Investigation of Natural Photonic crystal and Historical background of their development with future aspects

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Abstract— In this work, microstructural and optical characteristics nanoparticles of wings of Lemon pansy (Junonia lemonias) butterfly were studied with the help of different characterization techaniques. And the historical review of their fabrication and characterizations. We developed the sequence of descoveries and investigations which had happenned in past few years and described future advancements of photonic crystals, with their importance. The mathematical description given for the understanding different dtructures and relate them for the applications. We represented here optical images of butterfly wings which is taken by optical microscop.

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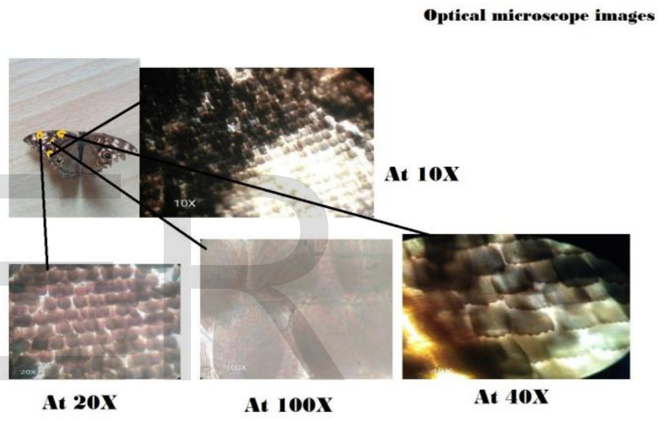
1 INTRODUCTION

THe Nature provides ample number of biological systems which display beautiful patterns and colours. The study of the microstructures in these systems gives hints about fabricating artificial photonic structures [1]. These biological systems provide novel platforms and templates so as to accommodate interesting inorganic materials. There are several biomaterials, such as bacteria [2] and fungal colonies [3], wood cells [4], diatoms [5], echinoid skeletal plates [6], pollen grains [7], eggshell membranes [8], human and dog's hair [9] and silk Historical Devolopment.

[10] which have been used for the biomimetic synthesis of a range of organized inorganic make ups that has potential in catalysis, magnetism, separation technology, electronics and photonics. Several research groups have worked on different novel methods to produce such inorganic materials using natural templates. In the recent years, butterfly wings as templates have gained enormous attention because of its complex yet extraordinary architecture. The Photonic crystals are composed of periodic dielectric, metallo dielectric or even superconductor microstructures or Nanostructures that effects electromagnetic wave propagation same way that the periodic potential in semiconductor crystal affects electron motion by defining allowed and forbidden electronic energy bands. In other words, The photonic crystal, in which the atoms or molecule are replaced by macroscopic media with differing dielectric constants, and the periodic potential is replaced by a periodic dielectric function (or, equivalently, a periodic index of refraction). Photonic crystal is the solution of the problem of optical control and manipulation is thus a photonic crystals.

The butterfly wings images taken by optical microscope at different different resolution is shown below. From these images the basic structure of butterfly wings can be understand.



Historical Background

Photonics is a science of light. Before the photonics word in 18th century Robert Hooke in 1665 and Isaac Newton in 1672 were among the underlying physics of light[11] They correctly predicted that the iridescent colours of peacock feathers and silverfish scales resulted from their physical structure rather than pigmentation. The word photonics is came from the Greek word "Phos" (Photo) meaning light. It came in the late 1960s to describe a research field whose goal was light performing functions. Photonics began in 1960 with the invention of laser.

The photonic crystals have been studied in one form or another since 1887,
Before 1987, one-dimensional photonic crystals in the form of periodic multi-layers dielectric stacks (such as the Bragg mirror) were studied extensively. Lord Rayleigh started their study in 1887[1], by showing that such systems have a one-dimensional photonic band-gap, a spectral range of large reflectivity, known as a stop-band. Today, such structures are used in a various range of applications; from reflective coatings to increase the efficiency of LEDs to highly reflective

mirrors in certain laser cavities.

A detailed theoretical study of one-dimensional optical structures was *performed by Vladimir P.Bykov,(1972)[2] who was the first to investigate the effect of* a photonic band-gap on the spontaneous emission from atoms and molecules placed within the photonic structure. Bykov also guessed as to what could happen if two- or three-dimensional periodic optical structures were used. The concept of three-dimensional photonic crystals was then discussed by Ohtaka in 1979[4], who also developed a formalism for the calculation of the photonic band structure. However, these ideas did not take off until after the publication of two milestone papers in 1987 by Yablonovitch and John[5,6]. Both these papers concerned high dimensional periodic optical structures – photonic crystals. Yablonovitch's main motivation was to engineer the photonic density of states, in order to control the spontaneous emission of materials placed within the photonic crystal; John's idea was to use photonic crystals to affect the localization and control of light.

After 1987, the number of research papers concerning photonic crystals began to grow exponentially. However, due to the difficulty of actually fabricating these structures at optical scales (see Fabrication Challenges), early studies were either theoretical or in the microwave regime, where photonic crystals can be built on the far more readily accessible centimeter scale. (This fact is due to a property of the electromagnetic field known as scale invariance – in essence, the electromagnetic fields, as the solutions to Maxwell equations, has no natural length scale, and so solutions for centimeter scale structure at microwave frequencies are the same as for nanometer scale structures at optical frequencies.) By 1991, Yablonovitch had demonstrated the first three-dimensional photonic band-gap in the microwave regime[7].

In 1996, Thomas Krauss made the first demonstration of a two-dimensional photonic crystal at optical wavelengths[8]. This opened up the way for photonic crystals to be fabricated in semiconductor materials by taking the methods used in the semiconductor industry. Today, such techniques use photonic crystal slabs, which are two dimensional photonic crystals "etched" into slabs of semiconductor; Total internal reflection confines light to the slab, and allows photonic crystal effects, such as engineering the photonic dispersion to be used in the slab. Research is underway around the world to use photonic crystal slabs in integrated computer chips, in order to improve the optical processing of communications both on-chip and between chips.

Although such techniques have yet to mature into commercial applications, two-dimensional photonic crystals have found commercial use in the form of Photonic crystal fiber. Photonic crystal fibers were first developed by Philip Russell in 1998, and can be designed to possess enhanced properties over (normal) Optical fiber.

The study of three-dimensional photonic crystals has proceeded more slowly than their two-dimensional counterparts. This is because of the increased difficulty in fabrication; there was no inheritance of readily applicable techniques from the semiconductor industry for fabricators of three-dimensional photonic crystals on it.

Attempts have been made, however, to modify some of the same techniques, and quite advanced examples have been example in the construction demonstrated, for of "woodpile" structures constructed on a planar layer-by-layer basis. Another shore of research has tried to construct three-dimensional photonic structures from self-assembly—essentially letting a mixture of dielectric nano-spheres settle from solution into three-dimensionally periodic structures that have photonic band-gaps.

Vasily Astratov's and his group from the Loffe Institute realized in 1995 that natural and synthetic opals are photonic crystals with an incomplete band gap[9]. The first demonstration of an "inverse opal" structure with a complete photonic band gap came in 2000, from researchers at the University Of Toronto, Canada[10]. The always expanding field of biomimetics- the study of natural structures to better understand and use them in design—is also helping researchers in photonic crystals. For example, in 2006 a naturally-occurring photonic crystal was discovered in the scales of a Brazilian beetle.

In the beginning of 21st century the research on photonic crystals focused on fabrication of high quality photonic crystals[12-14], study of physical phenomena in photonic crystals, and realization of optical devices based on photonic crystals high-quality three dimensional photonic crystals were fabricated by use of the vertical deposition method, the laser direct writing method, and the laser holographic lithography method[15,16]. The novel phenomena of negative refraction effect and slow light effect in photonic crystals were also confirmed during this period[17-19]. Various integrated photonic devices based on photonic crystals, such as photonic crystal filter, photonic crystal optical switching and photonic crystal laser, were realized experimentally[20-22]. In recent years, great attention has been paid to the realization of integrated photonic devices based on the new physical effects and phenomena in photonic crystals[23-25].

Moreover, photonic metamaterials, propagation and localization properties of surface Plasmon polarization in metal photonic crystals, and the quantum electrodynamics of high-quality photonic crystal microcavity coupled with quantum dots have been studied extensively[26-29].

Mathematical approach

For mathematical convenience, we employ the standard trick of using a complex-valued fieldandremembering to take the real part to obtain the physical fields. This allows us to write a harmonic mode as a spatial pattern (or "mode profile") times a complex exponential: $H(r,t) = H(r)e-i\omega t$ (1) $E(r,t) = E(r)e-i\omega t$. To find the equations governing the mode profiles for a given frequency, we insert the above equations into (3). The two divergence equations give the conditions $\nabla \cdot H(r) = 0$, $\nabla \cdot [\varepsilon(r)E(r)] = 0$, (2) which have a simple physical interpretation: there are no point sources or sinks of displacement and magnetic fields in the medium. Equivalently, the field configurations are built up of electromagnetic waves that are transverse. That is, ifwehaveaplane wave $H(r) = a\exp(ik \cdot r)$,forsomewavevectork, equation(3) requires that $a \cdot k = 0$. We can now focus our attention only on the other two of the Maxwell equations as long as we are always careful to enforce this transversality requirement. The two curl equations relate E(r) to H(r): $\nabla \times E(r) - i\omega\mu 0H(r) = 0$ (4) $\nabla \times H(r) + i\omega\varepsilon 0\varepsilon(r)E(r) = 0$. We can decouple the equations in the following way. Divide the bottom equation of (5) by ε(r), and then take the curl. Then use the first equation to eliminate E(r). Morever, the constants ε0 and μ0 can be combined to yield the vacuum speed of light, $c = 1/\sqrt{\varepsilon 0\mu 0}$. The result is an equation entirely in H(r): $\nabla \times [\ 1/\varepsilon(r)\nabla \times H(r)] = (\omega/c)^2 H(r)$. (6)

This is the master equation. Together with the divergence equation (52), it tells us everything we need to know about H(r). Our strategy will be as follows: for a given structure ε(r), solve the master equation to find the modes H(r) and the corresponding frequencies, subject to the transversality requirement.

With the help of master equation we can find different eigen modes and photonic band gap also.

Applications and Future aspects

Photonic crystals are attractive optical materials for controlling and manipulating light flow. One dimensional photonic crystals are already in widespread use, in the form of thin-film optics, with applications from low and high reflection coatings on lenses and mirrors to colour changing paints and inks. Higher-dimensional photonic crystals are of great interest for both fundamental and applied research, and the two dimensional ones are beginning to find commercial applications.

The first commercial products involving two-dimensionally periodic photonic crystals are already available in the form of photonic-crystal fibers, which use a microscale structure to confine light with radically different characteristics compared to conventional optical fiber for applications in nonlinear devices and guiding exotic wavelengths. The three-dimensional counterparts are still far from commercialization but may offer additional features such as optical nonlinearity required for the operation of optical transistors used in optical computers, when some technological aspects such as manufacturability and principal difficulties such as disorder are under control.

Conclusions

In this work, we made an attempt to understand the structure of naturl photonic crystal Lemon pansy butterfly (family-nymphalidae) tribe-junonini species. The optical properties studied through optical microscopy for the pure photonic crystal which is having periodicity. With the help of history we conclude that working sequence in thid field and how much we have done till now and what is required. The studies shows the photonic cystal having large amount of importance in daily life. And it will make the great change in the world in future. The establishment of fabrication technologies is first required in this field, but in these years, some semiconductor process techniques, nano-manipulation techniques, self-organization techniques, holographic techniques, etc., reached a sufficient level for the demonstration of a photonic bandgap and other phenomena, as seen in the next two presentations. Now, a number of worldwide groups are studying their applications to light sources including nanolasers, waveguide components for a next era functional circuits by photons, and passive components and fibers partly commercialized.

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