*Bulletin of Pure and Applied Science Physics, Vol.43D No.1, January-June 2024 P.14-18*
*Original Research Article*

*Print version ISSN 0970 6569*
*Online version ISSN 2320 3218*
*DOI: https://doi.org/10.52710/bpas-phy.3*
*Available online at www.bpasjournals.com*

# Characteristics Feature of Tunable Linear and Circular Dichroism for Applications in Sensing and Imaging

**[1]Santosh Kumar Suman* and [2]Ashok Kumar**

**Author's Affiliations:** [1]Research Scholar, University Department of Physics, B.N. Mandal University, Madhepura, North Campus, Singheshwar, Bihar 852128, India.
E-mail: kumarsantoshsuman1@gmail.com
[2]University Department of Physics, B.N. Mandal University, Madhepura, North Campus, Singheshwar, Bihar 852128, India.
E-mail: ashokabnu@yahoo.co.in

***Corresponding author:** **Santosh Kumar Suman**, Research Scholar, University Department of Physics, B.N. Mandal University, Madhepura, North Campus, Singheshwar, , Bihar 852128, India.
E-mail: kumarsantoshsuman1@gmail.com

**ABSTRACT** Dichroism is one of those natural mechanism of polarization control involved in the absorption of linear polarizations with light transmission. Some crystalline structures having circular dichroism rotate the electric field polarization of the incident light and this property was knows as optical activity. In the cae of linear dichroism it was based on the absorption of linear components, circular dichroism produced an absorption differential between the left and right handed circular polarizations. It was found that circularly or elliptically polarized light were produced from circularly dichroic materials. The circular and linear dichroism are natural ways to control polarized light are based on weak wave interactions. It was found that a variety of polarization states in the reflection spectrum, ranging from pure linearly dichroism behavior to pure circularly dichroism quarter wave plate behavior. The chiral metascreen based on graphene was its reconfigurable frequency response allowed to tune the polarization of the reflected wave to the desired state by varying the Fermi levels. The optical polarization control method was passive and low profile so the device integration at subwavelength scale was achieved. These practical bounds was taken into account the electromagnetic meta surfaces have been an efficient polarization control. The meta surfaces have been fabricated at microwave terahertz and optical frequencies for various applications ranging from perfect absorbers to sensors, thermal emitters and imaging devices. The geometrical chirality rendered a dichroic structure was obtained by etching mirror asymmetric unit cell on the graphene monolayer such that the structure supported the surface plasmon pair when interfaced with a dielectric material. The obtained results were found in good agreement with previously obtained results.

**KEYWORDS** Dichroism, Polarization, Absorption, Transmission, Optical Activity, Microwave, Chirality.

**How to cite this article:** Suman S.K. and Kumar A. (2024). Characteristics Feature of Tunable Linear and Circular Dichroism for Applications in Sensing and Imaging. *Bulletin of Pure and Applied Sciences- Physics,* 43D (2), 14-18.

## INTRODUCTION

Hetch [1] studied dichroic herapathite crystal which was used in Polaroid sheets. Laurence and Barron [2] studied circular and linear dichroism and were used as control polarized light and were based on weak wave interactions. Muhammad Amin et al. [3], Alexander et al. [4] and Zhao et al. [5] studied for efficient polarization control in the case of electromagnetic metasurfaces. Amin et al. [6-7] studied that metasurfaces were essential for near diffraction limit imaging and wide range beam screening applications. The thin film metasurfaces were designed for using metallic radiating elements for manipulation of electromagnetic waves [8-10]. Verbiest et al. [11] studied that linearly polarized incident waves were converted to cross or circularly polarized scattered waves depending on the dispersion relation. Zhijie et al. [12] and Zuojia wang [13] presented that the optical activity was derived from resonant unit cells and was extended the chiral meta surface designed that operated over broadband spectra into the microwave and optical regimes. Amin et al. [14-15] studied the dynamic control of the operating frequencies with tunable electromagnetic materials. Zhan Cheng et al. [16], Junyang Zhao [17] and Hunag Jiang [18] presented artificial materials, graphene based structures have been examined the properties and found that graphene was a natural condenser for tunable metasurfaces and for the variation of electrical properties directly by controlling the electric potential [19]. Vinit et al. [20] and Tianjing et al. [21] studied graphene based tunable cross polarizers to transform incident polarization to cross polarized fields. Khalji et al. [22] studied that in graphene nanoribbons offered measureable dips in extinction of the vibrational modes of molecules. Indra et al. [23] and Pedroti et al. [24] presented that many traditional polarization control systems employed either birefringent crystals or Faraday rotators to change the state of the electric field orientation. Daud Khan et al. [25], Rahman et al. [26] and Meraj et al. [27] presented the designation at microwave terahertz and optical frequencies for various applications ranging from perfect absorbers to sensors [28] and thermal emitters and imaging devices [29-30]. The transverse electromagnetic nature allowed light waves was characterized in terms of orientation of the associated electric field vectors of polarization.

## METHOD

The unit cell designed was based on chirality and leaded to highly symmetric radiations from the plasmon polariton surface currents leaded to the linear and circular dichroism. Due to interband transitions at infrared and optical frequencies which increased the losses due to the fixed value of the plasma frequency. The use of semiconductors such as transparent conductive oxides or metal nitrides to design tunable optical devices in the near infrared and infrared ranges. The graphene based tunable chiral metasurfaces have the potential to enhance capabilities of existing optical sensing and spectroscopic techniques. Exploiting the chirality graphene based terahertz sensors was improved in order to detect the dielectric properties of anisotropic materials. The surface plasmon modes in graphene based terahertz spectroscopy were found suitable for detection of the vibrational modes of molecules. Polarization state detection provided a sensitive to the existing surface plasmon method. The structures were found tunable leading to a broadband chiral response which is a desirable property in spectroscopic applications. We have presented a design of circularly chiral reflecting metasurfaces based on existing the surface plasmon polariton resonances on the graphene dielectric interface. The interface between the graphene and the dielectric supports the formation of surface plasmon polaritons on the graphene monolayer that propagated as surface waves in the $x-y$ plane. The diagonal symmetry of the unit cell allowed the production of helicoidal fields leaded to optical activity. A unique feature of the dichroic response that was due to the diagonally symmetric shape of the unit cell. The frequency dependent complex permittivity $\in_g$ of graphene was determined by the surface conductivity $\sigma_g$.

$$\varepsilon_g(\omega) = 1 + \frac{j\sigma_g(\omega)}{\varepsilon_0 \omega \Delta}$$

where $\in_0$ is the free space permittivity, $\omega$ is the angular frequency and $\Delta = 1$nm is the thickness of the graphene layer. The surface conductivity of graphene $\sigma_g$ was calculated from Kubo's formula. The conductivity was modeled by electron-hole pair excitations due to contributions from inter and intraband transitions within the graphene layer. At low frequencies interband transitions were negligible and the conductivity was due to interband transitions as

$$\sigma_g(w) = \frac{ie_0^2 k_B T}{\pi\hbar(\hbar\omega + i\Gamma)} \left\{ \frac{\mu_c}{k_B T} + 2\log.\left[\exp\left(-\frac{\mu_c}{k_B T}\right) + 1\right] \right\}$$

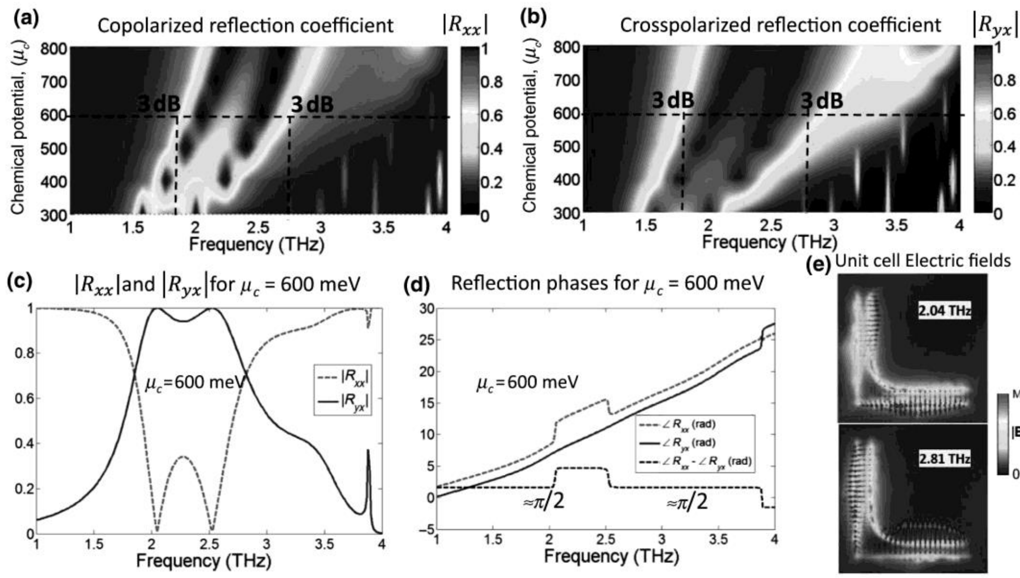
where $k_B$ is the Boltmann constant,$T$ is the temperature, $e_0$ is the electron charge, $\hbar$ is the reduced Plank's constant, $\Gamma$ is the damping coefficient and $\mu_c$ is the chemical potential of the graphene layer. The chemical potential was varied by chemical doping. The damping coefficient $\Gamma$ was calculated by the relation

$$\Gamma = -\frac{(e_0\hbar)\upsilon_f^2}{\mu\mu_c}.$$

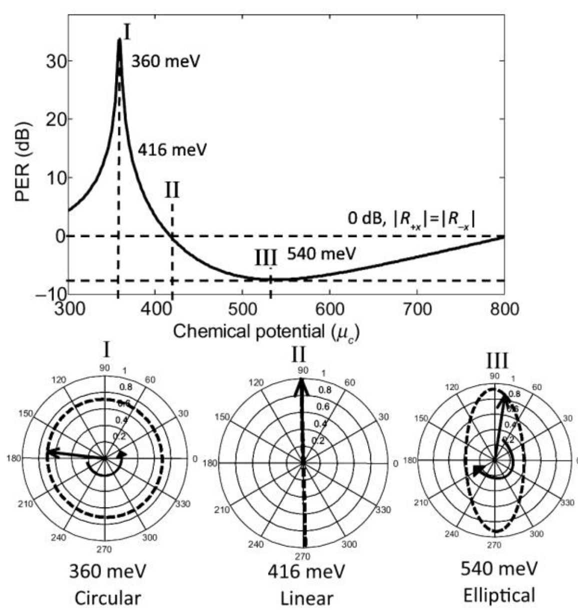
where $\upsilon_f = 10^6$ m/s and $\mu = 100{,}000 cm^2/Vs$ are the Fermi velocity and the electron mobility.

## RESULTS AND DISCUSSION

The study of characteristics feature of tunable linear and circular dichroism for the application in sensing and imaging was made. In this study the metascreen design consisted of periodically etched of different shapes on a graphene substrate backed by a conductive plane. The unit cell was designed based on chirality and leaded to highly asymmetric radiation. Graph (1)(a) and (1)(b) show the plot of resulting reflection coefficients as surface intensity over a wide range of terahertz spectrum. It was found that when the chemical potential was increased a shift in the meta-layer's resonance was present, which was consistent with the direct relation between graphene's Fermi level and the plasma resonances. The high optical activity in the region between the half power points indicated reflectance surface plots as shown in graph (1) at the 600 meV potential threshold. In this region considerable reflected power was carried by the y-polarized wave. Graph (1) (c) and (1) (d) show the magnitude and phase of the reflection coefficients were extracted for a chemical potential. A broad band region of high cross polarization conversion was observed between 1.94 and 2.68 terahertz. The incident fields were purely x-polarized the 100% y-polarized reflectance at some frequencies satisfied the half wave plate condition. Graph (2) shows the plot of the tenability variation of the polarization states as the chemical potential of the chiral graphene metasurfaces. The real strength of graphene metascreen was its property of reconfigurability which allowed the optical spectrum was optically tuned. We have shown this property by varying the chemical potential of the graphene monolayer from 300 to 800 meV with the frequency fixed at 2.25 terahertz. This plot is shown in graph (2) which indicated the polarization state changed from circular for a 360 meV bias to linear at about 416 meV and then to elliptical at 540 meV. The reconfigurable graphene chiral monolayer was potentially exploited in several optical devices such as optical displayes, polarizers, radiating elements and communication devices. The results obtained were compared with previously obtained results of theoretical and experimental research works and were found in good agreement.




**Graph 1:** Plot of reflection coefficient as surface intensity over wide range of spectrum.




**Graph 2:** Plot of tunablity variation of the polarizations states as the chemical potential of chiral graphene Meta surface.

## CONCLUSION

We have presented the characteristic features of tunable linear and circular dichroism for application in sensors and imaging and spectroscopy at terahertz frequencies. The unit cell designed so that were based on chirality and leaded to highly asymmetric radiations from the plasmon polariton surface currents in the case of linear and circular dichroism. We have found variety of polarization states in the reflection spectrum, ranging from the pure linearly dichroism behavior to pure circularly dichroism quarter wave plate behavior. The graphene metascreen converted the linear states to elliptical polarization states. The metascreen reflection was found angularly stable between 0° and 45°. The ultra compact unit all having size $\frac{\lambda}{15}$ was found suitable for device integration in sensing, imaging and spectroscopy applications at terahertz frequencies. Circularly polarized electric fields were effectively absorbed by the metasurface in different proportions. We have demonstrated through full wave simulations in which dichroic metascreen supported perfect linear to circular polarization conversion in two adjacent terahertz frequency bands. The obtained results were found in good agreement with previous obtained results.

**REFERENCES**


[1] Hecht. H, (2017), Optics, (Pearson, London, England) 5th ed.

[2] Laurance. D, Barron, (2009), Molecular Light scattering and Optical Activity (Cambridge University Press, Cambridge, England).

[3] Muhammad Amin and Adnan. D. Khan, (2015), J. Phys. Chem. C, 119, 21633.

[4] Alexander. Zhu. Y, Ting. Chen. Wei, Zaidi. Auu, Huang. Yao. Wei etal (2018), Light. Sci. Appl. 7, 17158.

[5] Zhao. Yizhe etal, (2018), Sci. Rep, 8, 1729.

[6] Amin. M, Siddiqui. O, etal, (2018), Phys. Rev. Appl. 10, 064030.

[7] Amin. M, Siddiqui. O, Farhat. Mohamed and Khelif. A, (2018), J. Appl. Phys. 123, 144502.

[8] Rogachev. A. V, Fedotov. V. A, Schwanecke and Zheludev. N. I, (2006), Phys. Rev. Lett. 97, 177401.

[9] Justyna. K, etal, (2009), Science, 325, 1513.

[10] Tretyakov. Sergei etal, (2003), J. Electromagnet Waves. Appl. 17, 695.

[11] Verbiest. Thierry, Koeckel Berghs and Champagne. Benoit, (2014), Opt. Mater. Express 4, 2663.

[12] Zhijie Ma Yi Li, Yang Li Yandong Gong, Stefan A. Maier and Hung. Minghui (2018), Opt. Express, 26, 6067.

[13] Wang. Zuojia, Cheng. Feng, Winsor Thomas and Liu. Yongmin, (2016), Nanotechnology 27, 412001.

[14] Amin. Muhammad, Farhat. Mohammad and Bagci. Hakan, (2013), Opt. Express. 21, 29938.

[15] Amin. M etal (2013), Sci. Rep. 3, 2105.

[16] Zhan Cheng Li, Wenwei Li, Cheng. Hua, Chen Shuqi and Tian. Jianguo, (2016), Opt. Lett. 41, 3142.

[17] Zhao. Jungang etal, (2016), J. Opt., 18, 095001.

[18] Jiang. Huan, Zao. Wenyu and Yongyuan, (2017), Opt. Express, 25, 19732.

[19] Koppers. Frank. H. L, Chang. Darrick. E and Garcia. De Abajo., F. Javier, (2011), Nano. Lett. 11, 3370.

[20] Yadav Vinit Singh, Gosh Sambit Kumar, Bhatacharya Somek and Das Santanu, (2018), Appl. Opt. 57, 8720.

[21] Guo. Tianjing and Argyropoulos. Christos, (2016), Opt. Lett. 41, 5592.

[22] Kaliji Kaveh. Etal, (2020), Phys. Rev. Appl. 13, 011002.

[23] Reddy Indra. K and Mehvar. Reza, (2004), Chirality in Drug. Design and Development (CRC Press, Florida, U.S.)

[24] Pedrotti. F, Pedrotti. L and Pedrotti. L, (2014), Introduction to Optics (Pearson, London, England), 3rd ed.

[25] Khan. Andan Daud, and Amin Muhammad, (2017), Plasmonics, R, 257.

[26] Ramzan Reshad etal, (2018), IEEE Access. 6, 77859.

[27] Mustafa. Meraj. E, Tahir. Farooq. A, Amin M and Siddiqui. O, (2018), J. Appl. Phys. 124, 146101.

[28] Amin Muhammad, Farhat. Mohamed and Bagci Hakan, (2014), Opt. Express. 22, 6966.

[29] Tittl. Andrees, Kartin. Ann, Michel U, Schaferleng. Martin etal, (2015), Adv. Mater. 27, 4597.

[30] Yao. Wei etal (2018), IEEE Photonics. J. 10, 1.