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Advancement in Polymer Blends and Composites: A Comprehensive Review of Structural, Optical, Thermal and Electrical Attributes for Multifaceted Applications

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Abstract: **-**The provided review article presents a comprehensive examination of the changing landscape within polymer blends and composites research. Encompassing a variety of investigations, this survey delves into the structural, optical, thermal, and electrical characteristics of these materials. A range of polymer matrices combined with diverse additives are studied to enhance specific traits for varied applications. Particularly noteworthy is the integration of nanoparticles, rare earth complexes, and other enhancers into polymers such as PMMA, PVC, PS, and PVDF, which significantly impact conductivity, luminescence, mechanical strength, and thermal resilience. Through methods spanning from solution casting to in-situ polymerization, the research highlights how customized doping techniques can introduce improved properties, opening new possibilities in fields like optoelectronics and materials science. Amid the extensive exploration of literature, numerous procedures for thin film sample preparation surface, emphasizing the strategic integration of appropriate materials as a promising approach to influence polymer characteristics. This revitalizes optical, thermal, and electrical attributes, spanning technical and biomedical applications.

Keywords: *Polymer thin film, Polymer blend, Doping, PS (Polystyrene), PMMA (Polymethyl methacrylate)*

1. Introduction

In the current era, polymers stand out as promising materials due to their affordability, ease of processing, lightweight nature, and feasibility in both thick and thin film sample fabrication. A particularly valuable attribute of polymers has been their ability to impede electrical conduction, serving as insulators. However, in this technologically advanced age, they have garnered significant attention as conductive polymers. The inherent process ability of polymers has positioned them as a focal point of interest. By blending and reinforcing polymers, it becomes possible to engineer materials with desired properties [31]. Polymer-based composites are extensively explored for both fundamental understanding and practical applications. These composites not only combine the beneficial characteristics of dopants and polymers but also introduce novel properties absent in single-phase materials. Introducing an appropriate dopant can substantially enhance the properties of a polymer [39].A polymer blend refers to a mixture of two or more polymers that are combined to yield a novel material with distinct physical properties. Various types of polymer blends exist, including thermoplastic blends, thermoplastic-rubber blends, thermoplastic-thermosetting blends, and rubber-thermosetting blends, all of which have undergone extensive investigation. The primary objective of polymer blending is to produce economically viable products with unique traits. Polymer blending is a vast and boundless field of study that demands comprehensive theoretical and experimental attention [19]. Numerous polymers that currently dominate the market fail to meet industry requirements. Therefore, significant efforts are directed toward enhancing polymer properties by incorporating additional components like fillers or other polymers. PMMA, renowned for its applications in glazing, boasts attributes such as stiffness, resistance to weathering, transparency, colorlessness, and high visible light transmission. Polystyrene (PS) offers toughness, resistance to radiation, solvents, heat, and flames. PMMA and PS find use in fabricating optical devices such as optical lenses and laser active mediums based on their optical properties [23].

Polymer thin films are assuming an increasingly pivotal role in the advancement of electronic devices, passivation coatings, chemical and electronic sensors, batteries, organic transistors, high-performance dielectrics, optical data storage and communication systems, and displays utilizing organic electroluminescent materials. It's widely acknowledged that the physical and chemical properties of a polymer can be controlled by introducing suitable dopants, significantly affecting their optical, thermal, and electrical characteristics [20]. Polymer composites exhibit a range of captivating optical properties, encompassing high/low refractive indices, tailored absorption/emission spectra, and potent optical nonlinearities. These exceptional properties position hybrids as promising candidates for potential optoelectronic applications [16].

2. Literature Review

Fenni S. E. et al. [1] conducted a comprehensive review on the nucleation and crystallization of semicrystalline polymer droplets in immiscible matrices, emphasizing the use of droplet dispersions and the "Turnbull number" to differentiate nucleation and growth kinetics, providing valuable insights into fundamental polymer nucleation mechanisms. Ismail A. S. et al. [2] blended epoxy with bio-phenolic materials (ranging from 5 to 25 wt %), leading to improved physical characteristics, dynamic properties, and thermal stability. Tests including density, void content, water absorption, FTIR analysis, DMA, and DSC were conducted, revealing enhanced properties with higher bio-phenolic content, showcasing potential cost-effective enhancements in polymer performance. Alshammari A. H. et al. [3] introduced PVC/PVP/$SrTiO_3$ nanocomposites, revealing enhanced thermal stability and notable improvements in optical properties including absorption, energy gap, and refractive indices, suggesting potential for optoelectronic applications. Tahir H. B. et al. [4] investigated H^+ ion transport and the impact of poly (2-ethyl-2-oxazoline) (POZ) on chitosan (CS) crystallinity, presenting a polymer blend electrolyte film for H^+ conduction with insights on structural changes and ion transport parameters. Bartkowiak A. et al. [5] examined mucoadhesive polymers, emphasizing the importance of careful polymer selection for effective mucoadhesion, with insights derived from rheometry, liquid penetration analysis, and texture analysis. Goodson A. et al. [6] aim to improve the efficiency and flexibility of thin films by doping Polystyrene (PS) matrices, with a focus on optical properties. The study analyzes absorption spectra and explores the influence of dopants on parameters like absorbance, transmittance, energy, absorption coefficient, extinction coefficient, and dielectric constant within the PS matrix. Kumar S. A. et al. [7] created a Polymer Blend (PB) using MEH-PPV and PMMA, modifying the MEH-PPV polymer chain size and shifting its emission color. PMMA's barrier properties enhanced PB stability, making it a potential candidate for use in Organic Light-Emitting Devices. Ugale A. et al. [8] synthesized organic rare earth complexes doped into PMMA and PS, resulting in strong orange/red emission. Absorption spectra analysis revealed distinct transitions, with red shifts observed in formic acid solvated films. These complexes demonstrate tunable emission potential for applications in OLEDs, flat panel displays, and solid-state lighting. Gil-Kowalczyk M. et al. [9] introduced hybrid materials using a PMMA matrix and lanthanide carboxylates (Eu:2,6-DClB and Tb:2,6-DClB) for potential use in optically active polymer-based optical fibers. The study encompassed thermal, mass spectroscopy, and optical evaluations, confirming the suitability of the material for fiber processing. Both lanthanide complexes exhibited robust luminescence, which remained strong after integration into PMMA, with minimal impact on thermal properties, facilitating further processing for optical fibers. Torab S. R. et al. [10] investigated the impact of irradiation on properties of PVA-EG blend films, finding increased gel fraction and micro-hardness with γ-ray doses up to 150 kGy and across all ion beam fluences, indicating crosslinking. Thermal behavior varied based on radiation type and dose, with distinct effects on thermal stability parameters, demonstrating diverse effects of different irradiation techniques.

Alsaad A. M. et al. [11] investigated optical, thermal, and lattice dynamical properties of ZnO nanoparticles doped into PMMA and PVA thin films. They determined optical characteristics, including band gap values, and identified bond vibrations using FTIR spectroscopy. The research highlighted the potential for creating high-tech devices with tailored optical, chemical, and thermal properties in doped polymerized films. Bataineh Al-Q. M. et al. [12] investigated nanocomposite thin films of PMMA blended with metal oxide nanoparticles (ZnO, CuO, TiO_2, SiO_2) and characterized them optically. The study highlighted decreased optical band-gap energy and improved thermal stability with the incorporation of metal oxide nanoparticles, indicating potential for efficient optoelectronic device fabrication. Abu Hassan Shaari H. et al. [13] enhanced the mechanical stability of PMMA by incorporating cost-effective conductive material, polyaniline (PANi). Blending PANi into PMMA improved dispersibility and overall properties, highlighting PANi's potential as a conductive material and providing insights into its integration with PMMA for enhanced conductivity. Zhang Y. et al. [14] focused on enhancing thermal and electrical stability in ferroelectric polymer capacitors, emphasizing the significance for modern electronics and hybrid vehicles. Their study on PVDF/PMMA blends, particularly PVDF/PMMA (80/20) ratio, demonstrated superior breakdown strength and lower conductivity at 70°C, achieving an impressive energy density of 4.82 J/cm^3, indicating promising prospects for high-energy-density dielectric materials. Haider A. J. et al. [15] investigated nanocomposite materials with TiO_2 nanoparticles and R6G dye in PS/PMMA blends (40% PS/60% PMMA and 50% PS/50% PMMA). Through UV-visible spectroscopy and SEM analysis, they assessed optical properties and observed optimized outcomes for the 50% PS/50% PMMA/TiO_2/R6G blend, indicating potential applications in optoelectronics. Al-Bataineh Q. M. et al. [16] introduced an optical model to analyze transmittance in PVC-PS hybrid films doped with silica nanoparticles, offering insights into optical bandgap correlations with film thickness. The study demonstrated enhanced transmittance, from 83% to 90%, upon silica nanoparticle incorporation, with potential applications in optoelectronics and photonics. Chitnis D. et al. [17] incorporated the red-light-emitting complex Eu (TTA) 3bipy with 2, 2′-bipyridine into PMMA and PS matrices, achieving enhanced photoluminescence intensity and consistent red emission, demonstrating potential for cost-effective fabrication of optoelectronic devices. Suhailath K. et al. [18] explored a conductive nanocomposite system of poly (butyl methacrylate) blended with neodymium-doped titanium dioxide, revealing enhanced conductivity with temperature and frequency, and highlighting the effectiveness of Mamunya's model in predicting conductivity. Hashim A. et al. [19] reviewed the [(PMMA)-PS] blend doped with nanoparticles, highlighting its diverse applications in fields like antibacterials, biosensors, electronics, and photovoltaics, emphasizing its versatility in environmental applications. Pandey N. et al. [20] incorporated TiO_2 dopants into PMMA thin films, observing a transition from amorphous to crystalline structure with increasing TiO_2 concentration, as revealed by XRD analysis. The crystallinity index ranged from 15.37% to 33.80%.

Bhadra J. et al. [21] investigated hydrochloric acid-doped polyaniline (PANI) blends with four different polymers, maintaining a constant PANI concentration. The study involved comprehensive characterization, confirming uniform blending of PANI with all polymers except PVC. PANI-PVA exhibited the highest conductivity (10^{-2} S/cm), while PANI-PVC showed the lowest (10^{-13} S/cm). Inamdar H. K. et al. [22] synthesized Polypyrrole/Cr_2O_3 nanocomposites through in-situ polymerization, incorporating varying percentages of Cr_2O_3 NPs. Characterization revealed nanocomposites with porous morphology, exhibiting significant DC conductivity increase with temperature. The nanocomposites also showed potential for commercial applications due to their near-white light emitting properties and band gap energies. Hameed N. J. et al. [23] investigated PS/PMMA blends with varying ratios, observing an increase in absorption spectra up to 50% PS/50% PMMA, leading to a shift towards longer wavelengths. An inverse relationship between energy gap and increasing PS ratio was noted, along with enhanced optical constants. Nagaraja S. et al. [24] synthesized PANI/PVDF composites with varying PVDF concentrations. The composites exhibited dielectric properties, including a frequency-dependent decrease in dielectric permittivity, followed by stabilization. Higher PVDF content led to increased dielectric permittivity, loss, and AC conductivity in the composites. Silva A. I. et al. [25] found that introducing a single efficient antenna ligand into a weakly luminescent europium complex significantly enhanced its luminescence. This approach led to a substantial increase in quantum efficiency compared to the original complex without the antenna ligand.

Al-Kadhemy M. F. H. et al. [26] studied the effects of gamma radiation on PMMA/PS blends at different concentrations. They examined optical properties including absorption coefficient, refractive index, and optical energy gap before and after irradiation, along with analyzing transmittance, absorbance, and reflectance spectra. Bhagat D. J. et al. [27] investigated polyindole/poly (vinyl acetate) composites, analyzing their ac conductivity, dielectric constant, and thermal properties. The composites demonstrated an ac conductivity of 1.88 x 10^{-6} S/cm at 373 K and underwent thorough analysis via microscopy, TG-DTA, DTG, and dielectric measurements. Manikandan K. M. et al. [28] developed a polymer electrolyte by incorporating nano Al_2O_3 into PMMA-LiBr via solution casting, significantly enhancing its conductivity. The highest room temperature conductivity, at 1.65479 x 10^{-7} S/cm, was achieved with 2.5% weight of Al_2O_3. The study employed impedance spectroscopy along with FTIR, XRD, and SEM for characterization. Ali U. et al. [29] provided a comprehensive overview of PMMA's fundamental properties and chemistry, emphasizing its recent applications in various fields like biomedicine, optics, solar technology, and more. The synthesis aims to broaden accessibility and understanding of these advancements. Puthiyottil R. et al. [30] synthesized and characterized europium-β-diketone chelate-doped poly (methyl methacrylate) (PMMA) and PMMA/poly (ethylene co-vinyl acetate) (EVA) blends. The study evaluated mechanical properties, thermal characteristics, and optical properties, indicating potential for optoelectronic device development with improved mechanical strength.

Meeta S. et al. [31] investigated MNA-doped Polystyrene/Polyvinyl chloride (PS/PVC) thin films using isothermal evaporation, focusing on the D.C. electrical conductivity of the samples. The study revealed conductivity values affected by the dopant in polyblend samples, exhibiting Arrhenius behavior within the studied temperature range. Vidhale S. G. et al. [32] synthesized Polystyrene (PS) and polymethyl methacrylate (PMMA) through solution polymerization. They created thin films of a 1:1 PS-PMMA blend, doping them with varying percentages of Salicylic Acid (SA) via isothermal evaporation. Measurements of AC conductivity and Dielectric Constant (εr) were conducted at different temperatures and frequencies, revealing a significant impact of IR radiation exposure. Prolonged exposure led to reduced AC Conductivity, while increased time resulted in a lower Dielectric Constant. Characterization via XRD, SEM, and FTIR offered insights into the samples' structural and compositional aspects. Puthiyottil R. et al. [33] investigated the doping of Europium complex (Eu $(C_{10}H_8N_2O_2)2(NO_3)3$) into poly (methyl methacrylate) (PMMA) matrix at various amounts (0.1-2 wt %). The resulting formulations underwent characterization using UV-visible spectroscopy, fluorescence spectroscopy, fluorescence lifetime analysis, X-ray diffraction, and infrared spectroscopy. Luminescent properties of the chelate-doped PMMA exhibited extended fluorescence lifetimes. The fluorescence lifetime of the composite changed with the chelate amount, indicating alterations in the microenvironment around the central metal ion. Optical properties also showed composition-dependent variations. The study provides insights into the structural and luminescent behavior of complex-doped PMMA composites, valuable for improved luminescent material development. Gibelli E. B. et al. [34] investigated the photoluminescence sensitization effect of the compound [Eu (tta) 3($DB_{18}C_6$)2(H_2O) 2] in a blend of poly (methyl methacrylate) (PMMA) and polyethylene glycol (PEG) in film form. Thermal analysis suggested an interaction of the $Eu3^+$-complex with the PMMA polymer, immobilizing it in the matrix. The luminescent behavior resembled that of the undoped polymer. Emission spectra of the $Eu3^+$-complex in the PMMA/PEG blends exhibited characteristic bands. The emission quantum efficiency of the doped films increased significantly, indicating an effective interaction between the complex and the matrix, enhancing the luminescence of the $Eu3^+$ ions through co-sensitization. Dwivedi Y. et al. [35] synthesized a Tb-doped polycarbonate: poly (methyl methacrylate) (Tb-PC: PMMA) blend with varying PC and PMMA proportions. Thermal and spectroscopic properties were analyzed using FTIR and DSC techniques. The blend with 10 wt% PC and 90 wt% PMMA exhibited improved miscibility. Optical properties of $Tb3^+$ ions were studied through UV-vis absorption and fluorescence excited by 355 nm radiation. The luminescence intensity of $Tb3^+$ ions was influenced by the PC: PMMA ratio and $Tb3^+$ concentration. Concentration quenching occurred for $TbCl_3{\cdot}6H_2O$ concentrations exceeding 4 wt%. The addition of salicylic acid to the blend enhanced $Tb3^+$ ion luminescence through non-radiative energy transfer from salicylic acid to $Tb3^+$ ions. Ahmed R. M. et al. [36] investigated transparent films from poly (methyl methacrylate)/poly (vinyl acetate) blends with varying concentrations via solution-casting. They analyzed FT-IR transmission spectra to assess the effect of UV radiation and conducted optical absorption measurements across a range of wavelengths. Changes in optical parameters, including band tail width and band gap energies, were studied before and after exposure to UV and filtered radiation. Refractive indices were calculated based on specular reflection and absorption spectra pre and post-exposure to UV and filtered radiation. Abd El-kader H. et al. [37] employed Differential Scanning Calorimetry (DSC) to investigate phase transitions in polyvinyl alcohol (PVA) doped with europium chloride ($EuCl_3$) and terbium chloride ($TbCl_3$). They examined dielectric properties, including dielectric constant and loss tangent, across a temperature range (1–100 kHz), revealing contributions from both dipolar and interfacial polarization. Parameters such as temperature coefficient of permittivity (TCP) and electrical dipole moment (m) were determined. Activation energy for glass relaxation was calculated based on dielectric loss tangent measurements. AC conductivity measurements at various temperatures and frequencies indicated a correlated barrier hopping (CBH) mechanism, with estimated parameters like hopping distance and barrier heights. Deshmukh S. H. et al. [38] investigated the electrical conductivity of polyaniline-doped polyvinyl chloride (PVC) and poly (methyl methacrylate) (PMMA) thin films. They analyzed I–V characteristics at various temperatures (323–363 K) and interpreted the results through Poole–Frenkel, Fowler–Nordheim, Schottky ln (J) vs T plots, Richardson, and Arrhenius plots, suggesting that Schottky and Richardson mechanisms primarily contribute to the observed conduction. Podgrabinski T. et al. [39] investigated the effects of diphenylsulfoxide (DS) doping on 1 µm thick films of polystyrene (PS) and polymethyl methacrylate (PMMA) prepared through spin-coating. The study found that DS doping reduced the glass transition temperature (Tg) of both films. Additionally, DS doping increased the relative permittivity in both films. The research also revealed differences in DS diffusion behavior between PS/DS and PMMA/DS films, with PMMA/DS exhibiting better thermal stability than PS/DS. Diaz-Garcia M. A. [40] focused on lasing properties of optically pumped polymer films, observing Amplified Spontaneous Emission (ASE) at around 400 nm in polystyrene (PS) and poly(N-vinylcarbazole) (PVK) films doped with up to 20% N, N'-bis(3-methylphenyl)-N, N'-diphenylbenzidine (TPD). TPD-based films hold potential for blue-emitting organic diode lasers. The study also explored energy transfer in PVK films doped with europium and samarium complexes, as well as PS films with specific compounds showing energy transfer to europium complexes, making them suitable for light-emitting diodes.

3. Concise Summary of Literature Review

Authors	Research Focus	Techniques used	Key findings
Fenni S. E. et al. [1]	Nucleation and crystallization of polymer droplets	Droplet dispersions, Turnbull number	Turnbull number distinguishes nucleation and growth effects. Self-nucleation and interfacial effects explored. Comprehensive grasp of polymer nucleation mechanisms.
Ismail A. S. et al. [2]	Blending epoxy and bio-phenolic polymer resins	Density assessment, FTIR, DMA, DSC	Bio-phenolic blending (5-25 wt %) with epoxy enhances physical properties. Improved thermal stability.
Alshammari A. H. et al. [3]	PVC/PVP/$SrTiO_3$ polymer blend nanocomposites	XRD, FTIR, Raman spectroscopy, TGA	Enhanced thermal stability. Improved optical properties. Fluorescence at 485 nm for potential optoelectronic applications.
Tahir H. B. et al. [4]	H^+ ion transport and influence of POZ on CS crystallinity	XRD, electrical impedance, FTIR	Reduction in crystallinity observed. Highest conductivity at 30% NH_4NO_3 concentration. Valuable insights for ion transport applications.
Bartkowiak A. et al. [5]	Mucoadhesive polymers and polymer blends	Rheometry, penetration analysis	Blends with Carbopol 974P NF or Noveon AA-1 exhibit stronger adhesion. Careful polymer selection crucial for effective mucoadhesion.
Goodson A. et	Minimizing	Incorporating	Dopants impact optical properties:

al. [6]	electronics size for thinner, lighter devices	dopants into Polystyrene (PS) matrix, Absorption spectra analysis	absorbance, transmittance, energy, absorption & extinction coefficients, and dielectric constant in PS matrix.
Kumar S. A. et al. [7]	Formulating a Polymer Blend (PB) for Organic Light-Emitting Devices	In situ polymerization of MEH-PPV and PMMA, Stability analysis	Modified MEH-PPV chain size, shift in emission color from red-orange to bluish-green. PMMA contributes to PB stability. Potential for Organic LED applications.
Ugale A. et al. [8]	Synthesis and study of organic rare earth complexes doped in PMMA & PS	Photoluminescence and absorption spectra analysis, Energy band gap determination	Strong orange/red emission in PL spectra, tunable emission potential for OLEDs and displays highlighted.
Gil-KowalczykM. et al. [9]	Hybrid materials for optically active polymer-based optical fibers	Thermal, mass spectroscopy, and optical characterizations, Luminescence study	Lanthanide complexes exhibit strong luminescence, minimal effect on thermal properties for fiber processing.
Torab S. R. et al. [10]	Effects of irradiation on PVA-EG blend films	Irradiation effects on gel fraction, micro-hardness, and thermal behavior	Gel fraction and micro-hardness increase with γ-ray doses and ion beam fluences, varied thermal behavior depending on radiation type and dose. Various effects of different irradiation techniques observed.
Bataineh Al-Q. M. et al. [12]	Nanocomposite thin films with metal oxide nanoparticles	Dip-coating, SEM, Transmittance and reflectance analysis, FTIR, TGA	Metal oxide nanoparticles enhance optical, thermal properties. Q-functional model for accurate band-gap evaluation. Improved thermal stability. Potential for optoelectronic devices.
Abu Hassan Shaari H. et al. [13]	Mechanical stability of PMMA blended with PANi	Blending PANi into PMMA, Improved mechanical properties, FTIR	PMMA enhances PANi properties. PANi's suitability as a conductive material. Focus on integration methods for enhanced conductivity. Insights into copolymer preparation.
Zhang Y. et al. [14]	Stability of energy density in ferroelectric polymer capacitors	PVDF/PMMA blends, Breakdown strength, Electrical conductivity, Energy density	PVDF/PMMA (80/20) blend achieves high breakdown strength and energy density. Promising for stable energy density at elevated temperatures. Future potential for electronic advancements.
Haider A. J. et al. [15]	Nanocomposite materials with TiO_2 nanoparticles and R6G dye	Casting method, UV-visible spectroscopy, SEM, Optical properties analysis	50% PS/50% PMMA/TiO_2/R6G blend showcases uniform distribution and TiO_2 nanoparticle porosity. Optical properties vary with PS ratio. Emission shifts observed in photoluminescence spectra.
Al-Bataineh Q. M. et al. [16]	Optical model for PVC-PS hybrid films doped with silica nanoparticles	Dip-coating, XRD, SEM	Innovative model correlates optical bandgap and film thickness. Silica doping enhances transmittance, vital for optoelectronic applications.
Chitnis D. et al. [17]	Synthesis of red-light-emitting complex	UV-visible absorption, PL	Blended films exhibit consistent red emission. Enhanced PL intensity in doped films. Potential for cost-effective

	Eu(TTA)3bipy in PMMA and PS matrices	spectra	optoelectronic devices with red light-emitting phosphors.
Suhailath K. et al. [18]	Conductive nanocomposite of PBMA blended with Nd-TiO_2	Free radical polymerization, SEM, XRD	Uniform dispersion of nanoparticles confirmed. Improved conductivity with Nd-TiO_2. Conformity with Mamunya's model.
Hashim A. et al. [19]	Review on potential of PMMA-PS blend doped with nanoparticles for various applications	Polymer structure, characterization	Versatility of PMMA-PS blend for medical, environmental, and industrial applications. Discussions on composite materials and nanocomposites.
Pandey N. et al. [20]	PMMA thin films doped with TiO_2 via solution-cast method	XRD analysis	Increasing TiO_2 doping shifts film structure from amorphous to crystalline. Crystallinity index varies with TiO_2 concentration.
BhadraJ. et al. [21]	PANI blends with different polymers	SEM, FTIR, TGA, Electrical conductivity	PANI blends with PVA, PS, SA exhibited uniform blending. PANI-PVA had highest conductivity (10^{-2} S/cm), PANI-PVC had lowest (10^{-13} S/cm). Chemical interaction observed.
Inamdar H. K. et al. [22]	Polypyrrole/Cr_2O_3 nanocomposites through in-situ polymerization	PXRD, SEM, TEM	Cr_2O_3 NPs (20 nm) synthesized using Aloe Vera gel. Porous particles observed. DC conductivity increased with temperature. Nanocomposites suitable for commercial applications with near-white light emitting properties.
Hameed N. J. et al. [23]	PS/PMMA blends with varying ratios	Spectrophotometer, Optical microscopy	Absorption spectra increased with PS ratio up to 50% PS/ 50% PMMA. Inverse relationship between energy gap and increasing PS ratio. Enhanced optical constants observed.
Nagaraja S. et al. [24]	PANI/PVDF composites with varying PVDF concentrations	XRD	Dielectric properties examined across frequency range. Dielectric permittivity stabilized at higher frequencies. AC conductivity correlated with PVDF content.
Silva A. I. et al. [25]	Impact of antenna ligands on europium complex luminescence	Photophysical measurements	Introduction of symmetry-breaking ligand enhanced luminescence. Effective antenna ligand crucial. Quantum efficiency increase demonstrated.
Al-Kadhemy M. F. H. et al. [26]	Impact of gamma radiation on PMMA/PS blends at various concentrations	Optical analysis	Gamma radiation effects on optical constants, energy gap. Spectral analysis of pure and blend polymers.
Bhagat D. J. et al. [27]	Analysis of polyindole/poly (vinyl acetate) composites	SEM, TG-DTA, DTG, AC conductivity, dielectric constant	Composites exhibited ac conductivity, thermal stability. Activation energy determined.

Manikandan K. M. et al. [28]	Polymer electrolyte using PMMA-LiBr with enhanced conductivity	Impedance spectroscopy, FTIR, XRD, SEM	Nano Al_2O_3 enhances conductivity. Ionic conductivity measured. Highest conductivity achieved at 2.5% Al_2O_3. Characterization via FTIR, XRD, SEM.
Ali U. et al. [29]	Overview of PMMA's fundamental properties and applications	Experimental insights, applications overview	Highlights PMMA's properties, chemistry, and applications in diverse fields. Aims to enhance accessibility to recent developments.
Puthiyottil R. et al. [30]	Synthesis and characterization of PMMA/EVA blends doped with Eu-β-diketone chelate	Mechanical testing, thermal analysis, photoluminesce-nce	Evaluation of tensile and impact strength, thermal characteristics. Chelate's influence on structural state and optical properties. Potential for optoelectronic device development.
Meeta S. et al. [31]	Investigation of MNA-doped PS/PVC thermo electret samples	Isothermal evaporation, Electrical testing	Dopant influenced conductivity in polyblend samples. Arrhenius behavior observed in conductivity.
Vidhale S. G. et al. [32]	Synthesis and characterization of PS-PMMA blend doped with Salicylic Acid	Solution polymerization, Isothermal evaporation, AC conductivity, Dielectric Constant measurements	IR radiation exposure impacted AC Conductivity and Dielectric Constant. Longer exposure led to decreased AC Conductivity. Increased exposure time resulted in reduced Dielectric Constant.
Puthiyottil R. et al. [33]	Doping of Europium complex into PMMA matrix at various amounts	UV-visible spectroscopy, Fluorescence spectroscopy, XRD, Infrared spectroscopy	Luminescent properties exhibited extended fluorescence lifetimes. Chelate amount affected fluorescence lifetime, indicating microenvironment alterations. Optical properties showed composition-dependent variations.
Gibelli E. B. et al. [34]	Photoluminescence sensitization effect of [Eu(tta)3(DB$_{18}$C6)2(H_2O)2] in PMMA/PEG blend	Thermal analysis, Emission spectroscopy	$Eu3^+$-complex interacted with PMMA polymer, immobilizing it. Luminescent behavior resembled undoped polymer. Increased emission quantum efficiency indicated effective interaction, enhancing $Eu3^+$ ions luminescence.
Dwivedi Y. et al. [35]	Synthesis of Tb-doped polycarbonate:PMMA blend with varying proportions	FTIR, DSC, UV-vis absorption, Fluorescence spectroscopy	Blend with 10% PC and 90% PMMA exhibited improved miscibility. $Tb3^+$ ion luminescence influenced by PC:PMMA ratio and $Tb3^+$ concentration. Salicylic acid addition enhanced $Tb3^+$ ion luminescence. Concentration quenching observed for high $TbCl_3\cdot 6H_2O$ concentrations.
Ahmed R. M. et al. [36]	Study of UV radiation impact on PMMA/PVA blends transparent films	Solution-casting, FT-IR, Optical absorption measurements, Refractive index	UV radiation induced changes in optical parameters like band tail width, band gap energies. Refractive indices variations before and after exposure.

		calculation	
Abd El-kader F. H. et al. [37]	DSC analysis of PVA doped with $EuCl_3$ and $TbCl_3$, Dielectric properties examination	Differential Scanning Calorimetry (DSC), Dielectric constant and loss tangent measurements	Dielectric dispersion involving dipolar and interfacial polarization. Parameters like TCP, m, and activation energy for glass relaxation determined. Correlated barrier hopping (CBH) mechanism observed in AC conductivity measurements.
Deshmukh S. H. et al. [38]	Electrical conductivity analysis of polyaniline-doped PVC and PMMA thin films	I-V characteristics, Analysis using Poole–Frenkel, Fowler–Nordheim, Schottky, Richardson, Arrhenius plots	Schottky and Richardson mechanisms primarily responsible for conduction.
Podgrabinski T. et al. [39]	Investigation of DS-doped PS and PMMA thin films, including thermal and electrical properties	Spin-coating, DSC, RBS, XPS, Capacitance measurement	Tg decrease with DS concentration. Increased relative permittivity with DS doping. DS diffusion differences in PS/DS and PMMA/DS films. PMMA/DS exhibited better thermal stability.
Diaz-Garcia M. A. [40]	Study of lasing properties in optically pumped polymer films	Amplified Spontaneous Emission (ASE), Investigation of various organic molecules and complexes	ASE observed at approximately 400 nm in PS and PVK films doped with TPD. TPD-based films potential for blue-emitting organic diode lasers. Energy transfer observed in PVK films doped with europium and samarium complexes. Energy transfer observed in PS films to europium complexes.

4. Conclusions

- The provided review article presents a comprehensive overview of the evolving landscape in polymer blends and composites research. It covers a wide range of studies focusing on the structural, optical, thermal, and electrical properties of these materials.
- The research explores various combinations of polymer matrices and diverse additives, with the goal of enhancing specific characteristics for a variety of applications.
- Additionally, the review highlights multiple procedures for thin film sample preparation, emphasizing the strategic integration of suitable materials as an effective approach to influencing polymer characteristics.
- This revitalization results in improvements in optical, thermal, and electrical attributes, with implications extending to technical, biomedical and multifaceted applications.
- The research underscores the dynamic and promising nature of the ongoing developments in polymer blends and composites.

Credit authorship contribution statement: Ms. Riya R. Tekade[1]:Collected, analyzed data, and drafted the review paper. **Dr. Shilpa G. Vidhale[2]**: Contributed to data interpretation and Supervision.

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