[1]S.V.Tayade
[2]S.A.Waghuley

"Study on Shielding Effectiveness and Efficiency of Polyaniline/CuO composites in the UV Region of the Electromagnetic Spectrum"

Journal of Electrical Systems

Abstract: - This study investigates the synthesis, structural characterization, and electromagnetic interference (EMI) shielding effectiveness of polyaniline (PANI)/copper oxide (CuO) nanocomposites in the ultraviolet (UV) region of the electromagnetic spectrum. The composites were synthesized via an ex-situ approach by incorporating varying weight percentages (1–3 wt%) of CuO into the PANI matrix. X-ray diffraction (XRD) analysis confirmed the semi-crystalline nature of PANI and the structural purity of CuO, with enhanced crystallinity observed in the composites. UV-Vis spectroscopy revealed characteristic π–π* transitions in PANI and additional absorption features associated with CuO, along with a red shift indicating strong interfacial interaction. The UV shielding effectiveness (SE) and shielding efficiency were evaluated in the frequency range of 789.4–882.3 THz. All samples demonstrated excellent EMI shielding performance, with efficiencies exceeding 95%. Samples with 2 wt% and 3 wt% CuO exhibited the highest shielding efficiencies of up to 99.7%, attributed primarily to absorption-dominated mechanisms. These findings highlight the potential of PANI/CuO nanocomposites as efficient, lightweight materials for UV-region EMI shielding applications.

Keywords: Electromagnetic Interference (EMI), Polyaniline; Copper Oxide; Shielding Effectiveness, shielding Efficiency

I. INTRODUCTION

Electromagnetic Interference (EMI) Shielding:

Electromagnetic interference (EMI) shielding is a crucial technique employed to protect electronic devices from external electromagnetic fields that can disrupt their normal operation [1]. Beyond safeguarding electronic equipment, EMI shielding also plays a significant role in human health by reducing exposure to electromagnetic fields (EMFs), which have been associated with various health concerns. Prolonged exposure to certain levels of EMFs has been linked to issues such as headaches, sleep disturbances, and, in some studies, potential correlations with cancer [2]. Common sources of EMFs include mobile phones, Wi-Fi routers, power lines, and household appliances [3].

EMI shielding mitigates exposure by preventing electromagnetic waves from penetrating or transmitting through materials. This is achieved through three primary mechanisms: absorption, reflection, and rerouting [4]. By incorporating advanced materials with high electrical conductivity and dielectric properties, such as conducting polymers and metal oxides, the efficiency of shielding can be significantly enhanced, making it vital for both technological applications and public health protection.

In this paper we are focussing on the shielding of UV lights from the electromagnetic spectrum which has wide application with respect to the human health. The main source of natural ultraviolet radiation is the sun. In addition to solar UV radiation, there are a variety of artificial sources of UV light. These sources are widely used in some occupational, medical, and recreational settings. The most common artificial sources of UV radiation are arc-lamps, and fluorescent or incandescent lighting [7]. Devices that emit ultraviolet (UV) radiation include UV lamps, sterilization units, UV-integrated electronic gadgets, portable UV-C tools, and UV LEDs, which are widely utilized for disinfection, illumination, and various industrial applications. Exposure to UV radiation, particularly UV-C and UV-B, can lead to serious health concerns such as skin burns, eye damage, and suppression of the immune response. Prolonged or excessive UV exposure has been linked to a range of health problems in humans, including skin cancer, cataracts, and compromised immune function. Ultraviolet light, especially in high doses, can result in harmful effects such as skin and eye injuries, DNA damage, heightened sensitivity to light, and long-term conditions like cancer and immune-related disorders [5]. The effects of UVA and UVB radiation on organisms range from erythema formation, through tanning and

[1]* Suraj. V. Tayade ,
Research student,
Department of Physics, Sant Gadge Baba Amravati University, Amravati 444602,
[2]S.A.Waghuley,
Professor and Head
Department of Physics, Sant Gadge Baba Amravati University, Amravati 444602,
Copyright©JES2024on-line:journal.esrgroups.org

reduced synthesis of macromolecules such as collagen and elastin, to carcinogenic DNA mutations. Some studies suggest that, in addition to the radiation emitted by the sun, artificial sources of radiation, such as commercial lamps, can also generate small amounts of UVA and UVB radiation. Depending on the source intensity and on the distance from the source, this radiation can be harmful to photosensitive individuals [6]. One of the most important drawbacks of classical and new advanced functional materials for applications outdoors, or in environments with high UV irradiation, is the light induced damage that reduces drastically their effective operation lifetime or durability. This makes protecting light sensitive materials against UV irradiation a nowadays important technological demand in almost every industrial field [7].

Now, a day polymer research is exploring the synergetic outcome of nano reinforcement in improving the range of properties of polymers. Carbon derivatives, among various nano reinforcement, shows a potential substitute for reinforcing polymers due to its exceptional mechanical properties, heat resistance, low density, high aspect ratio and high surface area. The properties of carbon derivatives based nanocomposites robustly depend on the dispersal state of carbon derivatives in polymer matrix and on the interfacial interface between carbon derivatives and polymer [8-10]. However, in the present work we studied the morphology, and Electromagnetic Interference shielding effectiveness, efficiency of PANI/CuO nanocomposites in UV Region of electromagnetic spectrum.

II. METHODOLOGY

Materials:

The chemicals required for the synthesis were aniline ($C_6H_5NH_2$), ammonium persulfate [$(NH_4)_2S_2O_8$], hydrochloric acid (HCl), acetone, and copper oxide (CuO). Distilled water was used throughout the synthesis process.

Synthesis:

Synthesis of Polyaniline: Monomer Aniline of 10 ml was taken and dissolved in 150 ml HCl solution in a beaker. This solution is kept on the magnetic stirrer. Then another solution was made of 10 gm of ammonium persulfate which was dissolved in 50 ml Double distilled water and this solution is added to aniline solution drop wise. For the proper mixing of chemicals in the solution, ammonium persulfate is added in drop wise. After 5 hours of stirring process, diamond green solution was formed. The whole reaction system was kept still at temperature of 25ºCto 30ºC. Then the stirred solution was filtered, and the obtained product was washed by double distilled water. The resulting polyaniline was dried in a vacuum oven at 40°C, yielding Polyaniline powder.

Synthesis of Polyaniline- CuO Nanocomposite: The composites between CuO and PANI were prepared by ex situ approach. The different composites were prepared by altering the wt% of CuO in PANI , with an interval 1 wt% as 1wt%(S1), 2wt%(S2), & 3wt%(S3), Both these chemicals were mixed in the presence of organic media that is acetone.

III. RESULTS AND DISCUSSION

*A. **XRD Analysis***

The X-ray diffraction (XRD) patterns of copper oxide (CuO) and polyaniline (PANI) were recorded using an X-ray diffractometer. **Figure 1** presents the XRD patterns of pure PANI and CuO. The characteristic diffraction peaks of CuO observed at $2\theta \approx 36°$ and 38° confirm its structural purity, as no additional impurity peaks are detected. In contrast, the XRD pattern of PANI exhibits a broad hump in the 2θ range of 20°–30°, indicating its predominantly amorphous nature. However, the presence of sharp peaks superimposed on the broad hump suggests an enhancement in the degree of crystallinity. This increased crystallinity contributes to a rougher surface morphology and is quantitatively expressed in terms of the degree of crystallinity, which reflects the proportion of crystalline regions within the material [14].

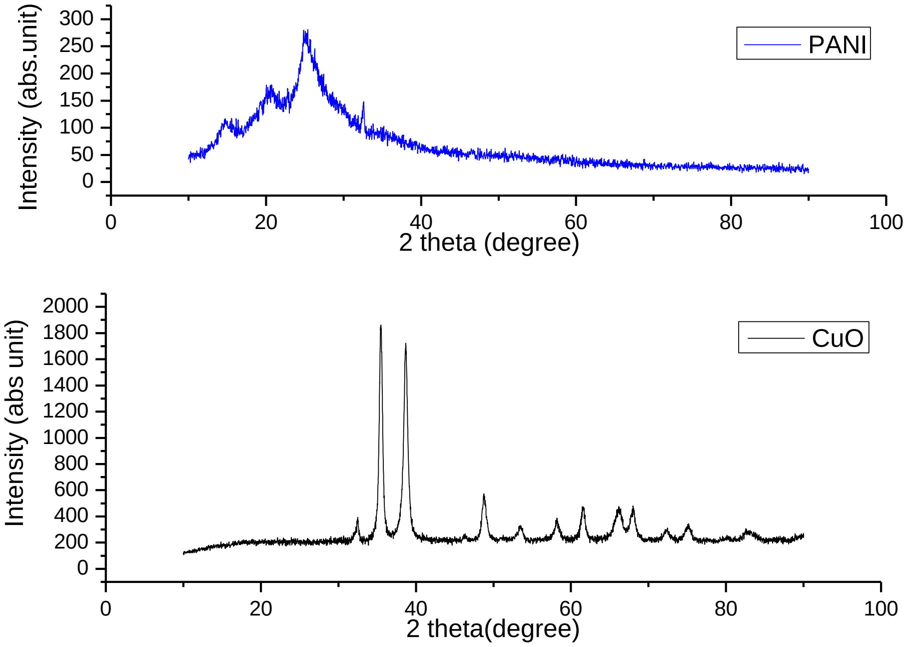

Figure 1. Xrd pattern of CuO and PANI

B. *UV absorption analysis*

Figure 2 presents the UV-Vis absorption spectra of PANI matrices incorporated with varying CuO content (1–3 wt%, in 1 wt% intervals), recorded in the wavelength range of 200–600 nm. The absorption coefficient shows a nearly linear increase in the 400–600 nm region. Broad absorption peaks observed in the 200–300 nm range are attributed to π–π* transitions within the polymer matrix, consistent with previous reports [12]. Additionally, increased absorption is noted in the 350–430 nm range, which is indicative of CuO incorporation. A slight red shift (towards lower energy) in the characteristic peaks of both PANI and CuO is observed, suggesting possible interaction or electronic coupling between the two phases [13].

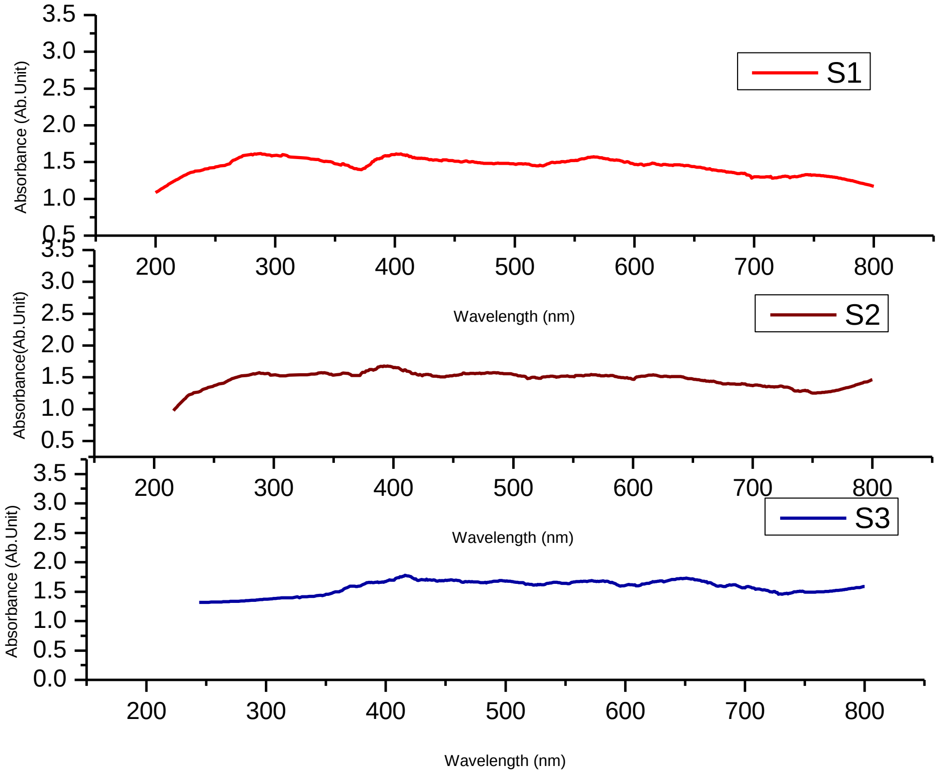

Figure 2: UV Absorption Spectra.

C. Shielding Effectiveness:

Electromagnetic Interference Shielding Effectiveness:

Electromagnetic interference shielding effectiveness (SE) refers to the attenuation of electromagnetic (EM) waves achieved through the use of shielding materials. Absorption serves as the primary mechanism, while reflection acts as a secondary mechanism [11]. multiple internal reflections (SEM) mechanism can be neglected if shielding effectiveness due to absorption(SEA) is greater than 10 dB [8].

Measure Absorbance(A): This is related to how much UV light is absorbed by the nanomaterial. It's often calculated as equation 1.[12].

$A = -\log(T)$ …………………………………… (1)

Higher absorbance values indicate better shielding effectiveness. To express shielding effectiveness as a percentage, it's usually directly represented by the absorbance value itself describe in equation 2:

Shielding Effectiveness $\approx A$……………………… (2)

(when expressed as a percentage)

To express shielding effectiveness in decibels (dB), need to convert the absorbance or transmittance into a decibel scale. Shielding effectiveness in dB quantifies how well a material blocks UV light, and it is commonly used in various fields to describe attenuation. It is given by equation 3.

Shielding Effectiveness SE (dB)$=10\times A$ (dB)………(3)

Figure 3 shows the shielding effectiveness (SE) of the PANI/CuO nanocomposites measured in the frequency range of 789.4–882.3 THz. The SE exhibits an increasing trend with increasing wavelength, which aligns with the inverse relationship between frequency and wavelength. As the CuO content increases from 1 wt% to 3 wt%, an overall enhancement in SE is observed. Among the samples, S2 (2 wt%) and S1 (1 wt%) demonstrate relatively higher shielding effectiveness compared to S3 (3 wt%). This variation may be attributed to the optimal dispersion and interaction of CuO within the PANI matrix at lower concentrations. The overall SE is primarily governed by absorption mechanisms, rather than reflection, indicating efficient electromagnetic energy dissipation within the material.

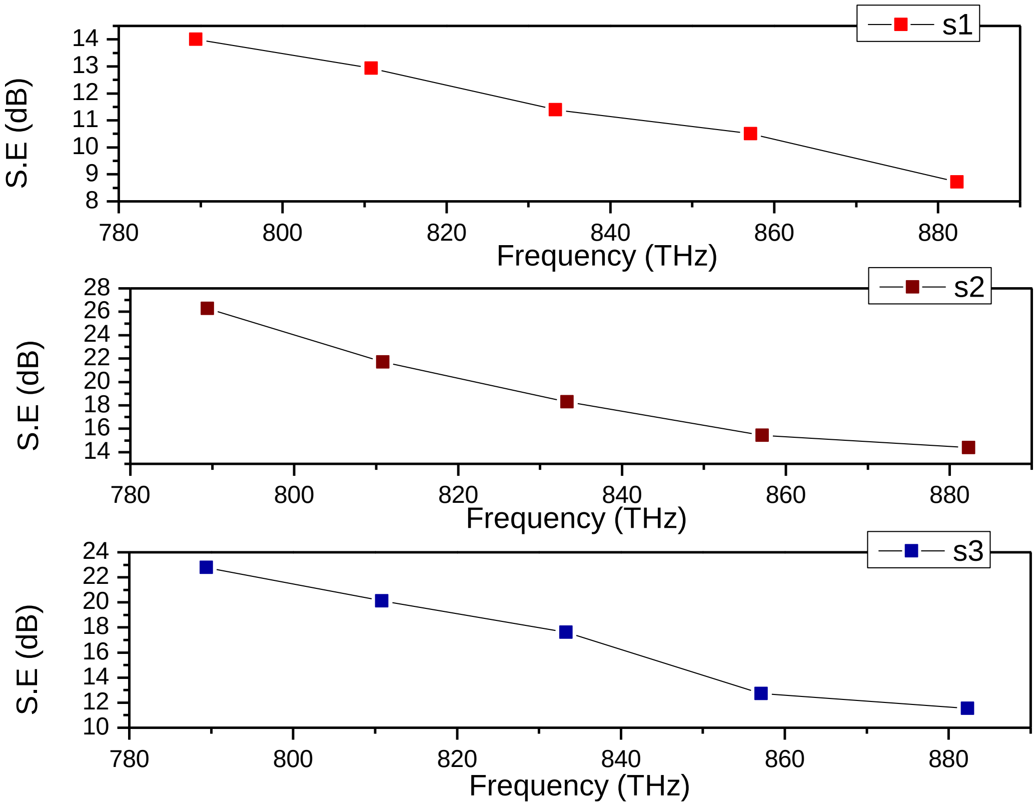

Figure 3: Shielding Effectiveness.

D. Shielding Efficiency

When calculating shielding effectiveness (SE) in the context of ultraviolet (UV) absorption, it is typically dealing with the **power** rather than the **field.**

The formula for Shielding Efficiency (as a percentage) is:

$\eta=(1-1/10^{SE/10})\times 100\%$

Figure 4 illustrates the shielding efficiency of samples S1, S2, and S3. All samples exhibit shielding efficiency above 95%, which is considered excellent for electromagnetic interference (EMI) shielding applications. Notably, samples S2 and S3 demonstrate even higher efficiencies of up to 99.4% and 99.7%, respectively, highlighting the significant potential of these materials for high-performance EMI shielding.

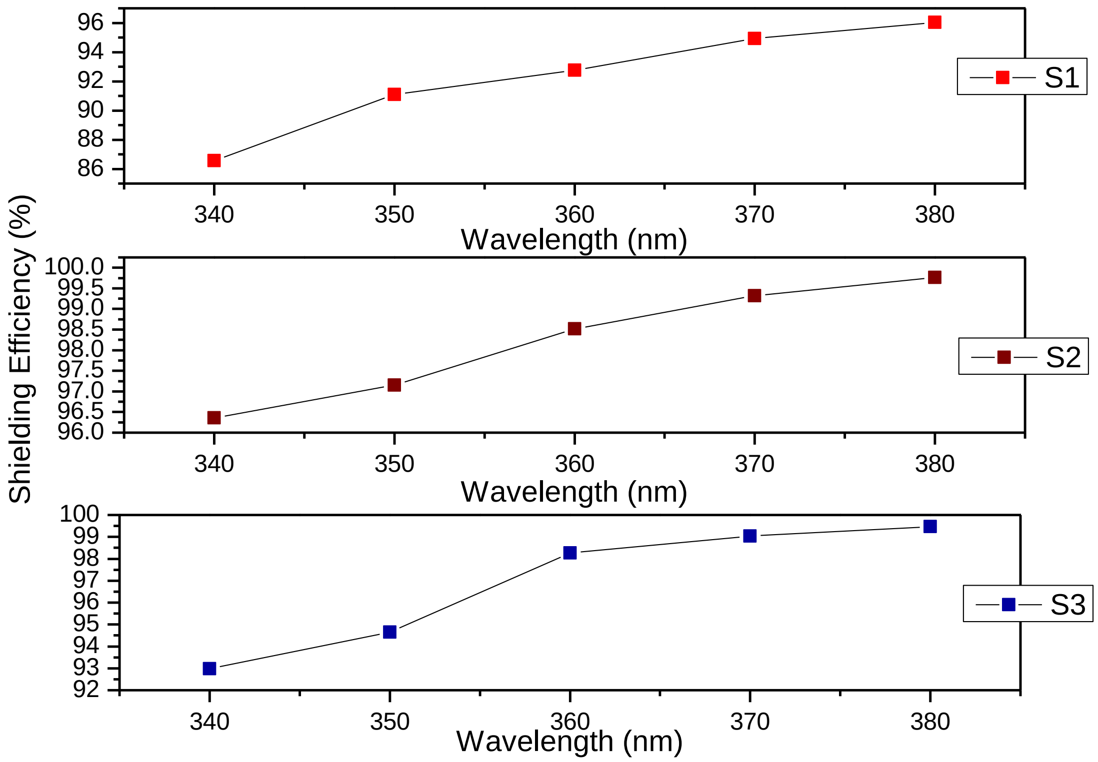

Figure 4: Shielding Efficiency.

IV. Conclusion

The structural, optical, and shielding properties of PANI/CuO nanocomposites were thoroughly investigated. XRD analysis confirmed the structural purity of CuO and the semi-crystalline nature of PANI, with enhanced crystallinity upon composite formation. UV-Vis spectroscopy revealed characteristic π–π* transitions in PANI and additional absorption features associated with CuO, along with a slight red shift indicating strong interaction between the two components. The shielding effectiveness (SE) of the composites, measured in the frequency range of 789.4–882.3 THz, showed excellent performance across all samples, with shielding efficiency values exceeding 95%. Notably, samples S2 and S3 displayed the highest shielding efficiencies of up to 99.7%, primarily driven by absorption-dominated mechanisms. These results highlight the strong potential of PANI/CuO nanocomposites as effective materials for electromagnetic interference (EMI) shielding applications. The results indicated that the absorption mechanism predominates, highlighting the potential of PANI/CuO nanocomposite as lightweight materials for EMI shielding applications.

Acknowledgment

The authors express their heartfelt gratitude to Dr. K..R. Nemade, Assistant Professor, Department of Physics, Indira Mahavidyalaya, Kalamb, for his valuable assistance and guidance. The authors also extend their sincere thanks to mr. Pursing Rathod, Assistant Professor, Department of Physics, Padmashri Vikhe Patil College of Arts, Science, and Commerce, Parvanagar, for his constructive suggestions and support.

References

[1] Kumar, P., Narayan Maiti, U., Sikdar, A., Kumar Das, T., Kumar, A., &Sudarsan, V. (2019). Recent advances in polymer and polymer composites for electromagnetic interference shielding: review and future prospects. *Polymer Reviews*, *59*(4), 687-738.

[2] Chen, Y., Li, J., Li, T., Zhang, L., &Meng, F. (2021). Recent advances in graphene-based films for electromagnetic interference shielding: Review and future prospects. *Carbon*, *180*, 163-184.

[3] Nazir, A. (2022). A review of polyvinylidene fluoride (PVDF), polyurethane (PU), and polyaniline (PANI) composites-based materials for electromagnetic interference shielding. *Journal of Thermoplastic Composite Materials*, *35*(10), 1790-1810.

[4] Ganguly, S., Bhawal, P., Ravindren, R., & Das, N. C. (2018). Polymer nanocomposites for electromagnetic interference shielding: a review. *Journal of Nanoscience and Nanotechnology*, *18*(11), 7641-7669.

[5] Furukawa, J. Y., Martinez, R. M., Morocho- Jácome , A. L., Castillo-Gómez, T. S., Pereda-Contreras, V. J., Rosado, C., ... & Baby, A. R. (2021). Skin impacts from exposure to ultraviolet, visible, infrared, and artificial lights–a review. *Journal of Cosmetic and Laser Therapy*, *23*(1-2), 1-7.

[6] Romanhole, R. C., Ataide, J. A., Moriel, P., & Mazzola, P. G. (2015). Update on ultraviolet A and B radiation generated by the sun and artificial lamps and their effects on skin. *International journal of cosmetic science*, *37*(4), 366-370.

[7] Zayat, M., Garcia-Parejo, P., & Levy, D. (2007). Preventing UV-light damage of light sensitive materials using a highly protective UV-absorbing coating. *Chemical Society Reviews*, *36*(8), 1270-1281.

[8] Modak, P., &Nandanwar, D. (2021, May). Enhanced electromagnetic interference shielding effectiveness of carbon-based conducting polymer nanocomposites. In *Journal of Physics: Conference Series* (Vol. 1913, No. 1, p. 012054). IOP Publishing.

[9] Goriparthi, B. K., Naveen, P. N. E., Ravi Sankar, H., & Ghosh, S. (2019). Effect of functionalization and concentration of carbon nanotubes on mechanical, wear and fatigue behaviours of polyoxymethylene/carbon nanotube nanocomposites. *Bulletin of Materials Science*, *42*(3), 98.

[10] Sankar, N., Reddy, M. N., & Prasad, R. K. (2016). Carbon nanotubes dispersed polymer nanocomposites: mechanical, electrical, thermal properties and surface morphology. *Bulletin of Materials Science*, *39*, 47-55.

[11] .Lyu, L., Liu, J., Liu, H., Liu, C., Lu, Y., Sun, K., ... &Wujcik, E. K. (2018). An overview of electrically conductive polymer nanocomposites toward electromagnetic interference shielding. *Engineered Science*, *2*(59), 26-42.

[12] A. Kaushik, J. Kumar, M.K. Tiwari, R. Khan, B.D. Malhotra, V. Gupta, S.P. Singh, J. Nanosci. Nanotechnol. 8, 1757 (2008)

[13] Jundale, D. M., Navale, S. T., Khuspe, G. D., Dalavi, D. S., Patil, P. S., & Patil, V. B. (2013). Polyaniline–CuO hybrid nanocomposites: synthesis, structural, morphological, optical and electrical transport studies. *Journal of Materials Science: Materials in Electronics*, *24*, 3526-3535.

[14] S.V.Tayade, & S.A.Waghuley (2025). Exploring Polyaniline, Graphene and Copper Oxide for Electromagnetic Interference (EMI) Shielding in UV Region. *Adarsha Journal of Research and Evaluation (AJRE) ISSN:22773983,643-648.*