# Synthesis of thermal interface material with high thermal conductivity for high efficiency of LED

C. J. Han, S. H. Yu, S. J. Hong, Y. S. Kim and J. I. Han*

*Korea Electronics Technology Institute, Flexible display research center,
#68 Yatap-dong, Bundang-gu, Seongnam-si, Gyeonggi-do 463-816, Korea, cjhan@keti.re.kr

## ABSTRACT

Thermal dissipation of LED is critical for high efficiency and reliability. Inorganic filled grease type thermal interface material (TIM) has widespread use for heat management of LED. Conventional TIM materials, however, has relatively low thermal conductivity (~ 2.0W/mK) rather than metals. To achieve high thermal conductivity comparable for metal, novel nano composite material is synthesized with nano fiber and filler.
***Keywords***: thermal interface material, LED, thermal, dissipation

## 1 INTRODUCTION

Light Emitting Diodes (LEDs) are one of the most prospective lighting sources due to several advantages such as high luminous efficiency (>100 lm/W), fast response time (~a few μs), long life time (>100,000 hr), and eco-friendly characteristics (Hg-free) [1-4]. However, LEDs as a light source of illumination lighting have a few drawbacks of high cost and thermal dependency problems [5]. Especially, the large amount of heat can lower the efficiency of devices [6]. Also, excessive heat can cause color shift to undesirable direction. The phenomena are originated from the electrical insulating epoxy between Cu and Al in MPCB. In this work, we adapted thermal conductive carbon nano-fibers (CNFs) in epoxy matrix for efficient thermal dissipation. In addition, we selected the inexpensive process of synthesizing CNFs to reduce the cost of production. LED lighting units fabricated with MPCB using CNF-mixed epoxy give a better heat dissipation and higher performance than normal LED lighting modules.

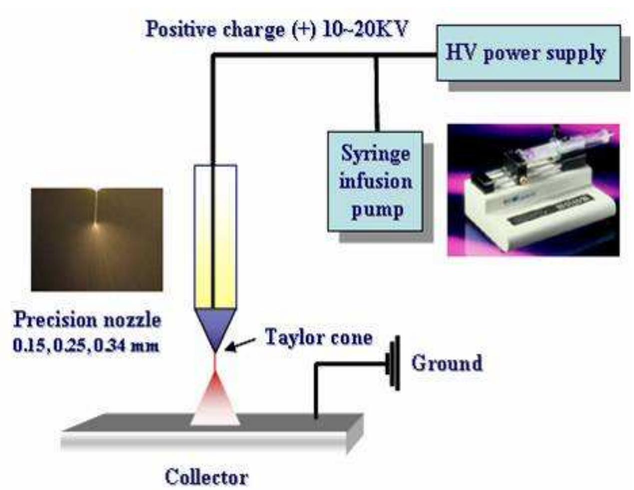


Figure 1. Schematic diagram of electrospinning process

## 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 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.

In Figure 3, the result of FTIR indicates that PAN fiber annealed at the temperature of 280-360 $^{o}$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

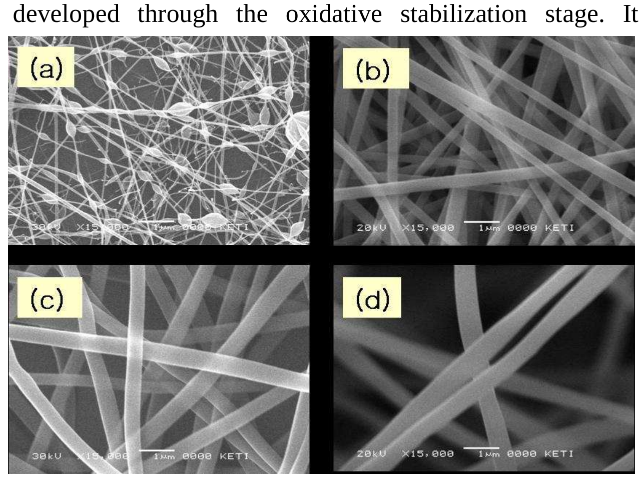


Figure 2. The SEM image of PAN web as a function of PAN concentration; (a) 5% (b) 7.5% (c) 10% (d) 12.5%

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].

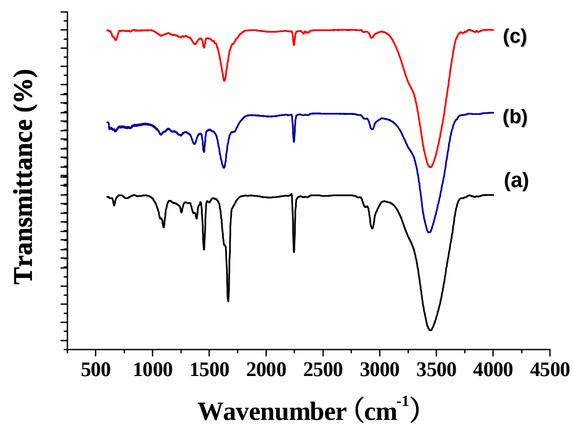


Figure 3. FT-IR data of PAN fiber at various annealing temperatures; (a) As-electrospun fiber, (b) 280°C oxidation, (c) 360 °C oxidation.

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].

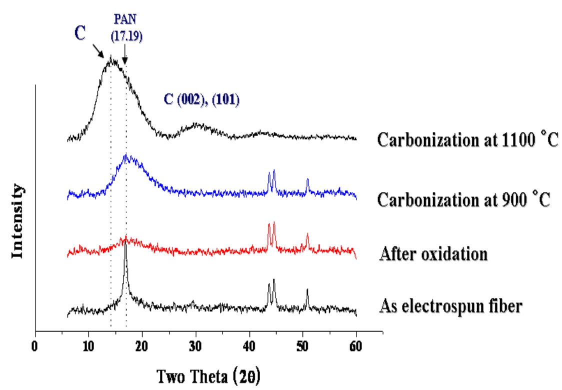


Figure 4. X-ray Diffraction data of PAN fiber in carbonization process.

After the PAN fibers were carbonized at temperature of 1100°C, these fibers are narrowed 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].

We fabricated thermal conductive epoxy sheet composed of CNF powder (0.5, 1, 2.0 wt %) 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 2.17 W/mK and 1.04x10$^{-4}$ m$^2$K/W, respectively.

| **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$^2$K/W)** | 0.000187 | 0.00012 | 0.00013 | 0.000108 |
| **Adhesive thickness(mm)** | 0.285 | 0.234 | 0.239 | 0.226 |
| **Adhesive thermal resistivity(m$^2$K/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 also fabricated LED package using CNF-mixed epoxy sheet as shown in Figure 5. The power LED source on discrete type metal core PCB or through hole PCB is made of Lumileds.

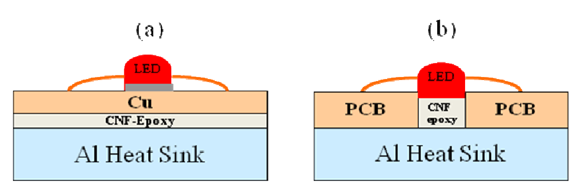


Figure 5.Structure of high thermal dissipation LED package structure (a) metal core PCB (b) through hole PCB

To characterize LED performance, module temperature, and luminance 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.

## 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 lightings of low cost and high performance.

## 4 ACKNOWLEDGEMENTS

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