

## Impact of 7:6 PEG/LDPE Ratio on the Structural Properties Prepared via Nanoprecipitation Method



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### KEYWORDS

PEG, LDPE, SEM, XRD, FTIR, UV-VIS

### ARTICLE DETAILS

Received 03 June 2025; revised 27 June 2025; accepted 28 July 2025

DOI: 10.26671/IJIRG.2025.3.14.156

### CITATION

Meshram, S. D., Sangawar, V. S. (2025). Impact of 7:6 PEG/LDPE Ratio on the Structural Properties Prepared via Nanoprecipitation Method. *Int J Innovat Res Growth*, 14(3), 143075-143079. DOI



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### Abstract

This study investigates the effect of 7:6 weight ratio of polyethylene glycol (PEG) to Low density polyethylene (LDPE) on the structural properties of the resulting blend, synthesized by using nanoprecipitation method. The high PEG content (54 wt.%) was expected to enhance colloidal stability and surface wettability, potentially forming a hydrophilic shell around a hydrophobic LDPE core. Surface morphology observed through SEM, FTIR confirmed characteristic functional groups and indicated partial compatibility between PEG and LDPE through observed shifts in a peak intensity, XRD analysis showed a semi crystalline structure with reduced crystallinity compared to pure components. Additionally, UV-Vis spectroscopy indicated improved light absorption. The 7:6 PEG/LDPE blend demonstrates promising features for biomedical and packaging applications due to its tunable properties and ease of fabrication.

## 1. Introduction

We focus on polyethylene for its unique characteristics (mechanical, chemical, and thermal resistance), wide application, and low price. Until now, various composite materials from PE and different particles have been synthesized [1] The properties of polyethylene vary depending on the molecular structure and density. It can be processed by general thermoplastics molding methods and is mainly used to manufacture thin films, containers, pipes, monofilament, wire and cable, daily necessities, etc. It is also applied in televisions, radar systems and other high-frequency insulation materials [2]

Low density polyethylene (LDPE) is produced by the polymerization of ethylene under high pressure. LDPE is chemically resistant and does not degrade easily in the environment, due to its high molecular weight, long chain carbon structures, significant crystallinity and hydrophobic nature.[3] LDPE is one of the most commonly used packaging plastics and is considered environmentally persistent due to its high resistance to degradation [4]

Polyethylene glycols (PEGs) are hydrophilic polymers, and their higher water solubility makes them ideal for biological applications., PEGs are often conjugated to hydrophobic molecules to increase their water solubility. Their end groups are easy to be modify, making them suitable for functionalization. and this modification is important to increase their applications.[5]

The nanoprecipitation technique, also named solvent injection, spontaneous emulsification, solvent displacement, solvent diffusion, interfacial deposition, mixing induced nanoprecipitation, or flash nanoprecipitation, is recognized as a versatile and effective strategy for encapsulating active molecules on the submicron and nanoscale levels.[6].

In this study a PEG/LDPE blend with a 7:6 weight ratio was prepared by using the nanoprecipitation method. The resulting blend was characterized by Scanning electron microscopy (SEM), Fourier –transform infrared spectroscopy (FTIR) X-Ray diffraction (XRD), and ultraviolet-visible (UV-Vis) spectroscopy.

## 2. Materials and Methods

### A. Materials

Low Density Polyethylene (LDPE) Polyethylene Glycol (PEG, molecular weight 6000 g/mol), Xylene (AR grade) was used to dissolve LDPE, Distilled water for nanoprecipitation process.

### B. Methods

A total weight 6gm LDPE was dissolved in 70 ml of xylene Heat the mixture on hot plate of magnetic stirrer at 110<sup>0</sup> C under constant stirring Add 7 gm of PEG into LDPE-xylene solution and continue stirring. Using a syringe, inject PEG/LDPE-Xylene solution dropwise into water under high speed 1000 rpm and filtrate it.

## 3. Results and Discussion

### 3.1 Scanning Electron Microscopy (SEM)

Morphology of the PEG/LDPE blends was examined using scanning electron microscopy (SEM).

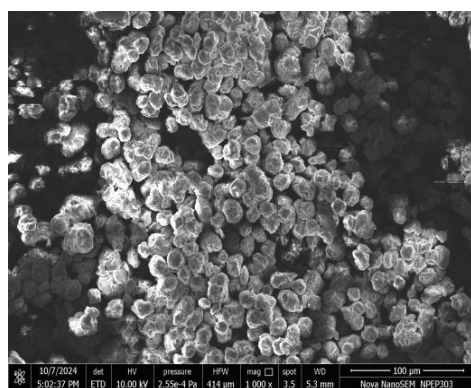


Fig.1 (a) SEM image of pure LDPE

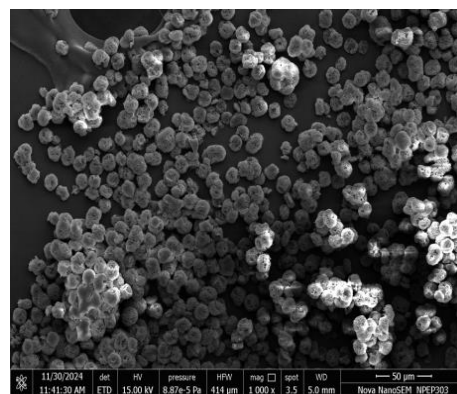


Fig.1(b) SEM image of 7:6 PEG/LDPE

From fig.1(a) shows SEM image of pure LDPE which is irregular size and large agglomeration. Strong tendency to agglomerate in nanoprecipitation due to hydrophobic nature and low polarity. particle often stick together.

From fig.1(b) shows SEM image of 7:6 PEG/LDPE which is smoother and more uniform surfaces, less agglomeration and spherical in shape.

7:6 PEG/LDPE this composition suggests a blend where phase separation is likely due to chemical incompatibility between hydrophilic PEG and hydrophobic LDPE. The higher PEG (7:6) content may enhance sphericity, as PEGs hydrophilic nature promotes stable interfacial interactions with aqueous non-solvent. reducing irregular shape.

### 3.2 Fourier Transform Infrared Spectroscopy (FTIR)

Functional group of the PEG/LDPE blends was examined by using Fourier Transform Infrared Spectroscopy (FTIR)

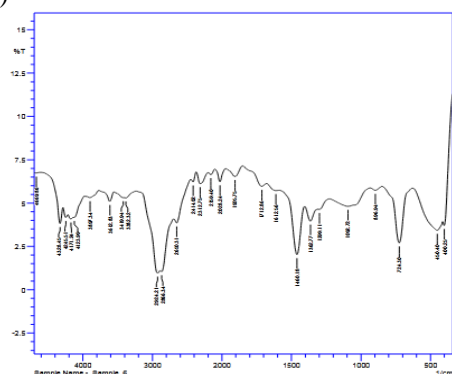


Fig.2 (a) FTIR spectra of pure LDPE

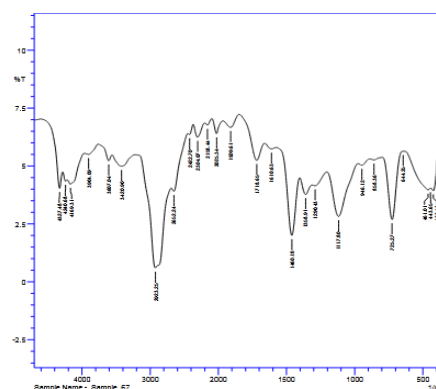


Fig.2(b) FTIR spectra of 7:6 PEG/LDPE

From fig.2(a) shows FTIR spectra of pure LDPE Characteristics peaks at  $3419.94\text{ cm}^{-1}$  confirms O-H stretching vibrations of hydroxyl groups, The peak at  $2924.21\text{ cm}^{-1}$  and  $2866.34\text{ cm}^{-1}$  due to asymmetrical and symmetric C-H stretching vibrations of the  $\text{CH}_2$  groups in the LDPE. The peak at  $1460.18\text{ cm}^{-1}$  and  $1362.77\text{ cm}^{-1}$  occurred due to C-H bending vibration and C-H bending of  $\text{CH}_3$  groups. The peak at  $724.3\text{ cm}^{-1}$  due to C-H rocking (Asymmetric C-H bending).[7]

From fig.2(b) shows FTIR spectra of 7:6 PEG/LDPE. Characteristics peaks at  $3420.9\text{ cm}^{-1}$  confirm O-H stretching from PEGs group, often more prominent due to PEGs hydrophilic nature. The peak at  $2923.25\text{ cm}^{-1}$  due to asymmetrical C-H stretching vibrations of LDPE. The peak at  $1460.18\text{ cm}^{-1}$  and  $1358.91\text{ cm}^{-1}$  occurred due to C-H bending vibration and C-H bending of  $\text{CH}_3$  groups. The peak at  $725.27\text{ cm}^{-1}$  due to C-H rocking (Asymmetric C-H bending). The peak at  $1117.8\text{ cm}^{-1}$  due to strong C-O-C stretching vibration, confirming the presence of ether linkage from PEG.

Table 1: Frequency correlation in unfilled and PEG filled LDPE

S. No.	Frequency ( $\text{cm}^{-1}$ )		Vibration
	LDPE	PEG/LDPE	
1	3419.94	3420.9	O-H stretching
2	2924.21	2923.25	Strong C-H stretching
3	1460.18	1460.18	C-H bending
4	724.3	725.27	C-H rocking

FTIR spectra of 7:6 PEG/LDPE blend have superposition of individual spectra of PEG and LDPE observed slightly shifts in a peak intensity. Shift or intensity changes in the O-H or C-H stretching peaks suggest intermolecular interactions between PEG and LDPE.

### 3.3 X-ray Diffraction

To study structural properties of solid-state such as the degree of crystallinity for semi-crystalline, amorphous polymeric and composite materials, X-ray diffraction analysis (XRD) was used Crystallinity of the PEG/LDPE blends was examined using X-ray Diffraction (XRD)

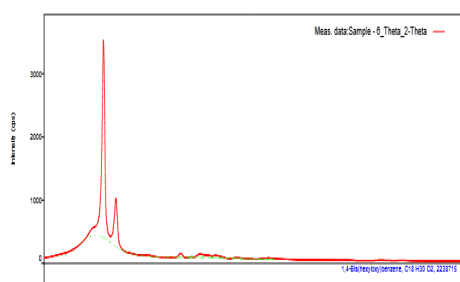


Fig.3 (a) XRD of pure LDPE

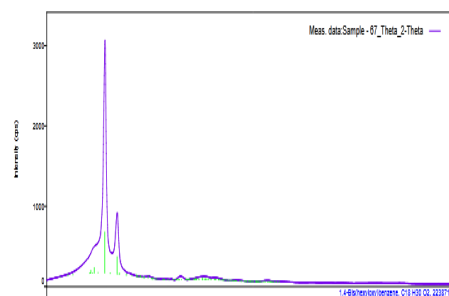


Fig.3 (b) XRD of 7:6 PEG/LDPE

From fig.3(a) shows XRD of pure LDPE. Two main broad peaks at  $21.33^\circ$  and a weak broad peak at  $23.67^\circ$ , corresponding to d-spacing is  $4.162 \text{ \AA}$  and  $3.756 \text{ \AA}$  respectively. These broad peaks indicate the semi-crystalline nature of LDPE corresponds to (110) and (200) reflections from the orthorhombic polyethylene crystals arose from crystalline and amorphous regions in LDPE [8]

From fig.3(b) shows XRD of 7:6 PEG/LDPE. A dominant fairly sharp peak at  $21.31^\circ$  and a weak broad peak at  $23.68^\circ$  corresponding to d-spacing is  $4.165 \text{ \AA}$  and  $3.753 \text{ \AA}$  respectively.

There might be slight shifts in the peak positions or changes in their intensities. This could be due to interaction between LDPE and PEG may not have strong interactions, resulting in minimum shifts.

Crystal size was calculated by using Debay Scherrer's formula.

$$D = 0.9 / \beta \cos \Theta$$

Where, D = Crystal size

$\lambda$  = Wavelength of X-ray

$\Theta$  = Bragg's angle in radian

B = Full width at half maximum

Table 2: XRD ,2θ and d-spacing values of pure LDPE and 7:6 PEG/LDPE samples

SAMPLE CODE	2θ	d-spacing	2θ	d-spacing
LDPE	$21.33^\circ$	$4.162 \text{ \AA}$	$23.67^\circ$	$3.756 \text{ \AA}$
7:6 PEG/LDPE	$21.31^\circ$	$4.165 \text{ \AA}$	$23.68^\circ$	$3.753 \text{ \AA}$

The crystal size of pure LDPE and 7:6 PEG/LDPE was found to be  $15.75 \mu\text{m}$  and  $14.43 \mu\text{m}$ . Thus, it is found that physically hinder crystal growth resulting in lower polymer crystallinity [9]

### 3.4 UV-Vis Spectroscopy

To analyze the UV-Vis spectroscopy characteristics of blend corresponding to 7:6 PEG/LDPE ratio, we need absorption properties of the blend in the ultraviolet-visible range (typically 200-1100nm).

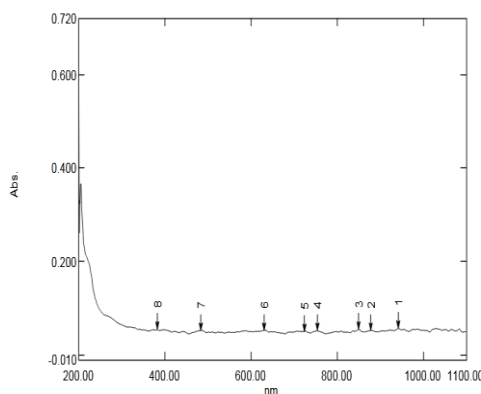


Fig.4 (a) UV-Vis spectra of pure LDPE

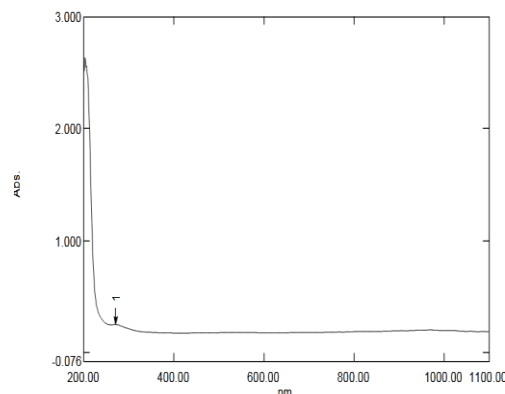


Fig.4(b) UV-Vis spectra of 7:6 PEG/LDPE

From fig.4(a) shows UV-Vis spectra of pure LDPE, Low absorbance overall with a small peak in the UV region 200-400 nm. Thus, LDPE is a saturated hydrocarbon polymer with minimal chromophores. It shows very little absorption in the visible range, which corresponds to LDPE being optically transparent.

From fig.4(b) shows UV-Vis spectra of 7:6 PEG/LDPE, Higher absorbance in the UV region compared to pure LDPE. A broad and weak absorption below 250 nm indicating the presence of PEG

UV-Vis spectroscopy confirms that blending PEG with LDPE modifies the optical properties, slight increases in absorbance between 200-300 nm may occur, attributed to structural reorganization, due to nanoprecipitation.

#### 4. Conclusions

The structural analysis of the 7:6 PEG/LDPE blend prepared via the nanoprecipitation method reveals significant changes in morphology, crystallinity, and interfacial compatibility. SEM analysis shows a relatively smooth, semi-porous surface morphology suggesting good phase distribution and interaction between the polymers. FTIR spectroscopy confirms the presence of both PEG and LDPE functional groups with evidence of intermolecular interactions. XRD patterns displays characteristic peaks of both PEG and LDPE reduced however slight shift in peaks indicate a decrease in crystallinity. UV-Vis spectroscopy highlights slight changes in light absorption reflecting increased phase interface.

#### Acknowledgement

We are very grateful to the Shivaji Science College, Amravati to provide XRD, UV and FTIR. Also grateful to the Pune University for providing SEM. We are also thankful to 4<sup>th</sup> Global Conference ETRD-2025 Organizing team to given an opportunity to present this paper.

#### Conflict of Interest

The authors say that there is no conflict of interest when it comes to publishing this study manuscript. The authors' ideas, results, and conclusions are their own and have not been affected by any personal, professional, or financial interests that could have an unfair effect on this work.

#### Source of Funding

The government, private groups, or non-profit groups did not give any money to this study project. The study was done on its own, without any outside help with money.

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