Development of new heat dissipated material in metal core PCB for LED backlight source

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Abstract
We report on carbon nano-fibers (CNFs) for applying to epoxy as a highly thermal conductive adhesive. In order to fabricate CNFs, electro-spinning process was performed with polyacrylonitrile (PAN) solutions. The sample was stabilized at the annealing temperature of 360°C, and carbonized from 900 to 1100°C. It is shown that the synthesized CNFs have a good thermal conductivity of several hundred W/m K. LED backlight units (BLUs) fabricated with MPCB using CNF-mixed epoxy give a better heat dissipation and higher performance than normal LED BLUs. On the basis of SEM, XRD, and FTIR, the characteristics of CNFs are described.

1. Introduction
LCD TV will play a leading role in future digital TV. Among issues of LCD TV, backlight units have had a great importance so far. Light emitting diodes are one of the most prospective lighting sources due to strong points such as a fast response time (~ a few μs), brilliant color gamut (> 100%), long life time (> 10^5 hr), and eco-friendly characteristics (Hg-free) [1-4]. However, LEDs as a light source of LCD have a few drawbacks of low radiation efficiency and high product cost [5]. Since the irradiated light can be released by heat energy, a large amount of heat can make the efficiency of devices degrade [6]. Also, excessive heat can cause color gamut to shift to different direction. The phenomena are originated from thermal insulating epoxy between Cu and Al in metal printed circuit board (MPCB). In this work, we adapted thermal conductive carbon nano-fibers in epoxy matrix for efficient thermal dissipation. In addition, we selected the inexpensive process of synthesizing CNFs to reduce the cost of production. LED BLU fabricated with MPCB using CNF-mixed epoxy give a better heat dissipation and higher performance than normal LED BLUs. Hence, we can improve the performance of LCD backlight like life-time and color gamut by reinforcing heat dissipation in MPCB.

2. Results
To fabricate CNFs, electro-spinning method was used with PAN solution ranged from 5 to 12.5 w.t.% in DMF (dimthyl formamide) solvent. A tip to collector distance is 10 cm and the inner diameter of

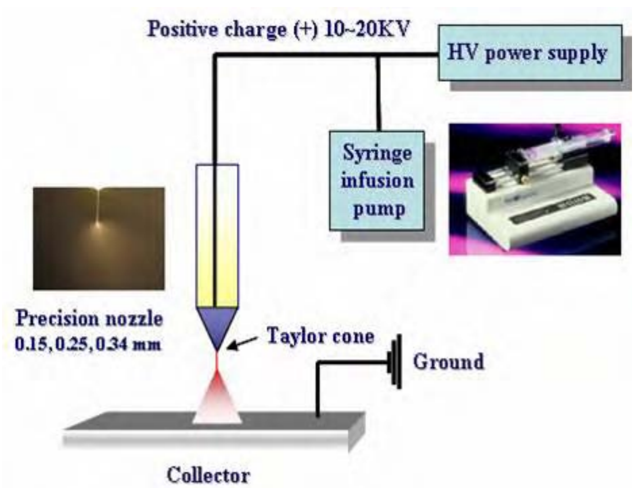

Figure 1 Schematic diagram of electrospinning process

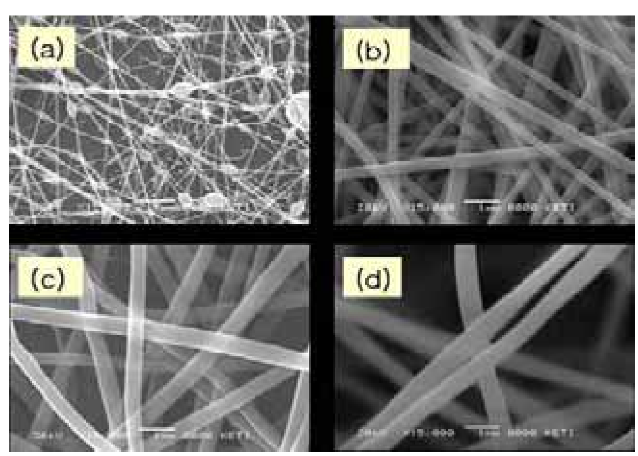

Figure 2 The SEM image of PAN web as a function of PAN concentration; (a) 5% (b) 7.5% (c) 10% (d) 12.5%

nozzle is 0.15, 0.25, and 0.34 mm, respectively.

High positive DC voltage (10~30 kV) was applied at tip nozzle at the room temperature. As shown in Fig.1, electrospun PAN web was collected on the earthed metal plate. The diameter of electrospun PAN fiber was changed from 1 μm to 100 μm as functions of PAN concentration, electric field, and nozzle size [7].

Figure 2 shows the variation of fiber diameter with PAN concentration. A beaded fiber appeared below 5 wt% PAN concentration. Average diameter is increased with increasing PAN concentration because larger portion of PAN in jet stream makes higher viscosity of solution.

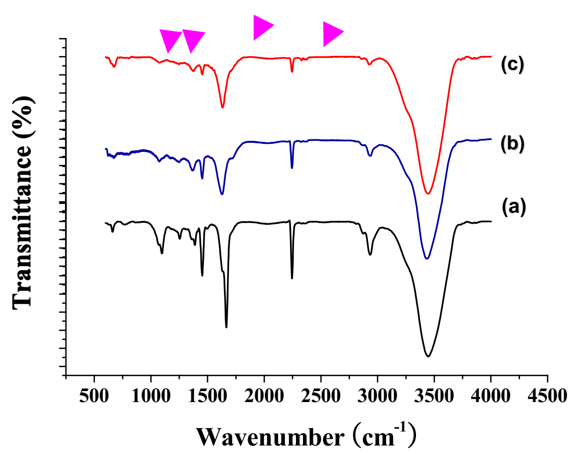

Figure 3 FT-IR data of PAN fiber at various annealing temperatures; (a) As-electrospun fiber, (b) 280°C oxidation, (c) 360 °C oxidation.

In Figure 3, the result of FTIR indicates that PAN fiber annealed at the temperature of 280-360 °C**.** It is shown that nitrile (CN) peaks are reduced as increasing annealing temperature, while carbonyl (C=O) peaks are newly developed through the oxidative stabilization stage. It means that bonding in PAN fibers became much more stable than that in as-spun sample. As increasing temperature, the procedures of cyclization, dehydrogenation and oxidation are orderly happened. In detail, the microstructure of CNF is changed from thermoplastic to nonplastic cyclic and ladder compound, resulting in decrease of average diameter [8.9]. This data has a good agreement with previous works of another group [10].

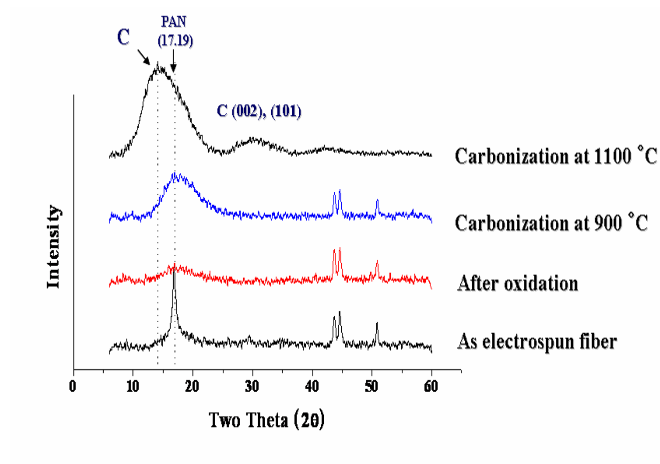

Figure 4 X-ray Diffraction data of PAN fiber in carbonization process.

Figure 4 shows XRD data as a carbonization procedure in high temperature. The intensity of PAN peak in XRD spectra decreases and the broad graphite peak appeared which means imperfect carbonization up to 1100°C. It is noted that there is possibility of full carbonization above 1100°C [8-9].

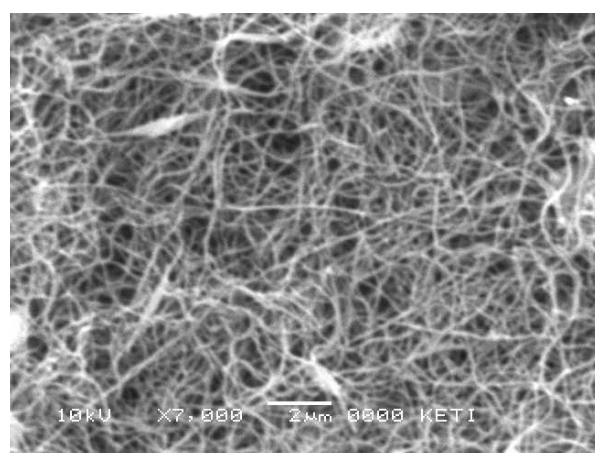

Figure 5 Scanning Electron Microscope image of carbon nano fibers.

Figure 5 shows SEM image of PAN fibers carbonized at temperature of 1100°C. As shown above, these fibers are narrower as compared with PAN fibers before heat treatment. Also, these CNFs have approximately the diameter of sub-hundred nanometer. This narrowed diameter notices that fibers have been shrunken and strengthened by rearranging their bonding throughout the process of dehydrogenation and denitrogenation [8-9].

Weight percent	0 wt%	0.5 wt%	1 wt%	2 wt%
Total thickness(mm)	1.31	1.259	1.264	1.251
Total thermal conductivity (W/m K)	7	10.44	10.05	11.63
Total thermal resistivity (m^2K/W)	0.000187	0.00012	0.00013	0.000108
Adhesive thickness(mm)	0.285	0.234	0.239	0.226
Adhesive thermal resistivity(m^2K/W)	0.000184	0.000117	0.00012	0.000104
Adhesive thermal conductivity (W/m K)	1.55	2	1.96	2.17

Table 1 Thermal properties of Cu foil laminating to Al plate using CNF mixed epoxy

We fabricated thermal conductive epoxy sheet composed of CNF powder (0.5, 1, 2.0 w.t.%) and thermal epoxy (Duralco 128). After dispersing CNF powder into epoxy matrix by using mechanical stirrer for a day, this sample was tape-casted on Al plate, and Al metal and thin Cu film were laminated together by CNF mixed epoxy sheet (200 °C, vacuum, 3.5 kg/cm^2 for 1 hour). As shown in Table 1, it is noted that adhesives including CNFs have a better thermal conductivity in comparison with those excluding CNFs according to an increase in CNF weight percent (the factor of thickness is almost negligible). Epoxy applying 2wt% CNF produces thermal conductivity and resistivity of 2.17W/m K and 1.04×10^{-4} m^{2}K/W, respectively.

We also fabricated direct type LED BLUs using CNF-mixed epoxy sheet as shown in Figure 6. The power LED source on discrete type metal core PCB is made of Lumileds for 17” of panel size. We select 3 cm as a mixing distance from the light source. To enhance the optical uniformity of LED BLUs, optical sheets, such as brightness enhancement film and dual brightness enhancement film, were used. To characterize LED performance, module temperature, color gamut, power consumption, and luminance uniformity were measured. The variation of LED characteristics with heat generation in MPCB was also measured with and without CNF epoxy sheet. In the case of using CNF epoxy sheet, the heat generation is significantly reduced, and the LED device performance is improved.

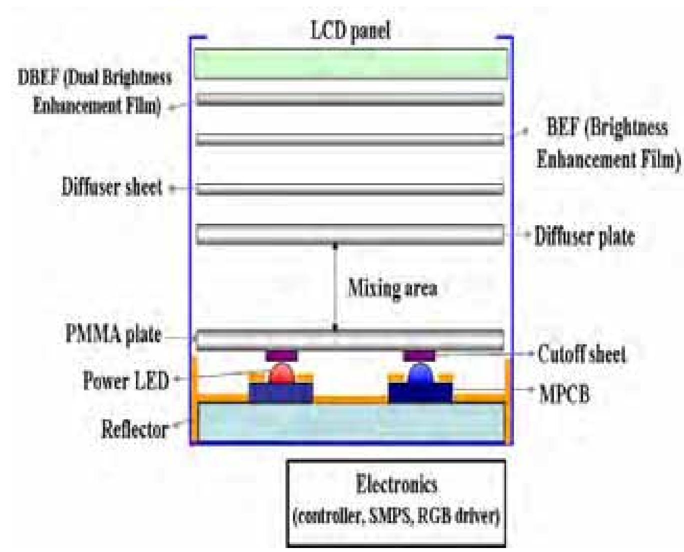

Figure 6 Structure of direct type BLUs for LCD TV

3. Conclusion

We have introduced carbon nano-fibers (CNFs) for applying to epoxy as a highly thermal conductive adhesive. The role of CNF-mixed epoxy resulted in the improvement of Metal core PCB. It is shown that thermal conductivity of CNF-mixed epoxy was increased by 140% as compared with thermal epoxy without CNFs. This replies that our results could definitely prove the applicability of MPCB structure for next generation LED BLUs of low cost and high performance.

4. Acknowledgements

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5. References

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