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# Surface Observation and Pore Size Analyses of Polypropylene/Low-Melting Point Polyester Filter Materials: Influences of Heat Treatment

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**Abstract.** This study proposes making filter materials with polypropylene (PP) and low-melting point (LPET) fibers. The influences of temperatures and times of heat treatment on the morphology of thermal bonding points and average pore size of the PP/LPET filter materials. The test results indicate that the morphology of thermal bonding points is highly correlated with the average pore size. When the temperature of heat treatment is increased, the fibers are joined first with the thermal bonding points, and then with the large thermal bonding areas, thereby decreasing the average pore size of the PP/LPET filter materials. A heat treatment of 110 °C for 60 seconds can decrease the pore size from 39.6 μm to 12.0 μm.
**Keywords:** polypropylene, low-melting polyester, filter material, heat treatment, average pore size.

## 1 Introduction

Air pollution poses threats to health, and this concept has been widely accepted by the public. According to the World Health Organization (WHO), air pollution ranks as the 14th most fatal factor in terms of global deaths [1]. The common airborne pollutants, including

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Carbon monoxide, Nitrogen dioxide, Trioxygen, particulates, Sulfur dioxide, and Plumbum, can cause different degrees of harm to people's health [2-4].

Air filters can be divided into mechanical capture and electrostatic adhesion types [5-7]. Mechanical capture requires very fine fibers that provide the filter materials with small pores, and moreover, it is also a relatively easy process. Filter materials used in mechanical capture are commonly woven fabrics or nonwoven fabrics. Nonwoven fabrics account for the majority of filter materials, and can filter pollutants according to the pore size of nonwoven fabrics.

The commercially available filter materials are primarily composed of polypropylene (PP) due to its chemical resistance and hydrophobic properties that allows for a wide variety of applications. These filter materials are primarily made by using PP fibers and a melt blown method that has a high energy cost. In this study, PP fibers are made by needle punching and heat treatment, and the fibers can thus be formed with a three-dimensional structure without reaching the necessary melting points of PP. The proposed experimental design is thus power efficient. This study uses nonwoven fabric manufacturing for the preparation of filter materials, during which the parameters of heat treatment are varied in order to change the pore size of PP/low-melting-point polyester (PET) filter materials, thereby attaining the goal of blocking small-size pollutants.

## 2 Experimental

Polypropylene (PP) fibers (Taiwan Polypropylene Co., Ltd.) have a fineness of 3 denier (D) and a length of 51 mm. Low-melting polyester (LPET) fibers (Far Eastern New Century Corporation, Taiwan) have a fineness of 4D and a length of 51 mm. The fibers are respectively processed via opening, and are then blended at a ratio of 1:1. The mixtures undergo carding and laminating, and heat treatment, whose parameters are tabulated in Table 1, in order to form PP/LPET filter materials. Differential scanning calorimetry (DSC) and a scanning electron microscope (SEM) are then used to evaluate the morphology of the thermal bonding points and the pore size of PP/LPET filter materials. Samples are denoted with the temperature ($^{o}$C) /time (second) of the heat treatment. For example, 70/30 refers to filter materials that are thermally treated at 70 oC for 30 seconds.

**Table 1.** Parameter of heat treatment of PP/LPET filter materials.

| Sample Code / Conditions | 70/30 | 70/60 | 90/30 | 90/60 | 110/30 | 110/60 |
|---|---|---|---|---|---|---|
| **Temperature ($^{o}$C)** | 70 | 70 | 90 | 90 | 110 | 110 |
| **Times (second)** | 30 | 60 | 30 | 60 | 30 | 60 |

## 3 Measurements

### 3.1 Differential Scanning Calorimetry (DSC)

Samples are placed in the DSC (Q20, TA Instruments, US), and are then heated from 40 ˚C to 200 ˚C in increments of 10 ˚C/min. The DSC curves are recorded.

### 3.2 Scanning Electron Microscope (SEM)

An Ion Sputter (E-1010, HITACHI, Japan) is used to apply a thin layer of gold on the samples for 30 seconds. An SEM (S3000, HITACHI, Japan) is then used to observe the surface of the samples in order to analyze the morphology of thermal bonding points and pore sizes.

## 4 Results and Discussion

### 4.1 Effects of Heat Treatment on the Morphology of PP/LPET Filter Materials

Figure 1 shows that the thermal bonding area is increased as a result of increasing heat treatment time. When fiber mixtures are thermally treated for thirty seconds, the thermal bonding points are present where the fibers have contact, as indicated in Figure 1 (c and e). A heat treatment for sixty seconds causes the thermal bonding points to enlarge into a flake-like thermal bonding area. A long heat treatment allows more time for fibers to be softened, melted, and flow. As a result, the morphology of thermal bonding points is signficantly expanded into thermal bonding areas. This transformation of morphology is associated with the melting points of LPET fibers. The LPET fibers have a core-sheath structure, and the melting point of the sheath is 73.16 oC, as indicated in Figure 2. Increasing the temperature of heat treatment results in high mobility of the melted sheath, and eventually an increasingly large thermal bonding area. Moreover, as shown in Figure 3, the melting point of PP fibers is 166.00 $^{o}$C, indicating that the heat treatment barely influences the PP fibers.

### 4.2 Effects of Heat Treatment on the Pore Size of PP/LPET Filter Materials

The average pore size of PP/LPET filter materials is decreased as a result of an increase in heat treatment time, as indicated in Table 2. A long hot treatment provides the LPET fibers with plenty of time to flow, which in turn increases the thermal bonding area and simultaneously decreases the pore size of the filter materials. Similarly, a high temperature in heat treatment also decreases the pore size. A high temperature in heat treatment contributes to a high mobility of the melted sheath of LPET fibers, which in turn increases the thermal bonding area and decreases the average pore size. As a result, both the increasing temperature of heat treatment and heat treatment time have a positive influence on the average pore size, as indicted in Figure 4.

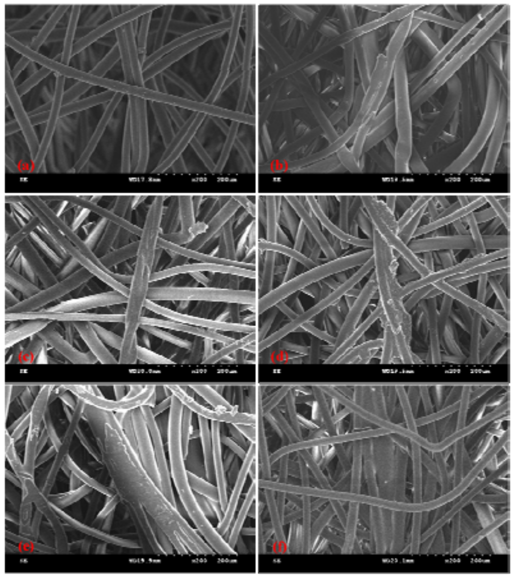


**Figure 1.** SEM images (200x) of the morphology of PP/LPET filter materials in relation to temperature/time of heat treatment of a) 70/30, b) 70/60, c) 90/30, d) 90/60, e) 110/30, and f) 110/60.

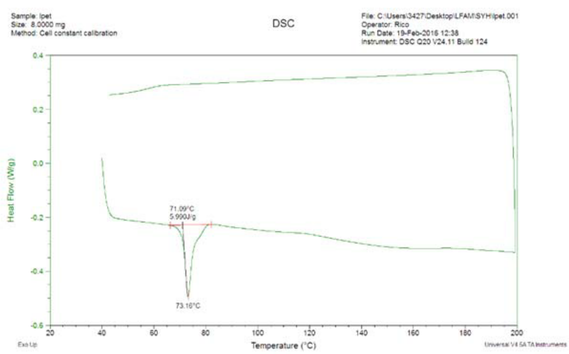


**Figure 2.** DSC curves of LPET fibers. The   increments are 10 oC/min.

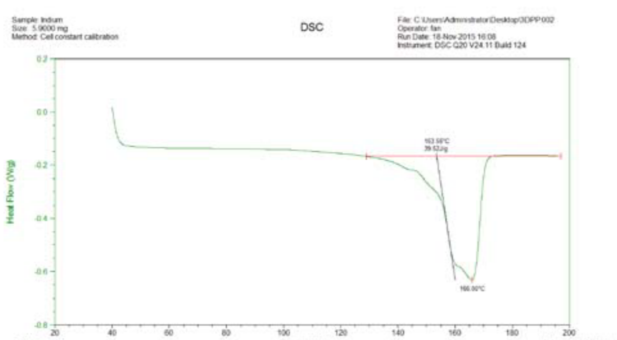


**Figure 3.** DSC curves of PP fibers. The increments are 10 oC/min.

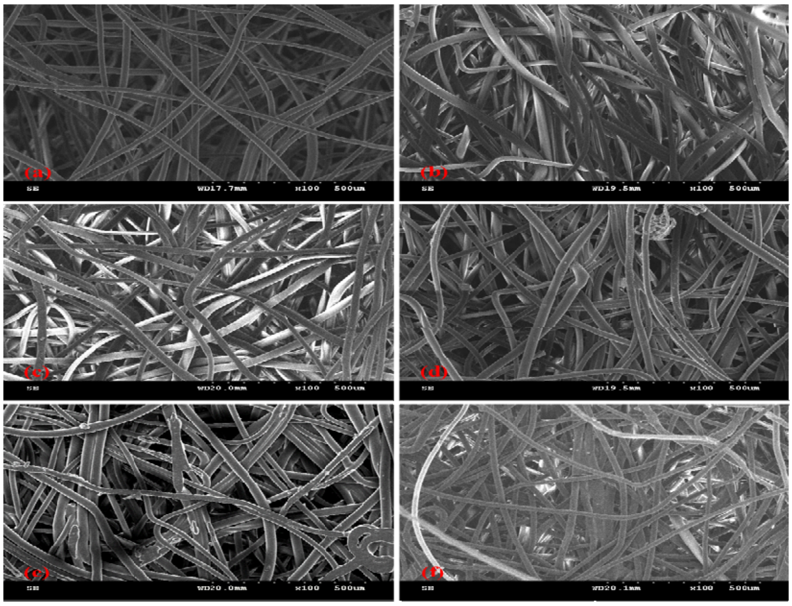

**Figure 4**. SEM images (100x) of the morphology of PP/LPET filter materials in relation to temperature/time of heat treatment of a)70/30, b)70/60, c) 90/30, d)90/60, e)110/30, and f)110/60.

**Table 2.** The pore size of PP/LPET filter materials in relation to heat treatment.

| Sample Code | Average Pore Size (μm) |
|---|---|
| **70/30** | 39.6±10.4 |
| **70/60** | 25.4±3.8 |
| **90/30** | 24.6±6.1 |
| **90/60** | 20.2±4.0 |
| **110/30** | 20.3±3.6 |
| **110/60** | 12.0±2.7 |

## 5 Conclusion

This study successfully examines the relationship between heat treatment conditions and the pore sizes of PP/LPET filter materials. An increase in the temperature or heat treatment time effectively decreases the average pore size of the filter materials. This study can serve as a reference for future studies on evaluations and analyses. Moreover, in this study, only the average pore size and the morphology of thermal bonding are examined; therefore, it is suggested that future studies explore the influences of the amount of LPET fibers on the porosity of the filter materials.

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