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Fabrication and Evaluation of EPDM/PVC Composite Films for Advanced Insulation and Structural Applications

Jisha Victor J.L[a], S. Ginil Mon[*a], Y. Jaya Vinse Ruban[b]

[a]Research Scholar (Reg. No. 21113112032009), Department of Chemistry & Research, Nesamony Memorial Christian College (Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli), Marthandam-629 165, Tamil Nadu, India.

*[*a] Corresponding Author, Department of Chemistry & Research, Nesamony Memorial Christian College, Marthandam-629 165, Tamil Nadu, India.*
E-mail:therocksgm@yahoo.com, Mobile No. +91-9994029920, Fax No. +91-4651-272059

[b]Department of Chemistry & Research, St. Xavier's College (Autonomous), Palayamkottai, Tirunelveli-627 002, Tamil Nadu, India

The development of new polymer composites with enhanced properties is a rapidly evolving field, especially in high-performance engineering applications where ease of processing is indispensable. Composite materials are extensively utilized in aerospace, automotive, and structural engineering sectors due to their superior physico-chemical properties and application-specific versatility. Among these, rubber-based composites hold significant industrial relevance owing to their lightweight nature, high flexibility, hydrophobicity, low cost, and ease of fabrication.

In the present study, EPDM/PVC nanocomposite films were prepared at varying concentrations to investigate their mechanical and thermal properties. The composites were synthesized via a solution blending method, wherein EPDM and PVC were refluxed in toluene at 60 °C under constant stirring for 5 hours. The resulting blends were cast into films using glass moulds and allowed to air dry. Mechanical properties such as tensile strength and hardness were evaluated, alongside thermal conductivity and insulation performance, using standard ASTM methods. The results demonstrated improved mechanical strength, enhanced thermal insulation, and increased material robustness with specific blend ratios. These findings indicate the potential applicability of EPDM/PVC composites in advanced thermal insulation systems, flexible electronics, and high-performance engineering components.

Keywords: EPDM/PVC Blend, Mechanical properties, thermal conductivity

INTRODUCTION

Ethylene Propylene Diene Monomer (EPDM) rubber is a widely used synthetic elastomer known for its excellent resistance to heat, ozone, and weathering. EPDM is synthesized from monomers such as ethylene, propylene, and a non-conjugated diene, typically dicyclopentadiene (DCPD), ethylidene norbornene (ENB), or vinyl norbornene (VNB). To develop functional rubbery properties, EPDM must be compounded with fillers (e.g., carbon black, calcium carbonate), plasticisers (e.g., paraffinic oils), and other additives. Furthermore, it requires crosslinking—either sulfur vulcanization or peroxide curing—to achieve its final performance characteristics. Due to its outstanding durability and resistance to environmental degradation, EPDM is extensively used in outdoor and automotive applications, including door and window seals, roofing membranes, solar panel heat collector systems, electrical insulation, and weather-resistant gaskets. EPDM also shows good low-temperature flexibility and electrical insulation properties, making it valuable in both structural and electrical sectors.

Polyvinyl chloride (PVC) is the third most widely produced synthetic polymer globally and is valued for its versatility, chemical resistance, and cost-effectiveness. Rigid PVC is extensively used in construction for pipes, window frames, doors, and siding. Flexible PVC, produced by adding plasticizers, is commonly used in electrical cable insulation, inflatable products, food packaging, and synthetic leather. PVC has a maximum continuous service temperature of around 60 °C, above which thermal distortion may occur. It resists corrosion, weathering, and most chemicals, which makes it highly suitable for harsh and chemically aggressive environments. PVC's adaptability has also extended into areas such as wire ropes (where a PVC coating enhances handling and corrosion resistance), musical instruments (as a cost-effective alternative to metal), and medical devices. Furthermore, its flame retardancy and electrical insulation characteristics make it an ideal material for safety-critical applications.

Both EPDM and PVC are industrially important polymers owing to their cost-efficiency and performance across diverse environmental conditions. EPDM, as a thermosetting elastomer with superior ozone, UV, and weather resistance, complements PVC, a thermoplastic polymer with excellent rigidity, chemical resistance, and formability. However, blending these polymers presents a significant challenge due to their inherently different polarities—EPDM being non-polar and PVC being highly polar. This incompatibility often leads to phase separation and weak interfacial adhesion, which can negatively impact the composite's mechanical and thermal properties.

To overcome these limitations, researchers have explored the use of compatibilizers, reactive blending, nanofillers, and modified processing techniques. The objective is to enhance the interfacial bonding between the two phases and develop composite materials with synergistic properties. Successfully combining EPDM and PVC can open pathways to advanced materials that integrate the flexibility and weatherability of rubbers with the chemical and structural advantages of thermoplastics, particularly for use in insulation, flexible tubing, automotive interiors, and weather-sealing systems

EXPERIMENTAL DETAILS

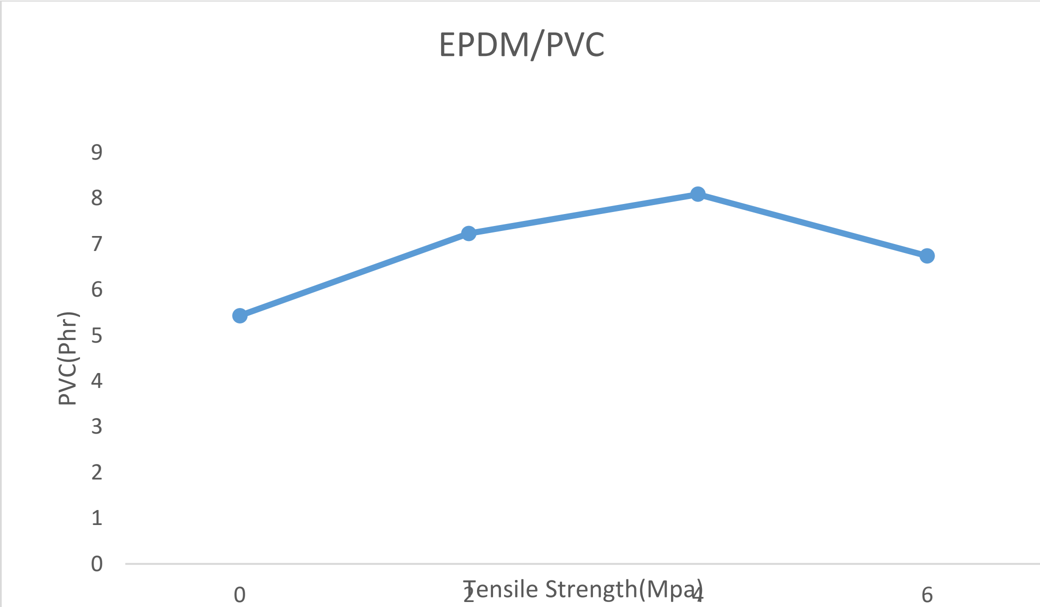
MATERIALS

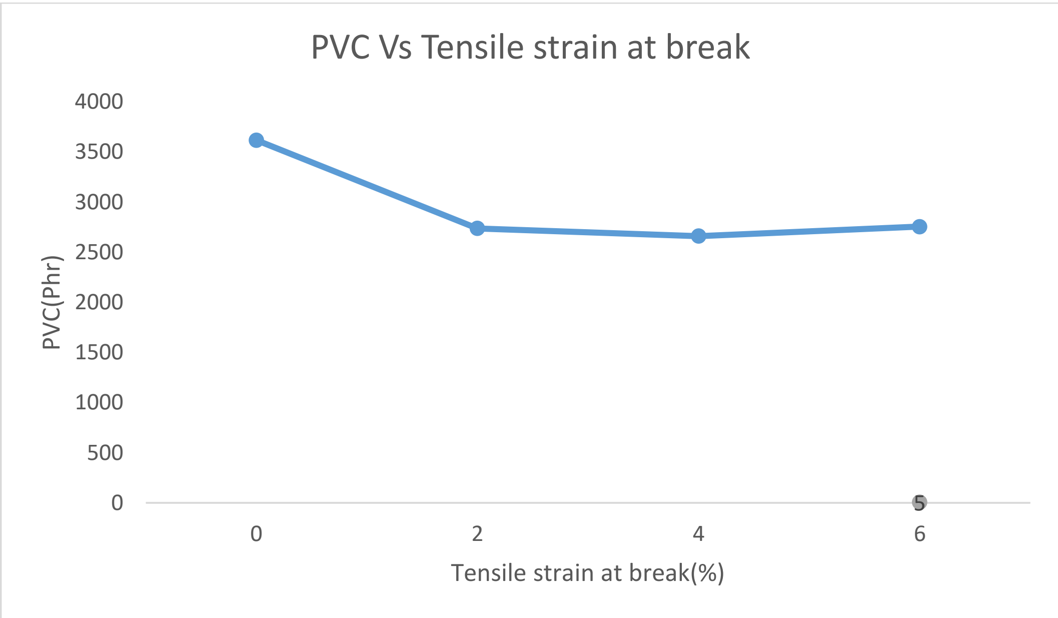
EPDM rubber sample pack was obtained from Dupont–Dow. PVC was obtained from local market. Toluene and cyclohexane were supplied by CDH, New Delhi. Double distilled water was used throughout the study.

BLEND PREPARATION

PVC-EPDM nano composites films of various concentrations were prepared by refluxing with toluene at 60^{o}c with constant stirring for 5 hours. 4g of EPDM is mixed with 100ml toluene and refluxed using a mechanical stirrer at 60c with constant stirring for 5 hours. After four hours of reflexion 0.4 g of PVC dissolved in 5ml cyclohexanone and 10ml of toluene and 0.8 g of dichromyl peroxide is added to the refluxing solution. The films were collected after the refluxed solution was air dried in glass moulds.

The mechanical testing of the films was evaluated. PVC/EPDM composites were carried out according to ASTM D882. The sample was fixed between the upper and lower pneumatic grips with a gauge length of 10mm.A cross head speed of 500mm/min was used. The sample were analysed up to failure at Sree Chithra Tirunal Institute for Medical science and Technology (Thiruvananthapuram). Shore-A hardness measurements were performed with a Durometer Prufstander model OS-2 (Hildebrand, Germany) following the ASTM D2240 standard. At least five tests were carried out for each composition. The thermal conductivity was measured using a heat-flow meter (NETZSCH 446 Lambda Small, Selb, Germany) in accordance with the ISO 8301 standard. The area of the specimen was 50 mm × 50 mm. The instrument was calibrated by measuring a NETZSCH reference sample of expanded polystyrene. Typical accuracy of the heat-flow meter (HFM) is ± 1%. The measurements were performed at mean sample temperatures of 0 °C, 5 °C and 10 °C under nitrogen flux (10 mL/min) while a 20 °C temperature difference between hot and cold plates was maintained.





The mechanical properties showed significant improvement of EPDM/PVC composites with neat EPDM. The mechanical testing was performed on the EPDM/PVC blend under different concentration of PVC and variation in tensile strength (fig.1) shows that there is a small increase of tensile strength until 2% of PVC content and almost doubled at for 4% of PVC content. Tensile strength decreases at 6% of PVC. That is maximum tensile property occurs at 4% of PVC. Fig2 shows effect of PVC on tensile strain at break. Incorporation of PVC decreases the tensile strain at break. Least value occurs at 4% of PVC. Fig 3. shows that change in the modulus when different concentrations of PVC added to 100% EPDM. Modulus increases considerably at 4% of PVC then decreases.

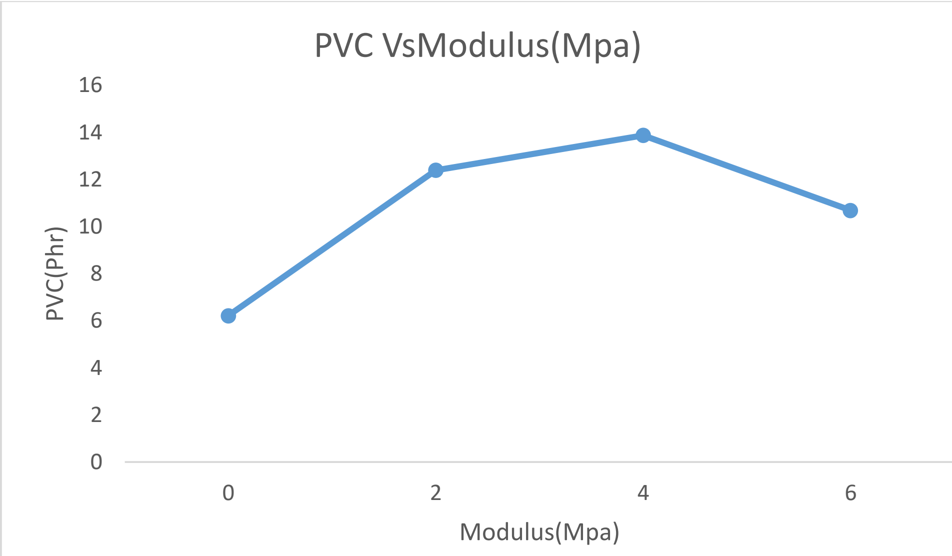


Table 1: Mechanical Properties of EPDM/PVC Blends

Amount of PVC (phr)	Tensile Modulus MPa	Tensile Strength MPa	Elongation at Break	Shore A Hardness	Geodensity g/cm3
0	6.22	5.43	3617.82	35.33	0.578
2	12.4	7.23	2736.73	46.47	0.652
4	13.88	8.09	2660.07	55.89	0.755
6	10.69	6.74	2754.6	65.03	0.814

The best combination to be considered for further study is the sample with 4 phr PVC. The decrease in elongation is attributed to the less elasticity of PVC compared to the EPDM rubber. Since the PVC-EPDM combination has blended well in the given composition, there is increase in the tensile strength. This incorporation of PVC in EPDM will be provide additional properties to the matrix.

Table 2: Thermal Conductivity of the Films

	Thermal Conductivity W/m.K		
Amount of PVC (phr)	0ºC	5 ºC	10 ºC
0	0.068	0.0704	0.0718
2	0.0841	0.0848	0.0852
4	0.0712	0.0719	0.0725
6	0.0641	0.0645	0.0648

The Shore A hardness of the samples increases on addition of PVC (Table 1). This is due to the absence of elasticity in PVC which when added to the rubbery EPDM decreases the eleasticity and increases the rigidity.The low-density blend panels were then evaluated for their insulating behaviour. The thermal conductivity values of all the samples were obtained at three different mean sample temperatures (i.e., 0 °C, 5 °C and 10 °C) and are compared in Table 2. As expectedly, all the samples including the pure expanded EPDM panels showed roughly similar thermal conductivity behaviour apart from some exceptions. Notably, EPDM-2PVC showed relatively higher thermal conductivity values probably due to lack of optimum time required to evaporate the moisture in the blend panel. On the other hand, EPDM-2PVC 10ºC also showed higher thermal conductivity owed to the fact that too much temperature resulted in the escape of moisture from the panel before the expansion was allowed. The same could be presumed for the EPDM-4PVC also showed peculiar result respect to other blend panels. Overall, the positive effect of PVC in EPDM can be seen in which the PVC not only reduces the thermal conductivity by 25% (Mahmood and Pegoretti, 2021) but also provides the possibility to expand the EPDM rubber due to the presence of moisture in the PVC. Overall, such contribution led to achieve lowest thermal conductivity values for samples containing 6 phr PVC by weight.

CONCLUSION

EPDM rubber was combined with PVC in various compositions. The prepared samples were subjected to mechanical analysis. The addition of PVC improves the mechanical properties of the mechanical properties of the EPDM/PVC blend as compared to clean EPDM with a small change in elongation which is insignificant in this case. 4 phr PVC added sample is the best one in this combination. The thermal conductivity of the samples decreases with the amount of PVC. Additionally, the expansion in the rubber matrix positively induced thermal insulation behavior where the thermal conductivity values reached a minimum as low as 0.065 W/m.K.

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