

A STUDY ON MICRO-PORE FORMATION INDUCED BY LASER PROCESSING IN POLYETHYLENE(PE) FILM WITH CHEMICAL BLOWING AGENT AZODICARBONAMIDE(ADCA)

Chae Yoon Shin¹, Bosung Shin^{*1,2}

1. Department of Cogno-Mechatronics Engineering, Pusan National University

2. Department of Optics and Mechatronics Engineering, Pusan National University

Busan, 609-735, Republic of Korea

* E-mail: bosung@pusan.ac.kr

ABSTRACT

In this study, pore formation in polyethylene (PE) film with azodicarbonamide (ADCA) was induced by laser processing. We investigated the process of pore formation by observing the distribution of the pores formed in the film and examining how they varied depending on the beam diameter. A PE film containing 2% ADCA was prepared with 0.02 mm thickness and attached to a copper plate inclining 45 degrees. The number of laser processing was 1, 2, 3, 5, and 10. Pores were observed through an optical microscope, and analyzed according to the number of laser processes. Additionally, the fluence was changed gradually due to the film attached to the diagonal surface, which created diverse pores. The diameter of the pores ranged from 6.73 to 30.43 μm after the laser pulses were applied. Furthermore, when laser processing was conducted with the film attached to an inclined surface, the number of pores increased as the focus approached, and the shapes became clearer. This demonstrated that ADCA foamed appropriately depending on the fluence, allowing us to infer the pore formation process.

KEY WORDS

Chemical blowing agent, polyethylene, laser processing, pore formation

1. INTRODUCTION

Porous polymeric films have been widely applied for various industrial purposes. These polymeric films have advantages such as selective permeability, elasticity, stability, and lightweight properties.¹ For food packages, porous films are capable of extended storage of fresh vegetables and fruits, by regulating humidity and concentration of oxygen.^{2,3} For filtration purposes, these films function as effective barriers of particulates such as contaminants in water or air systems, while allowing fluid or gas to pass through.⁴⁻⁶ In the biomedical engineering field, these polymeric films with porous structures can provide improved breathability, supplying adequate oxygen to wound sites while simultaneously protecting them from external contaminants. Additionally, when developed as patch forms with drugs embedded in the porous

structure, they enable effective and sustained drug delivery.⁷ Given these applications, development of efficient methods to control the porosity and pore structure of films has become important.

Polyethylene (PE) is a polymer with high-performance for its durability and flexibility and is widely used in industrial products.⁸ Azodicarbonamide (ADCA) induces foaming in plastics through thermal decomposition, increasing the porosity.⁹⁻¹¹ By combining PE with ADCA, ADCA acts as chemical blowing agent forming pores within the PE under thermal decomposition, thereby enhancing the permeability and functionality.¹²

Laser processing, a non-contact technique for precise micro-machining of materials with high accuracy, can facilitate the thermal decomposition of ADCA in PE films, resulting in pore formation with controlled location and size. In this paper, we induced the pore formation the micro-pore formation within PE film and measured the morphology and distribution of pores under different laser fluence.

2. METHODS

2.1 Laser processing

Polyethylene (PE) film containing 2% ADCA was fabricated with a thickness of 0.02 mm. The film was fixed at a 45-degree inclined surface, and laser processing was performed using a 450 nm wavelength laser (5 W power, 2500 Hz pulse frequency, and 5 ns pulse duration). The laser focus was aligned to the center of the film, and laser scanning was performed from the top to the bottom of the inclined surface. The scanning was set to 1, 2, 3, 5, and 10 times. (see Fig. 1)

2.2 Laser fluence and temperature

To calculate the fluence values that vary across each processed region on the film fixed at a 45-degree inclined surface, the following equation was used. The temperature applied to the film was determined in polar coordinates based on laser irradiation, considering fluence, material constants, and thermal diffusivity. The processed regions of the film were classified into types a, b, c, d, and e. The laser parameters used in this experiment

included laser spot diameter, wavelength, pulse frequency, pulse duration, average power, peak power per pulse, and absorption rate. The absorption rate was derived using values for the density, specific heat, thermal conductivity, and thermal diffusivity of ADCA. Using these values, the fluence per pulse and the maximum temperature at the center were theoretically calculated.

2.3 Pore observation

After laser processing, we observed the pores in PE films by optical microscopy, and counted the pores in different sites by using Image J.

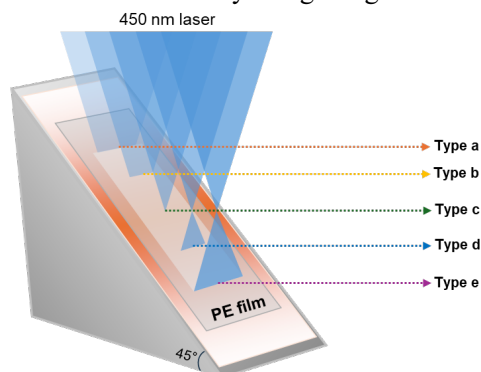


Fig. 1. Schematic diagram of laser processing on PE film with ADCA 2%

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