FTIR Analysis of Ethyl Cellulose (EC) and Polyvinyl Chloride (PVC) Polyblends Thin Films Doped With Salicylic Acid

Unhale S.B.

Department of Physics, Dr. Manorama & Prof Haribhau Shankar Rao Pundkar
Arts, Commerce and Science College, Balapur, Dist. Akola, M.S. 444302

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Abstract

This study examines the structural features and molecular interactions in thin films of Ethyl Cellulose (EC) and Polyvinyl Chloride (PVC) polyblends doped with salicylic acid (SA), prepared in a **1:1 (EC:PVC)** ratio via isothermal evaporation. FTIR spectroscopy characterized pure and SA-doped films at varying dopant concentrations.

The undoped polyblend spectra showed characteristic bands of EC (C–O–C stretching at 1100–1000 cm^{-1}, C–H vibrations) and PVC (C–Cl stretching at 600–700 cm^{-1}, C–H deformations).

Doping with SA introduced new peaks confirming its incorporation, including aromatic C=C (~1600–1450 cm^{-1}), broad O–H stretching (~3200–3400 cm^{-1}), and C=O (~1680–1650 cm^{-1}). Increasing SA concentration caused peak shifts (often to higher wavenumbers) and intensity changes, indicating intermolecular interactions like hydrogen bonding between SA's hydroxyl/carboxyl groups and EC's oxygen moieties or PVC's chlorine atoms.

These observations suggest improved miscibility, possible charge-transfer complexes, and good dopant-matrix compatibility. The FTIR findings reveal key chemical environments and interaction mechanisms in SA-doped EC-PVC polyblend films, with potential applications in controlled-release systems, optical coatings, and functional polymers.

Keywords: *Ethyl Cellulose; Polyvinyl Chloride; Polyblends; Salicylic Acid; FTIR; Thin films; Molecular interactions*

1. Introduction

Polymers are a vital class of materials essential to modern life, surrounding us in forms like rubber, plastics, resins, adhesives, and tapes. The term "polymer" comes from Greek words "poly" (many) and "meros" (parts), referring to giant macromolecules of high molecular weight built by linking numerous small repeating units called monomers through a chemical reaction known as polymerization. The repeating unit in the polymer is usually identical or very similar to the original monomer. Historically, the macromolecular concept—viewing polymers as long covalently bonded chains rather than colloidal aggregates—was championed by Hermann Staudinger, who proposed it in 1920 (with key publications starting around then), leading to widespread acceptance in the 1920s and earning him the Nobel

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Prize in Chemistry in 1953. This view was further supported by Wallace Carothers' quantitative investigations in the late 1920s and early 1930s (notably 1929–1931), which provided strong evidence for the macromolecular hypothesis and advanced synthetic polymer development [1-3]

Polymers have existed in natural forms since the dawn of life, with vital biomolecules such as DNA, RNA, proteins, and polysaccharides playing essential roles in plant and animal biology, while humans have long exploited naturally occurring polymers like wood, leather, cotton, wool, grasses, and natural rubber for clothing, shelter, tools, weapons, decoration, papermaking, and glues dating back to antiquity. The modern polymer industry traces its origins to the 19th century, when key modifications of natural polymers emerged: in the 1830s–1840s, Thomas Hancock and Charles Goodyear independently developed the vulcanization of natural rubber by blending it with sulfur and heat (Hancock in the UK in 1843–1844, Goodyear in the US in 1844), dramatically improving its durability and enabling practical applications like waterproofing and tires. This era also saw semi-synthetic polymers, such as cellulose nitrate (nitrocellulose) plasticized with camphor to create celluloid around 1868–1885 (popular for stiff collars, motion picture film by Thomas Edison, lacquers, and billiard balls, though highly flammable), and regenerated cellulose processes like Chardonnet's artificial silk (1884) leading to the viscose rayon method still used today. The first fully synthetic polymer arrived in 1907–1909 with Leo Baekeland's Bakelite, a thermosetting phenol-formaldehyde resin used for electrical appliances, records, and insulators, marking the birth of the synthetic plastics era independent of natural precursors. Initially, polymers were employed empirically with little understanding of structure-property relationships, but the systematic foundation of polymer science began around a century ago through the pioneering work of Hermann Staudinger, who in 1920 (with concepts published as early as 1919–1920) redefined polymers as high-molecular-mass compounds composed of long chains of covalently bonded repeating units—macromolecules—overturning earlier colloidal aggregate theories and earning him the Nobel Prize in Chemistry in 1953[4- 6].

Studies on electrical conductivity and related properties in polymer blends**,** particularly involving polyvinyl chloride (PVC) and polymethyl methacrylate (PMMA**)**, reveal diverse conduction mechanisms and enhancements through doping, blending, or additives. Dakare and Lamdhade [7] investigated oxalic acid-doped PVC-PMMA blends, measuring conductivity from 313 K to 373 K; the I-V characteristics deviated from power law and ohmic behaviour, with models like Poole–Frenkel, Fowler–Nordheim, Schottky, ln(J) vs. T, Richardson, and Arrhenius plots evaluated—the dominant mechanism identified as Schottky-Richardson emission, driven by electrode-limited conduction influenced by temperature and field. Similarly, Saxena et al. [8] examined PVC: PMMA thin-film thermo electrets using Al, Cu, and Ag electrodes at 323–363 K, reporting I-V characteristics in structures like Al-film-Al, Al-film-Cu, and Al-film-Ag; conduction could not be described by Poole–Frenkel or Fowler–Nordheim but aligned closely with Schottky and Richardson mechanisms, with electrode material significantly affecting charge transfer in these amorphous semiconductor-like blends.

In conducting polymer systems, Chen et al. [9] explored DC conductivity in blends of PEDOT: PSS (with or without NMP) and PVA, prepared via aqueous spin-coating on glass; conductivity rose with higher PEDOT: PSS or PEDOT: PSS: NMP content, and NMP addition boosted it by 2–5 orders of magnitude (depending on PVA fraction) through conformational changes in PEDOT chains that improve chain alignment and charge transport. For PVC-based electroactive gels, Ali et al. [10] transformed electrically inactive PVC plastisol into plasticized PVC gel by heating, revealing high dielectric constant at low frequencies (1–1000 Hz), asymmetric space charge distribution, strong mechanical properties, and electromechanical response (e.g., electrostatic adhesion to anode under DC fields), with structural insights from small- and wide-angle X-ray scattering supporting potential actuator applications.

Zainab et al. [11] studied PVC composites filled with magnesium powder at varying concentrations and thicknesses; DC conductivity exhibited a sharp percolation-like increase by several orders of magnitude at a critical filler weight fraction, with temperature-dependent conductivity and activation energy decreasing as filler content rose, indicating filler-induced pathways for enhanced charge transport in these insulating polymer matrices. Overall, these works highlight how doping, blending, fillers, and processing tailor electrical properties in polymers, often favouring Schottky/Richardson mechanisms in PVC-PMMA systems while enabling conductivity jumps in filled or conducting blends for electronics and actuators.

The aim of present work is to study the FTIR analysis of ethyl cellulose (EC) and polyvinyl chloride (PVC) thin film prepared from isothermal evaporation method.

2. Experimental

- **Methods of Preparation of EC and PVC film without Dopant**

In the present study, polymer blend films of ethyl cellulose (EC) and polyvinyl chloride (PVC) were prepared using the isothermal evaporation technique. The two polymers were mixed in different weight ratios—1:1 and dissolved in a common solvent, tetrahydrofuran (THF). The mixture was allowed to stand for 3–4 days at room temperature to ensure complete dissolution and formation of a homogeneous, uniform solution. A thoroughly cleaned glass plate (15 × 15 cm), first washed with water and then acetone, served as the substrate. To ensure perfect levelling and uniform film thickness, the glass plate was placed over a pool of mercury, which provided a flat, vibration-free surface. The polymer solution was then poured onto the centre of the glass plate and allowed to spread evenly in all directions. The entire setup was kept in a dust-free chamber at ambient temperature, permitting slow, isothermal evaporation of the THF solvent until the film was completely air-dried. Once solidified, the resulting film was carefully peeled off the substrate and cut into smaller pieces of desired dimensions. Finally, the detached films were further dried for three days under ambient conditions to eliminate any residual solvent traces, yielding solvent-free, uniform EC-PVC blend films suitable for subsequent characterization and analysis. This simple, cost-effective casting method via controlled solvent evaporation ensures good reproducibility and homogeneity in the prepared blend films.

- **Methods of Preparation of EC and PVC film with Dopant**

In the present experimental work, ethyl cellulose (EC)-polyvinyl chloride (PVC) blend films doped with salicylic acid were prepared via the isothermal evaporation technique, following established methods reported by Sangawar and Adgaonkar (1995) [12] and Bahri and Sood (1983)[13]. Specifically, 0.5 g EC was dissolved in 10 ml THF, 0.5 g PVC (for a 1:1 weight ratio) in another 10 ml THF, and 0.05 g salicylic acid (5 wt% doping) in 10 ml THF; each component was dissolved separately until complete homogeneity was achieved. These three solutions were then combined and thoroughly mixed. The resulting mixture was heated at 60°C for 1 hour to obtain a clear, uniform solution. A clean glass plate (15 cm × 15 cm), washed first with hot water and then acetone, served as the substrate. For optimal levelling and uniform film thickness, the plate was positioned in a plastic tray containing a pool of mercury to minimize surface tension effects and vibrations. The homogeneous solution was poured onto the centre of the glass plate and allowed to spread evenly in all directions. The assembly was placed in a dust-free chamber at constant (room) temperature, permitting slow, controlled isothermal evaporation of the THF solvent. After 12 hours at room temperature to remove most of the solvent, the solidified film was carefully peeled from the substrate, cut into small pieces of appropriate size, and washed with acetone to eliminate any surface impurities. Finally, the films were subjected to further drying (typically implied for residual solvent removal in similar protocols) to ensure purity and stability. This solvent-casting approach yields reproducible, thin, uniform doped polymer blend films suitable for electrical, dielectric, or other physicochemical characterizations, with salicylic acid acting as an organic dopant to potentially enhance conductivity or charge storage properties in the EC-PVC matrix

- **Sample Code :** All the samples are listed in the following table 1.

Table 1 Sample Code

EC-PVC + 0% Salicylic Acid	1:1 EC-PVC SA(0)
EC-PVC + 5% Salicylic Acid	1:1 EC-PVC SA(5)

EC-PVC + 10% Salicylic Acid	1:1 EC-PVC SA(10)
EC-PVC + 15% Salicylic Acid	1:1 EC-PVC SA(15)

3. Results and Discussion

- **Fourier Transform Infrared Spectroscopy (FTIR)**

In the present work, Fourier Transform Infrared (FTIR) spectra of all samples were recorded using a Shimadzu IR Affinity model spectrophotometer at a resolution of 4 cm⁻¹, a standard setting for solid polymer films that provides sufficient detail to distinguish key vibrational modes while balancing signal-to-noise ratio and measurement time (typically involving multiple scans for high-quality data in the 4000–400 cm⁻¹ range). FTIR spectroscopy serves as a powerful tool to assess compatibility or miscibility in polymer blends: if two polymers like ethyl cellulose (EC) and polyvinyl chloride (PVC) are completely incompatible, their spectra in the blend approximate a simple superposition of the individual pure component spectra, with minimal shifts or interactions, as each polymer effectively does not "recognize" the other's presence at the molecular level. Conversely, compatible or partially miscible blends exhibit noticeable differences—such as band shifts, broadening, intensity changes, or appearance/disappearance of new peaks—arising from intermolecular interactions (e.g., hydrogen bonding, dipole-dipole forces, or weak chemical associations) between functional groups of the components. In this study, FTIR analysis focused on EC-PVC blend films in a 1:1 weight ratio with doped (with salicylic acid as an organic dopant), prepared via the isothermal evaporation technique from THF solutions. The resulting spectra are presented in Fig. 1(a-d), 1:1 EC-PVC SA(0), 1:1 EC-PVC SA(5), 1:1 EC-PVC SA(10), 1:1 EC-PVC SA(10) undoped and doped blends.

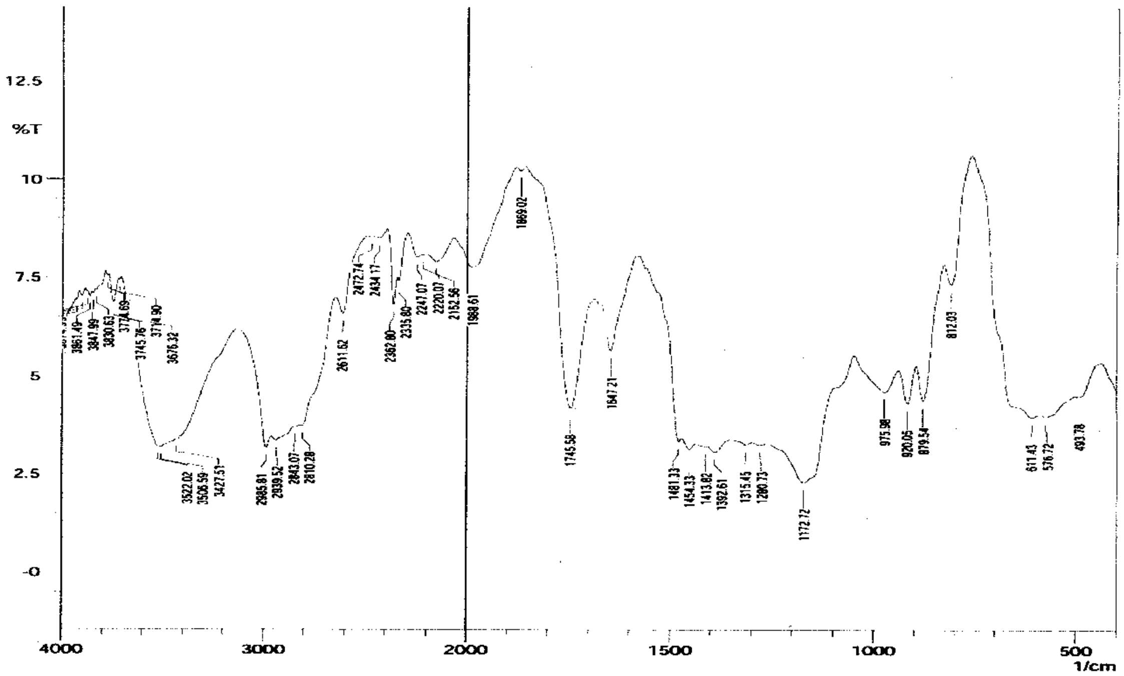

Fig. 1. (a) FTIR of 1:1 EC-PVC SA (0)

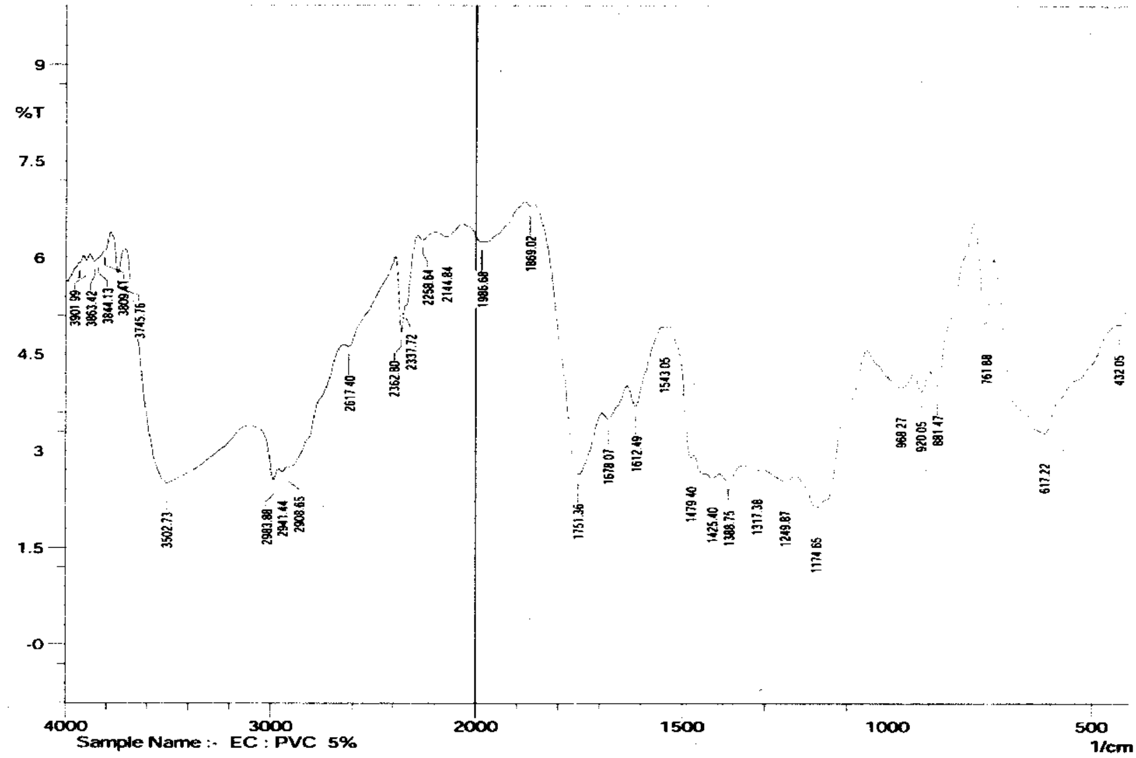

Fig. 1. (b) FTIR of 1:1 EC-PVC SA (5)

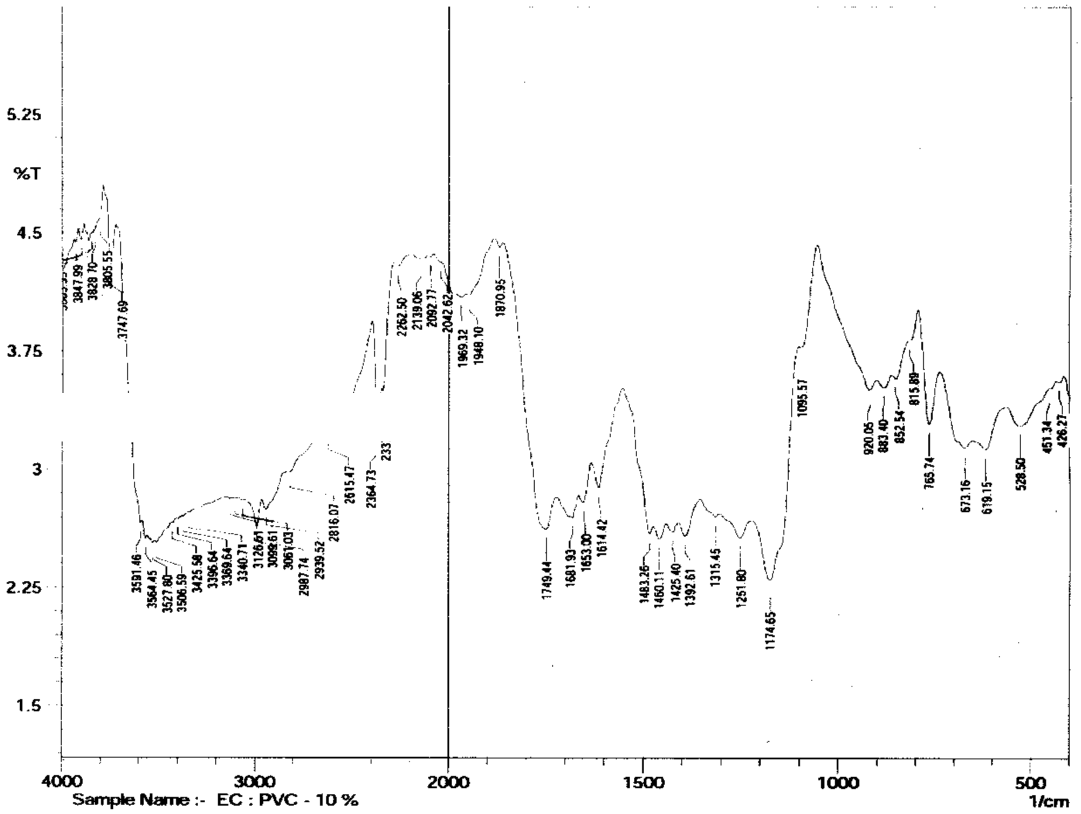

Fig. 1. (c) FTIR of 1:1 EC-PVC SA (10)

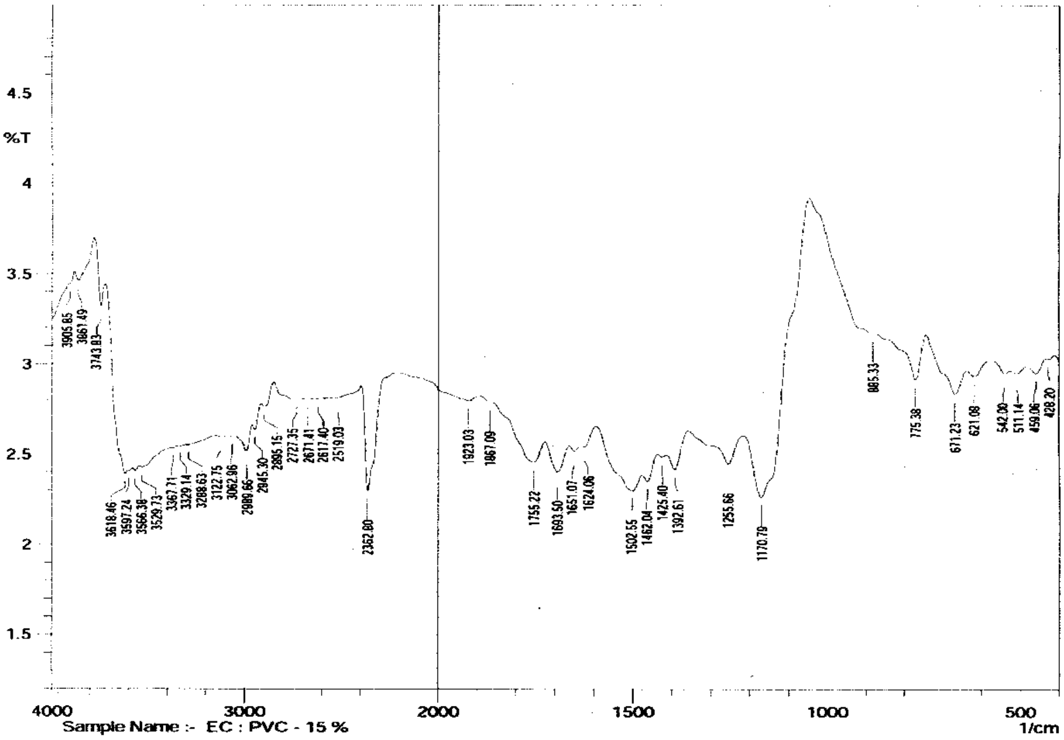

Fig. 1. (d) FTIR of 1:1 EC-PVC SA (15)

Table 2.1 and 2.3 consist of major infrared bands in (EC - PVC) blends shows Standard Vibrations in EC and PVC.

Table 2.1 Major infrared bands of Ethyl Cellulose (EC)

Wave Number (cm^{-1})	**Assignment**	**References**
1052	C–O–C stretching	Sutar et al. [14]
1081	C–O Stretching	Khichar et al. [15]
1369	C–H bending	Sutar et al. [14]
1324	C–O–H Stretching	Khichar et al. [15]
1610	C=O Carbonyl Stretching	Khichar et al. [15]
2917	CH_2 asymmetric Stretching	Khichar et al. [15]
2880 & 2970	C–H Stretching	Sutar et al. [14]

Table 2.2 Major infrared bands of Polyvinyl Chloride (PVC)

Wave Number (cm^{-1})	**Assignment**	**References**
2972 & 2910	CH_2 asymmetric Stretching	Pandey et al. [16]
1717	C=O	Bushra et al. [17]

615, 700	C–Cl Vibration	Bushra et al. [17]
1272	C–H rocking	Bushra et al. [17]
1250	C–H bending	Pandey et al. [16]
1325	CH_2 deformation	Bushra et al. [17]
2960	C–H stretching	Rajendra et al. [18]
1074	C–H rocking	Rajendra and Uma [19]

Table 2.3 Major infrared bands of Salicylic Acid (SA)

Wave Number (cm^{-1})	Assignment	References
2999-3004	C–H Stretching	Trivedi et al.[20]
1652-1670	C=O asymmetric Stretching	Guhan et al.[21]
759-669	C–H bending	Trivedi et al. [20]
1386	C=O symmetric Stretching	Guhan et al.[21]
1324	O–H bending	Trivedi et al. [20]
3233	O–H stretching	Guhan et al.[21]
1296	C–O stretching	Guhan et al.[21]

- **Explanation from the Graph**

FTIR analysis of the 1:1 ethyl cellulose (EC)-polyvinyl chloride (PVC) blend films, both undoped and salicylic acid (SA)-doped, prepared via isothermal evaporation, was conducted using a Shimadzu IR Affinity spectrophotometer at 4 cm^{-1} resolution to evaluate molecular interactions, compatibility, and dopant effects. Tables 21 and 2.2 summarize the major characteristic bands: for pure EC (Table 4.1), key peaks include C–O–C stretching at 1052 cm^{-1}, C–O stretching at 1081 cm^{-1}, C–H bending at 1369 cm^{-1}, C–O–H stretching at 1324 cm^{-1}, carbonyl C=O at 1610 cm^{-1}, CH_2 asymmetric stretching at 2917 cm^{-1}, and C–H stretching at 2880 & 2970 cm^{-1}; for pure PVC (Table 2.2), prominent bands are CH_2 asymmetric stretching at 2972 & 2910 cm^{-1}, C=O at 1717 cm^{-1}, strong C–Cl vibrations at 615 & 700 cm^{-1}, C–H rocking at 1272 & 1074 cm^{-1}, C–H bending at 1250 cm^{-1}, CH_2 deformation at 1325 cm^{-1}, and C–H stretching at 2960 cm^{-1}. Table 4.3 lists SA bands: C–H stretching at 2999–3004 cm^{-1}, C=O asymmetric stretching at 1652–1670 cm^{-1}, C–H bending at 759–669 cm^{-1}, C=O symmetric stretching at 1386 cm^{-1}, O–H bending at 1324 cm^{-1}, O–H stretching at 3233 cm^{-1}, and C–O stretching at 1296 cm^{-1}.

In the undoped 1:1 EC-PVC blend (Fig. 1(a)), the spectrum shows reappearance of characteristic peaks from both components, confirming successful blend formation without major loss of identity. Literature-assigned PVC CH_2 asymmetric stretching (2972–2910 cm^{-1}) appears shifted to 2985 cm^{-1} (asymmetric C–H) and 2939 cm^{-1} (symmetric C–H). PVC's C=O at 1717 cm^{-1} shifts to higher wavenumber (1745 cm^{-1}) upon EC addition, indicating interaction. Other PVC peaks at ~611 cm^{-1} (C–Cl-related), 1280 cm^{-1} (C–H wagging near Cl), and 1315 cm^{-1} (CH_2 deformation) persist, alongside EC contributions at 1172 cm^{-1} (C–O–C stretching), 1792 cm^{-1} (possibly C–H bending or carbonyl influence), 1647 cm^{-1} (C=O carbonyl), and 1454 cm^{-1} (CH_2 bending). These observations suggest partial compatibility through weak intermolecular forces (e.g., dipole or hydrogen bonding between EC's ether/OH and PVC's C–Cl/CH_2), with no drastic new bands but subtle shifts evidencing molecular-level mixing [18-20].

For SA-doped blends (Fig. 1(b-d), 5–15% doping), increasing dopant concentration causes shifts to higher wavenumbers in key bands: C–H wagging, C–Cl stretching, C–H bending near Cl, and CH_2 deformation from PVC, plus C–O–C stretching (1172 cm^{-1}) from EC. Additional dopant-specific peaks emerge, such as 1612 cm^{-1} and 1553 cm^{-1} (C=C stretching in SA aromatic ring) and 761 cm^{-1} (C–H bending in SA) in the 5% blend; these peaks shift further to higher wavenumbers with increasing doping but decrease in intensity, indicating SA incorporation, possible charge-transfer or hydrogen-bonding interactions with the EC-PVC matrix (e.g., SA's OH/carboxyl with EC's ether or PVC's sites), and enhanced miscibility or conformational changes. Extra peaks and progressive shifts/intensity reductions in doped spectra relative to the virgin blend highlight SA's role in modifying the blend's vibrational environment, supporting its use as a dopant to tune electrical/dielectric properties in these films. Overall, the FTIR results affirm good blend compatibility with dopant-induced perturbations, consistent with literature on similar systems [21].

4. Conclusions

Overall, any observed deviations from additive spectra in FTIR provide direct evidence of the degree of compatibility in these EC-PVC systems, supporting their suitability for tailored electrical or dielectric applications as explored in related characterizations.

References

Billmeyer, F. W., Jr. (1984). *Textbook of polymer science* (3rd ed.). Wiley-Interscience.

Gowariker, V. R., Viswanathan, N. V., & Sreedhar, J. (1998). *Polymer science*. New Age International.

Furukawa, Y. (1998). *Inventing polymer science: The birth of the industrial laboratory*. University of Pennsylvania Press.

Morawetz, H. (1985). *Polymers: The origins and growth of a science*. Wiley-Interscience.

Sperling, L. H. (1987). Polymer news, *13*, 332.

Dakare, A. B., & Lamdhade, G. T. (2012). Schottky-Richardson mechanism in oxalic acid doped (PVC-PMMA) blends. *International Journal of Science and Research, 1*(6), 231–234.

Saxena, G., Kulshrestha, Y. K., & Upadhyay, D. J. K. (2014). Electrical conductivity study of PVC:PMMA polymer blend thin film thermoelectret using Al, Cu and Ag electrodes. *IOSR Journal of Applied Physics, 6*(3, Ver. IV), 1–14. https://doi.org/10.9790/4861-06340114

Chen, C., LaRue, J. C., Nelson, R. D., Kulinsky, L., & Madou, M. J. (2012). Electrical conductivity of polymer blends of poly(3,4-ethylene dioxythiophene):poly(styrenesulfonate):N-methyl-2-pyrrolidinone and polyvinyl alcohol. *Journal of Applied Polymer Science, 125*(4), 3134–3141. https://doi.org/10.1002/app.36474

Ali, M., Ueki, T., Hirai, T., Sato, T., & Sato, T. (2013). Dielectric and electromechanical studies of plasticized poly(vinyl chloride) fabricated from plastisol. *Polymer International, 62*(3), 501–506. https://doi.org/10.1002/pi.4343

Zainab, N., Ramdhan, A. H., Marwa, A. M., & Talib, H. H. (2014). [Title not specified in source]. *International Journal of Science and Research, 8*(2), 56–64.

Sangawar, V., & Adgaonkar, C. S. (1995). [Title not specified in source]. *Indian Journal of Pure and Applied Physics, 33*, 401–411.

Bahri, R., & Sood, B. R. (1983). Effect of iodine doping on the photoconductivity of polystyrene thin films. *Thin Solid Films, 100*(1), L5–L8. https://doi.org/10.1016/0040-6090(83)90232-8

Suthar, V., Pratap, A., & Raval, H. (2000). Studies on poly(hydroxy alkanoates)/(ethylcellulose) blends. *Bulletin of Materials Science, 23*(3), 215–219. https://doi.org/10.1007/BF02719913

Khichar, K. K., Dangi, S. B., Dhayal, V., Kumar, U., Hashmi, S. Z., Sadhu, V., Choudhary, B. L., Kumar, S., & Kaya, S. (2020). Structural, optical, and surface morphological studies of ethyl cellulose/graphene oxide nanocomposites. *Polymer Composites, 41*(7), 2792–2802. https://doi.org/10.1002/pc.25576

Pandey, M., Joshi, G. M., Mukherjee, A., & Thomas, P. (2016). Electrical properties and thermal degradation of poly(vinyl chloride)/polyvinylidene fluoride/ZnO polymer nanocomposites. *Polymer International*. https://doi.org/10.1002/pi.5254

Hasan, B. A., Hasan, A. A., & Duaa-A-Umran. (2013). [Title not specified in source]. *International Journal of Application or Innovation in Engineering & Management, 2*(11), 86.

Rajendran, S., Kannan, R., & Mahendran, O. (2001). Ionic conductivity studies in poly(methylmethacrylate)–polyethylene oxide hybrid polymer electrolytes with lithium salts. *Journal of Power Sources, 96*(2), 406–410. https://doi.org/10.1016/S0378-7753(00)00573-5

Rajendran, S., & Uma, T. (2000). Conductivity studies on PVC/PMMA polymer blend electrolyte. *Materials Letters, 44*(3-4), 242–247. https://doi.org/10.1016/S0167-577X(00)00036-7

Trivedi, M. K., Branton, A., Trivedi, D., Shettigar, H., & Bairwa, K. (2015). Fourier transform infrared and ultraviolet-visible spectroscopic characterization of biofield treated salicylic acid and sparfloxacin. *Natural Products Chemistry & Research, 3*(5), 186. https://doi.org/10.4172/2329-6836.1000186

Guan, X. H., Chen, G. H., & Shang, C. (2007). ATR-FTIR and XPS study on the structure of complexes formed upon the adsorption of simple organic acids on aluminum hydroxide. *Journal of Environmental Sciences, 19*(4), 438–443. https://doi.org/10.1016/S1001-0742(07)60073-4