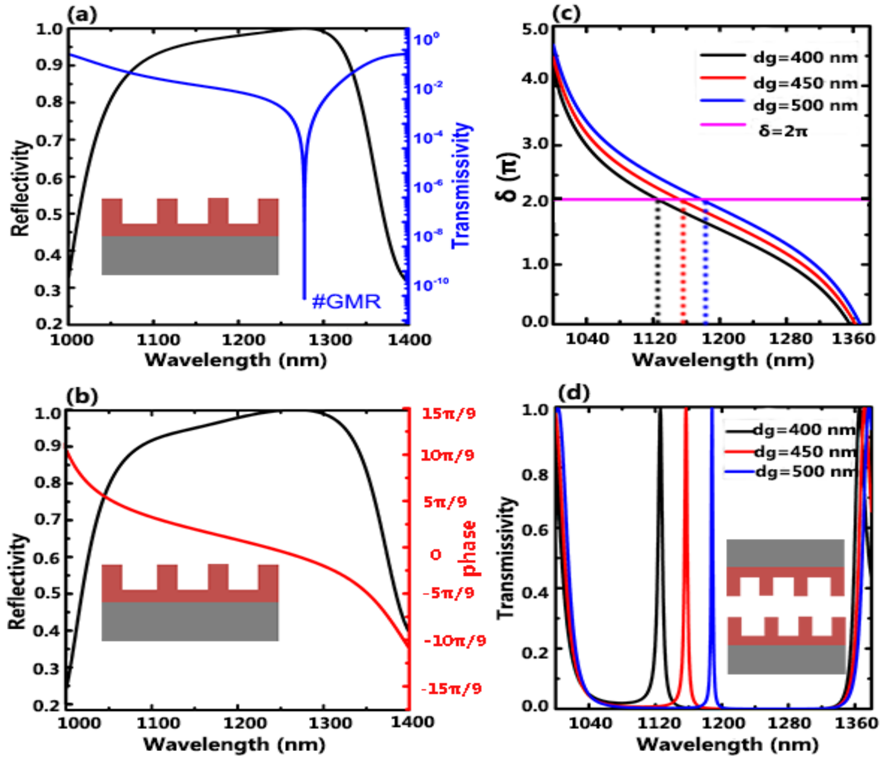

Fig. 2. (a) Spectral response of the single grating membrane. (b) Reflection response and reflection phase of the single grating membrane. (c) Transmission peaks of the CGs sensor estimated by using the FP-like model for different gap thickness. (d) Transmission response of the CGs sensor for different gap thickness

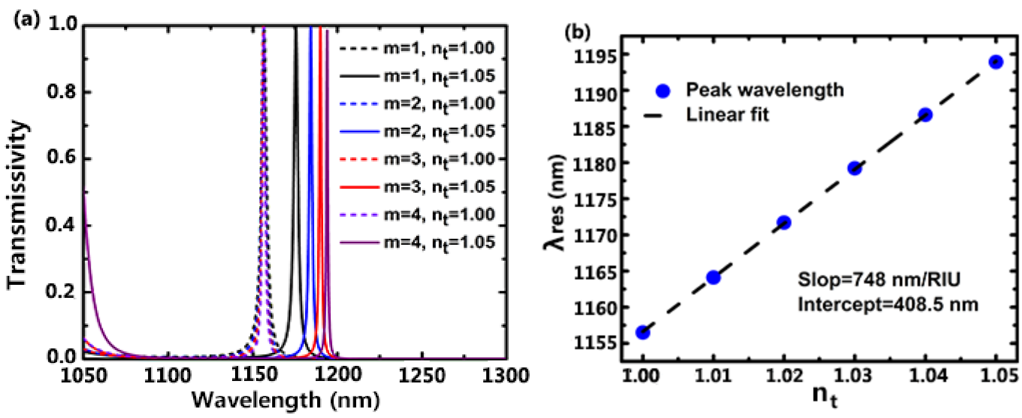

Fig. 3. (a) Transmission spectra of the CGs sensor as function of the RI of the analyte for different modes. (b) Spectral position of the resonant peak as a function of the RI of the analyte with m = 4

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PLASMA-CHEMICAL DEPOSITION, STRUCTURE, PROPERTIES AND APPLICATION OF NANOCOMPOSITE POLYMER-BASED COATINGS

A. A. Rogachev, Xiaohong Jiang, M. A. Yarmolenko, A. V. Rogachev

International Chinese-Belarusian scientific laboratory by vacuum-plasma technologies

The nanocomposite polymer-based thin layers have unique properties that cannot be generally obtained by their individual constituent elements. Particularly, are interesting thin-layer systems containing nanoparticles of noble metals, another polymer or semiconductors. Among the different ways to synthesize these nanocomposites, the vacuum solvent-free methods such as physical, chemical vapor deposition and hybrid plasma chemical techniques are advantageous and provide easy control not only of nanocluster growth but also of its size, shape and distribution into polymer matrix volume. The advantages of vacuum-plasma chemical methods of nanocomposite systems synthesis can be the absence of limitations in the solubility of polymer matrix, for example, sparingly soluble [1].

The works [1–2] suggests a new electron-beam approach to fabricate organosilicon magnesium containing coatings by laser assistive processing. The low-energy electron beam on organosilicon resin, initiates the detachment of methyl substituents. The chemically cross-linked Si-O structures resistant to electron-beam are formed on the target and deposited layers are partially cross-linked. The laser assistive influence is accompanied by decrease in the reactivity of the generated products of resin destruction. The UV (266 nm) laser emission leads to an increase of cross-linked structures in the coating. The optical emission (532 nm) on the organosilicon resin activates significantly the methyl substituents detachment. The use of magnesium makes it possible to increase the percentage of the organosilicon compound conversion into the coating. Meanwhile, the laser emission influence on the molecular structure of the coating is weakened. Interaction of the metal with organosilicon molecules leads to the formation of magnesium silicide. The UV laser and optical emission lead to the formation of magnesium hydroxide ($Mg(OH)_2$), magnesium oxide (MgO) respectively. The coatings are potential candidates for deposition on implants aiming at stimulating of osseointegration processes. Highly ordered conductive polyaniline (PANI) coatings containing gold nanoparticles were prepared by low-energy electron beam deposition method, with emeraldine base and chloroauric acid used as target materials. It was found that the emeraldine base layers formed from the products of electron-beam dispersion have extended, non-conductive polymer chains with partially reduced structure, with the ratio of imine and amine groups equal to 0.54. In case of electron-beam dispersion of the emeraldine base and chloroauric acid, a protoemeraldine structure is formed with conductivity 0.1 S/cm. The doping of this structure was carried out due to hydrochloric acid vapor and gold nanoparticles formed by decomposition of chloroauric acid, which have a narrow size distribution, with the most probable diameter about 40 nm. These gold nanoparticles improve the conductivity of the thin layers of PANI+Au composite, promoting intra- and intermolecular charge transfer of the PANI macromolecules aligned along the coating surface both at direct and alternating voltage. The proposed deposition method of highly oriented, conductive nanocomposite PANI-based coatings may be used in the direct formation of functional layers on conductive and non-conductive substrates [3].

Polytetrafluoroethylene (PTFE) composite coatings doped with copper acetate and polyethylene (PE) were fabricated on rubber substrate by electron beam dispersion technique. The effects of dopant nature and glow discharge treatment on morphology, structural and tribological properties of the coatings were investigated. Glow discharge enhances the crystallinity and ordering degree of composite coatings. Friction experiments indicated the significant difference of composite coatings in the nature of their destruction during friction. PE–PTFE coating is characterized of the brittle fracture with clear failure boundaries but Cu–PE–PTFE coating shows a rough surface without cracking and delaminating after friction. Cu doping increases the dynamic coefficient of friction of PE and PE–PTFE composite coatings, but discharge plasma decreases the dynamic coefficient of friction. Cu–PE–PTFE composite coating after discharge treatment has the decreased dynamic coefficient of friction and improved wear resistance [4]. A comprehensive study of the effectiveness of two-layer coatings based on PEG and silver nitrate to combat pathogenic microorganisms – the agents of implant-associated infections was conducted. The paper deals with the features of the structural transformations that occur in the polymer matrix at the stage of deposition and formation of the thin layer, as well as when the thin layer is heat-treated. The PEG matrix was shown to promote thermal stabilization of silver nitrate, which is manifested in the presence of significant amount of oxide (AgO and Ag_2O) and undecomposed salt, in addition to silver nanoparticles, in the annealed organic layer [5]. A new method of forming coatings containing copper nanoparticles and the products of polyethylene thermal destruction is suggested. The method comprises the heat treatment of the two-layer copper acetate-polyethylene system deposited in a vacuum using low-energy electron flux. The effect of the medium composition and the annealing temperature on the structural and phase state of the copper nanoparticles and the matrix is determined. The high antibacterial activity of the heat-treated surfaces against Escherichia coli ATCC 25922 is shown [6].

The plasma chemical solvent-free method of doped and nanocomposite polyaniline-based conductive coatings deposition was elaborated. The nanocomposite PANI-based coatings were deposited onto interdigital capacitor for ammonia gas sensing applications. The increasing of the sensing performance of the PANI-based coatings with silver nanoparticles was established in particular at the low frequency region of impedance spectra. The high sensitivity and linearity of this sensor response were examined at a direct and alternating voltage with ammonia concentrations up to 10 ppm [7].

The features or chemical composition and molecular structure ot polymer silver containing coatings and their changes under the heating were studied. The coatings have been deposited from the gas phase formed by electron-beam dispersion of polymer and silver salt mixture. The impact of polymer matrix and silver salt nature on the parameters of surface plasmon effect occurrence, as well as on the molecular structure of the coatings has been established [8].

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QUANTUM COHERENCE AND QUANTUM CORRELATION OF TWO QUBITS MEDIATED BY A ONE-DIMENSIONAL PLASMONIC WAVEGUIDE

Zheng-Da Hu, Xiuye Liang, Jicheng Wang, and Yixin Zhang

School of Science, Jiangsu Provincial Research Center of Light Industrial Optoelectronic Engineering and Technology, Jiangnan University, Wuxi 214122, China

Abstract. We investigate the dynamics of quantum coherence and quantum correlation of two qubits mediated by a one-dimensional plasmonic waveguide. The analytical expression of the dissipative dynamics of the two qubits is obtained for the initial *X* state. The dynamical behaviors of the quantum coherence and quantum correlation are shown to be largely dependent on the parameters of the initial state. Starting from a product state, quantum coherence and quantum correlation can be induced by the plasmonic waveguide. Under continuous drivings, steady quantum correlation can be obtained at specific distance larger than the operating wavelength and large values of steady quantum coherence are attainable at arbitrary distance. The detuning effect on the dissipation-driven generation of steady quantum coherence and quantum correlation is also explored.

Introduction. Decoherence is usually unavoidable due to the fact that any realistic quantum system is disturbed by its surrounding which may lead to loss of quantum coherence [1]. The presence of decoherence causes obstacles for precisely carrying out quantum tasks because quantum states (to be distributed) and nonclassical correlations (used as resources) are easily destroyed. In this sense, the mediations of nonclassical correlations (between two nodes of a quantum network) in dissipative environments are crucial in quantum information science [2]. It has been reported that photons can be used as a medium to mediate the entanglement between two nodes [3,4]. Recently, some proposals for long-distance entanglement of two nodes by using plasmons instead of photons have attracted considerable interest [5–9]. Plasmons traveling along an interface are known as surface plasmon polaritons [10, 11] and display strong local surface effect, which is effective for breaking the classical diffraction limit and manipulating light in the nanoscale domain.With the development of nanotechnologies, strong and efficient coupling in plasmonic quantum electrodynamics is attainable and much work has been devoted to exploring potential applications of plasmonic nanostructures to quantum information science [12,13]. In this theses, we report the dynamics of quantum coherence and quantum correlation between two separated qubits which are modulated by a one-dimensional (1D) plasmonic waveguide (PW) via quantum coherence and quantum correlation, respectively. The analytical solution for the dynamics of the two-qubit system is obtained for initial X states. By considering a concrete class of X states, i.e., the extended Werner-like states, the dynamical behaviors of the quantum coherence and quantum correlation is shown to be largely dependent on the parameters of the initial state. The phenomena of sudden change or double sudden changes occur in the dynamics of quantum correlation. Besides, the incoherent coupling parameter is more crucial in the creation of quantum coherence and quantum correlation from the initial product state of the two qubits, although they decay to zero asymptotically due to the individual spontaneous emission. To obtain steady quantum coherence and quantum correlation, classical fields for driving can be locally applied to the qubits. Under the continuous drivings, the second sudden change point is removed and steady quantum correlation can be obtained at specific distance larger than the operating wavelength. By contrast, large values for steady quantum coherence are attainable at arbitrary distance. Finally, we explore the detuning effect on the dissipation-driven generation of steady quantum coherence and quantum correlation.

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