

PVC/LDPE Blends: Relationship Between Thermal/Mechanical Properties, Structure and Blend Behaviour

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Abstract. In this paper the effect of LDPE content in PVC foams are examined on the structure of both the foam and the LDPE. We attempt to understand how LDPE content affects the structure of PVC in blends and how it changes the glass-transition (T_g). These parameters often provide important information related to the overall macromolecular structure of the polymer blend. Thermal analytical techniques such as differential scanning calorimetry (DSC) often used to determine the structural transformation of samples. The effect of the miscibility and composition of the PVC/LDPE foam blends on the thermal stability were also investigated.

Introduction

Polymer blends are usually classified as homogenous mixtures, in which the components are miscible and the inhomogeneous blends, in which the components are immiscible. It is well known that the binary mix of PVC and LDPE at molecular level typically unmixed because of the poor interphase. Due to the poor interaction between the two polymers the mechanical properties deteriorate [1]. Most of the polymer blends are immiscible due to the small combinatorial entropy and positive enthalpy of mixing [2]. In order to improve the miscibility of the mixture, often use solid phase dispersants are used such as CPE, EPDM, ABS and PU, which improve the tensile strength of the blends. A study has reported that by mixing PVC and LDPE short chain LDPE grafted PVC copolymers can be formed. In addition, if dicumyl-peroxide (DCPE) initiator is used a phase dispersed cross linked PVC-LDPE can be formed. This results in improved mechanical and thermal properties [3].

The other researcher work of Arnold and Maund [4] and Minsker [5] investigated the structural impurity of PVC due to thermal decomposition. They have found that medium density polyethylene accelerated the PVC degradation process by 0.2%. The results can be explained by the formation of PE free radicals. The increase of free radicals removed the stabilizer compounds from the system that resulted in the rapid degradation of PVC.

Pospisil investigated the thermo-mechanical and thermal decomposition properties of various polymer blends. The results of the research are that PVC blended with LDPE withstands the processing temperatures of 180°C. If the PVC/PE mixtures temperature is raised above the PE's melt temperature and at the same time the PE content is high in the blends then the decomposition of PVC is more significant [6].

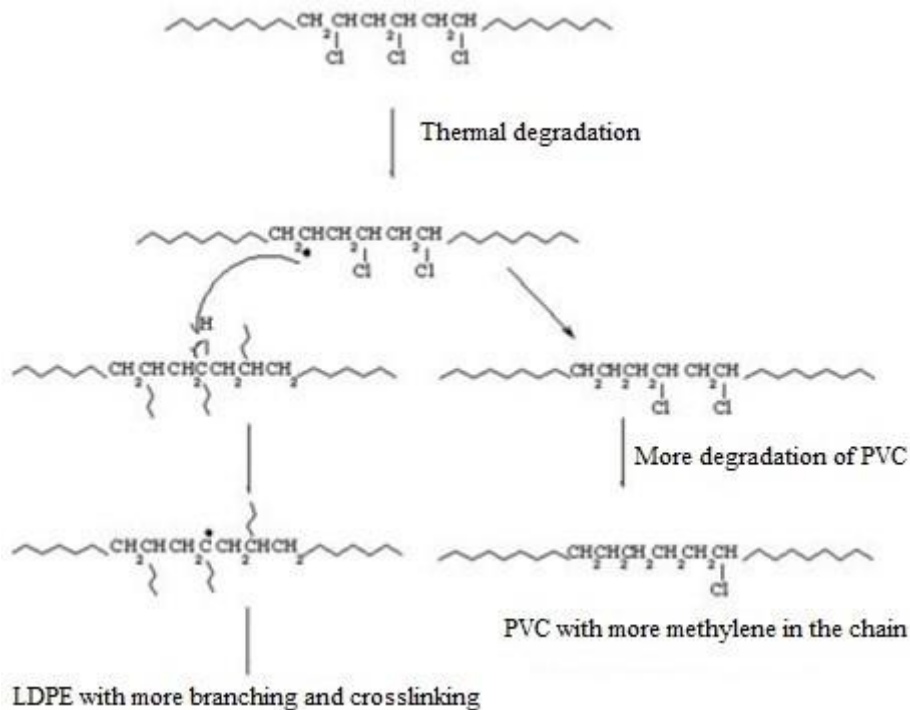


Figure 1. PVC thermal degradation [6]

1. Experimental

1.1 Materials

The study was performed in two different formulations: “A” – PVC foam compound without LDPE and “B” – PVC foam compound with LDPE. The foamed PVC/LDPE blend was prepared according to the following composition: PVC resin (k-value=57)/Ca-Zn stabilizer/paraffin wax/lubricants/processing aid/CaCO₃/azodicarbonamide/LDPE. The “A” PVC foam contained every required additive except the LDPE polymer. Poly (vinyl-chloride) and low density polyethylene (LDPE) materials used in this work were kindly supplied by the BorsodChem Zrt. PVC was used as base material of the samples. The bowling agent was added at 1.5phr.

1.1.1 Mixture preparation

The ingredients were dry-blended (PVC – LDPE mass ratio100/20) in a high speed mixer, in which the temperature was set to 110°C. Foams were produced by an extrusion technique. Using a twin screw laboratory extruder and the temperature profile was 170/175/175/180/185°C. The final thickness of the sheets was approximately 4 mm.

1.2. Measurement methods

Various mechanical tests were performed, such as hardness-, tensile- and impact tests.

Based on principle of Archimedes, the density values were determined by water immersion measurement with a METTLER TOLEDO digital analytical scale.

The hardness tests were carried out with a Zwick/Roell durometer on the D scale. Twenty measurements were taken on each sample.

The tensile tests were performed on a INSTRON 5566 universal testing machine at room temperature (23 ± 1 °C, 50%RH). The cross-head speed was 100 mm/min.

Impact tests were carried out on a CEAST 6545 testing machine. During the Charpy tests a 2J hammer was used. The radius of notch was 0.25 mm, depth 2 mm. Seven specimens were tested from each sample both for tensile and impact tests.

The SEM analysis carried out with ZEISS measuring equipment. The morphology of the foam profile was studied by using optical microscopy. Scanning electron microscopy (SEM) was done to analyse the fracture surface of the samples. The mechanical properties of the foams will be greatly influenced by the material's internal cells structure. Further affects are: the cell size, cell shape, cell wall thickness and the material density.

DSC measurements were made on a METTLER TOLEDO analyser. The glass transition temperature was measured using differential scanning calorimetry. The heat stability and processing of the material can be determined by the measurement results.

2. Results and Discussion

Significant improvement was observed in case of LDPE additive containing samples on the density- and hardness values. The "B" material is stronger and more rigid than the other foam. The density results confirmed these facts since LDPE has higher hardness value than the neat foam polymer. The LDPE has a strengthening effect in the foam structure. As it increases the polymer content, and thus the wall thicknesses.

The tensile tests results show "A" material has lower strength properties than the "B" type of polymer blends. This is also the result of the above mentioned wall thickness increase.

Impact testing has shown that the impact strength values decrease, which is expected in a multiphase polymer system. This proves the poor compatibility between the PVC and the LDPE phases. As it has been mentioned previously these is a need for solid phase dispersants, compatibilizers in the foam.

Sample	Shore D	Density [g/cm ³]	Tensile strength [MPa]	Impact strength [kJ/m ²]
PVC foam	37.76±1.5	0.7±0.0	15.0±1.1	2.2±0.0
PVC/LDPE foam	60.3±1.1	1.1±0.0	27.9±1.3	0.9±0.0

Table 1. Results of the mechanical tests of PVC/LDPE samples

In order to evaluate the changes in surface morphology of the polymer blends samples were subjected to scanning electron microscopy. The morphology of immiscible polymer blends depends on the

component, ratios; components melt viscosities and processing conditions as well. SEM microscopy clearly shows the difference in the structure of the polymer foam blends. From Figure 2 – “B” are completely incompatible. Figure 2 – “A” shows the original PVC foam and its well-formed cellular structure.

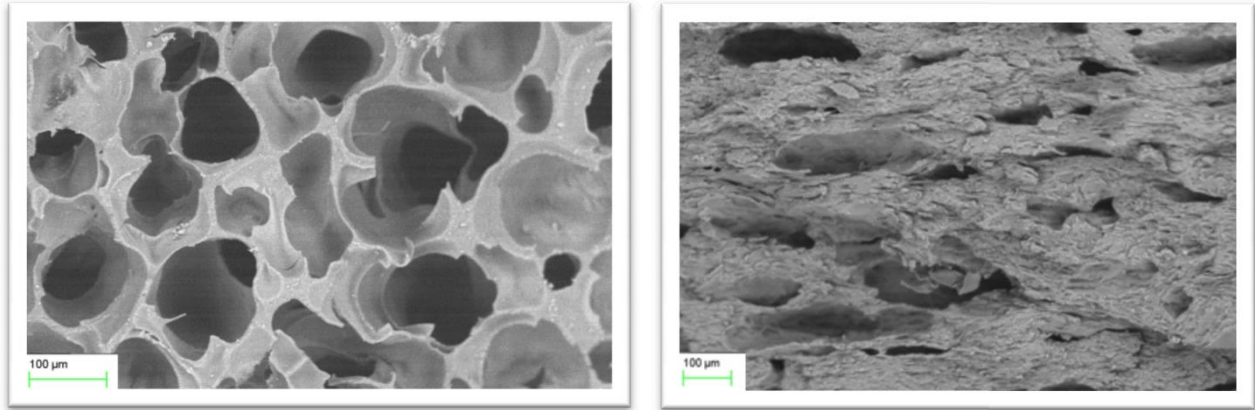


Figure 2. Scanning Electron Microscope fractured structure of “A” (left) and “B” (right) foam

Figure 3 of sample “B” shows the DSC curve for a “B” compound polymer foam which contains Low Density Polyethylene (LDPE). From this curve we observed the melting temperature for the LDPE are approximately 110.4 °C. The peak of the 160.38° and 191.71°C shows the processing temperatures of PVC materials. The 184°C and 90% interpreted the extrusion process of the “B” foam material. In contrast to the Figure 3 – “A” shows the result of origin “A” foam, where the processing temperature can be determined (197°C).

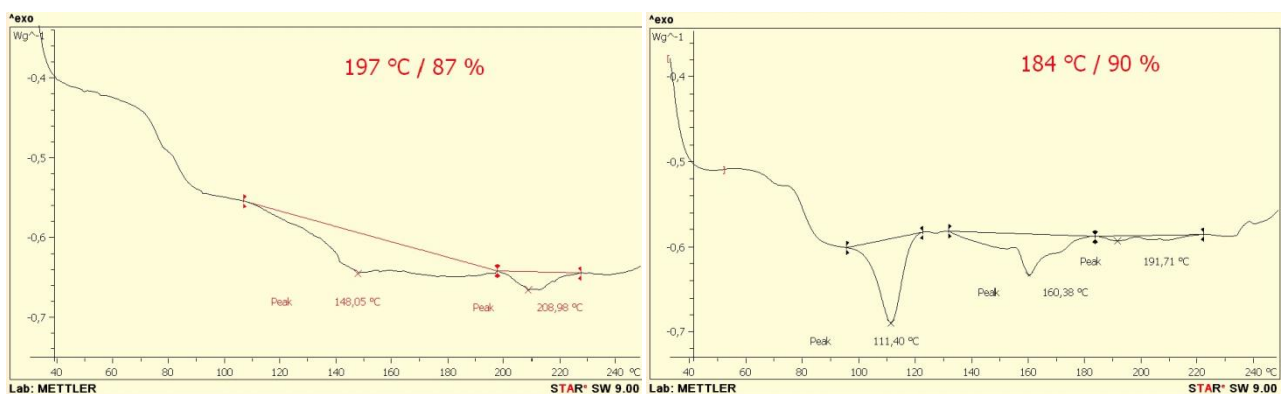


Figure 3. DSC curves of “A” (left) and “B” (right) blends

Conclusion

Our purpose is to examine the thermal-, structural and the mechanical properties of PVC/LDPE blends for foam applications. Signs of thermodynamic incompatibility of PVC and LDPE polymers were observed during the SEM analysis. The results show that the LPDE as an additive for PVC deteriorates the properties of the composite. As a result, we have experienced the formation of different phases. To avoid an inhomogeneous structure, the uses of coupling agents are necessary in order to increase the

compatibility between the two polymers. Usage of compatibilizing agents could lead to more homogeneous improved blends.

Acknowledgments

The described article was carried out as part of the EFOP-3.6.1-16-2016-00011 “Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation” project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.”

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