카본블랙/나일론 66 혼합 나노섬유웹의 마이크로파에 의한 접착거동

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Bonding Behavior of Carbon Black/Nylon 66 Hybrid Nanofiber Webs via Microwave Heating

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1. Introduction

Conventional heating the heat source cause the molecules to react from the surface toward the center so that successive layers of molecules heat in turn. The product surfaces may be in danger of over heating by the time heat penetrates the material. Microwave, however, produce a volume heating effect. All molecules are set in action at the same time. It also evens temperature gradients and offers other important benefits such as selective heating. Microwave heating is widely used of its efficiency in various field.[1] But there have been a little studies aimed at thermal-bonding of fiber by microwave heating.[2,3] In dielectric heating, the dielectric constant of materials must be high so as to increase heat-quantity emitted materials. Since most of thermoplastic fibrous materials have low dielectric constant[4], it is very difficult to directly bond fibrous materials by dielectric heating. Thus, microwave bonded thermoplastic fibers using organic solvents and spaying inorganic particles were previously studied.[4,5] The previous study is not eco-friendly and need extra processing. Also, there have been no studies aimed at bonding and strength of electrospun nanofiber webs.

Thus, the Nylon 66(N66) nanofiber webs are produced with the Carbon black(CB) particles having high permittivity by the electrospinning method in this study. And we investigate the bonding behavior and strength properties of CB/N66 hybrid nanofiber webs(HNFW) with microwave treatment time.

2. Experimental

The N66 chips(Solusia Co., France) with the number average molecular weight of 27,000 was used. And the dielectric constant and particle size of the used CB(Korea Carbonblack Co., Korea) are 1000[6] and 25nm, respectively. Also, dielectric constant of general N66 was 3.03.[7] The CB/N66 HNFW were produced by the electrospinning method in our laboratory with different CB contents(0 and 3wt.%). The electrospinning condition for making samples was electrical potential of 30kV, spinning distance of 10cm and collecting time of 10min. Samples were treated by the microwave system with a multi-mode furnace consisted of a steel rectangular cavity of 34cm× 22cm×34cm. Microwave energy was supplied by a 720W 2450MHz microwave generator(LG Co., Korea) and entered the furnace through a port in one end of the cavity. Samples were placed on a rotating table and treated with different time(0~7min).

Scanning electron microscope(S-2350, Hitachi Co., Japan) was employed to investigate the morphological structure of the sample. To observe of strength properties, the thickness of samples was measured by used webs weight. Weight and thickness measurements were made using an electronic balance(AB204-S, Mettler toledo Co., Switzerland) having a sensitivity of ±0.1mg. and the thickness gauge for fabrics(Custom scientific instruments. INC., Germany), respectively. The tensile strength and tearing force of samples were measured by tensile tester(Instron 4467). The sample sizes of tensile strength and tearing force were 70mm×10mm and 50mm×20mm, respectively. A both tester crosshead speed was used 2mm/min, load cell was 5kgf.

3. Results and discussion

Figure 1 shows the surface structure of bonding region of the CB/N66 HNFW by microwave heating with different treatment time. The bonding region increased with increasing treatment time, since it melted indirectly by heat generation of CB due to high dielectric constant. By reason of increase to treatment time, the melted solution of CB/N66 HNFW bonded by increasing temperature flowed forward the intersection region between fibers. Thus, the area of intersection increased gradually. Because the melted solution flowed into the crossing point to minimize the surface energy and formed a quadrant shape at each corner of the intersection.

Figure 2 shows the tearing behavior of CB/N66 HNFW(3/97) with treatment time of 6 minute, and the change of the arrangement with fiber position in the fiberwebs. In the Figure 3, we diagrammatize tearing behavior in the Figure 2, concretely. In the Figure 2(a) and 3(a), the structures of the webs were randomly interlaced with nanofibers, this region was not applied to tearing force. The second step began fiber movement to the parallel direction applying to tearing force, and intersected fiber was arranged to one axis(Figure 2(b) and 3(b)). Figure 2(c) and 3(c) show the cutting of fiber that occurred in the weak point of paralleled fibers. Figure 2(d and e) and Figure 4 show the appearance of ruptured fibers. The rupture of fiber occurred in the intersection points and fibers. These results were caused by the bonding strength of inter-fiber larger than tensile strength of fiber.

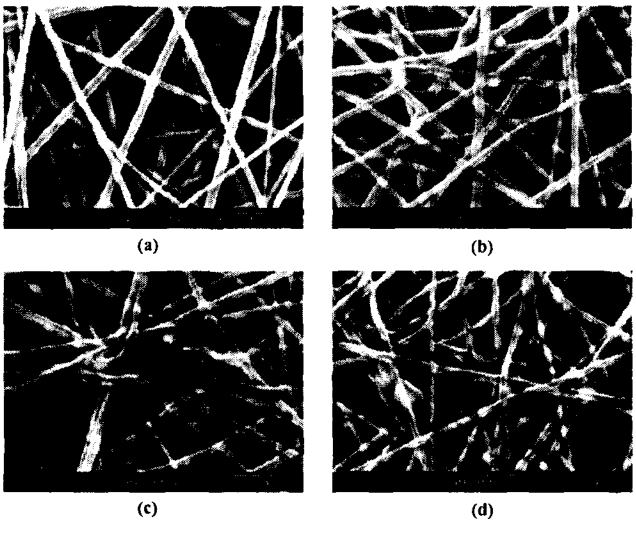

Figure 1. Microphotographs of microwave bonded CB/N66 HNFW(3/97).
(a: 0min, b: 5min, c: 6min, d: 7min)

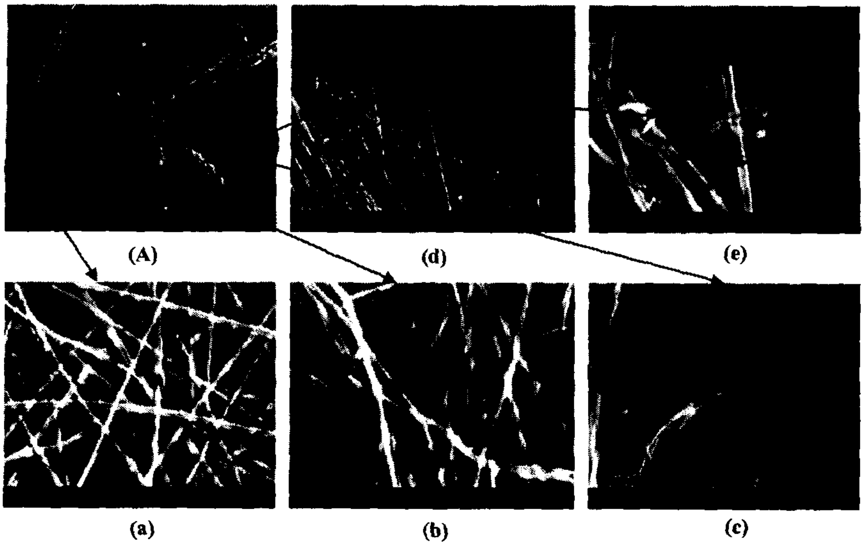

Figure 2. Tearing behavior of the CB/N66 HNFW(3/97) with 6 minute treatment time.

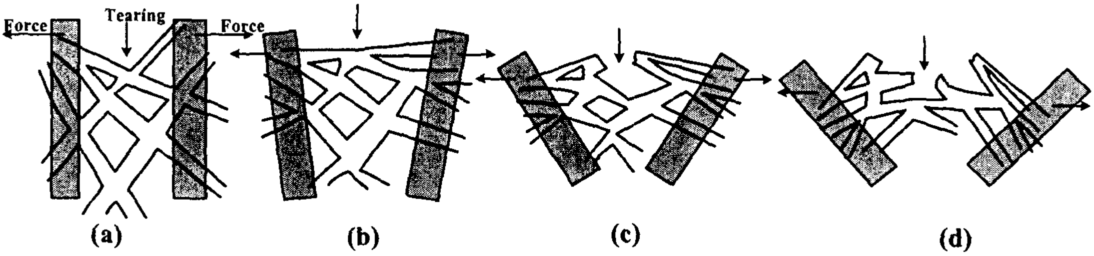

Figure 3. Schematic of tearing behavior in the CB/N66 HNFW(3/97) with microwave heating.

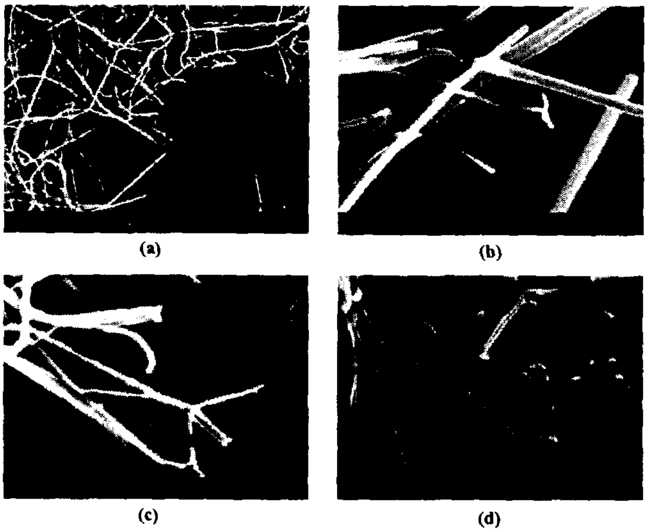

Figure 4. Microphotographs of ruptured fibers in tearing test.

Figure 5 shows the tearing force of CB/N66 HNFW with different CB contents and treatment time. A is the tearing curves of pure N66 and B is the tearing curves of CB/N66 HNFW(3/97). As the treatment time increased, the load/deformation curves of pure N66 were smooth because of weak fiber bonding. Meanwhile that of CB/N66 HNFW(3/97) increased with increasing treatment time except for at B-7min and the slip and stick behavior was remarkably appeared. It resulted from the low permittivity of N66. When the treatment time was over 5minute, slip and stick occurred. Slip and stick can be explained with Figure 3. The stick was generated by the necessary force to break crossed fiber from (a) to (c) of Figure 3. In cause from (c) to (d) of Figure 3, the slip occurred. It is fallen line of Figure 6 that shows the tearing behavior of B-6min in detail.

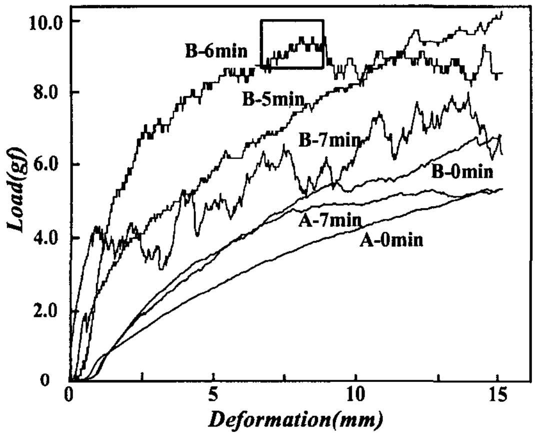

Figure 5. Tearing force of CB/N66 HNFW with different CB contents and treatment time. (A: pure, B: 3wt.%)

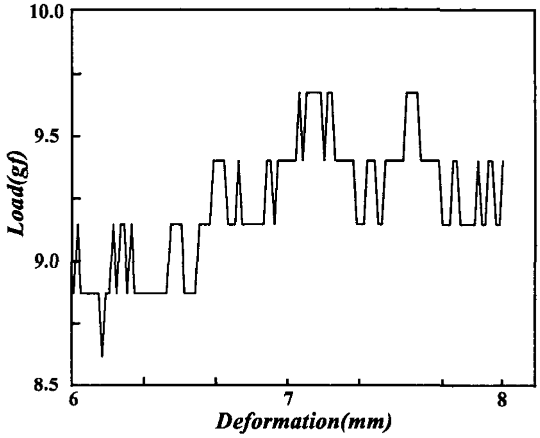

Figure 6. Enlarging of tearing behavior.(×7.5)

4. Conclusions

Bonding of pure N66 by microwave heating was weak due to the low permittivity of N66. But when the treatment time was over 5minute, bonding of CB/N66 HNFW(3/97) was occurred by heat generation of CB due to high dielectric constant. These results can be confirm by the surface structure and tearing behavior. The tearing behavior of CB/N66 HNFW(3/97) appeared by repeat that parallelism of fiber and rupture in the weak point. Thus slip and stick occurred.

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5. Reference

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