High Power Carbon Nanotube Heater

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Abstract

Many practical applications of carbon nanotubes(CNTs) have been proposed and there have been attempts to utilize CNT films as transparent electrodes for solar cells and displays [1]. Our group has considered the use of CNT films as a thin film heater (TFH) and proposed it for the first time and reported the thermal behavior of the TFH made of single walled CNTs [2, 3]. When the CNT film is used as a heating device, the broader the operating temperature range the more useful the CNT film heater would be. However, there are two technical barriers in the application of TFH to high temperature regime. One of them is the oxidative damage in high temperature range and the other is the relatively high electrical resistance of the CNT film. To overcome these obstacles, we found a stable coating method to prevent the oxidative damage and adopted a ‘branch electrodes’ concept to increase the film conductance dramatically.

Figure 1 shows irreversible increase of a CNT film resistance at high temperature over 500℃. It is because of the oxidation of the CNTs as other researchers reported [4]. To protect the CNT film from the thermal damage, we have tried SiO_2 coating on the CNT film through plasma enhanced chemical vapor deposition (PECVD) process and also tried coating with spin on glass (SOG) material and sealing with another glass substrate with ceramic bonds as shown in figure 2(a). Figure 2(b) shows that the resistance of the sealed CNT heater changes little even after exposure to high temperature environment. Hence, we selected the idea of sealing as most superior protective coating.

Meanwhile, to lower the resistance of the CNT film, we adopted an idea of branch electrodes as shown in figure 3(a) [5]. If two branch electrodes are inserted into a TFH whose original electrical resistance is R, the total resistance will be reduced to R/9. Because of the increased aspect ratio, the resistance of each segmented TFH will be reduced to R/3. Furthermore, since they are connected in parallel, the total resistance reduces to R/9. This could be extended to n branch electrodes, and the total resistance of the film will be reduced to $R/(n+1)^2$, if the resistance of electrodes are negligibly small. We fabricated the heaters with different number of branch electrodes as shown in figure 3(b). The number of branch electrodes of the fabricated heaters are 0, 2, 4, 8 and their electrical resistance are 101.4, 39.5, 20.0, 15.4 Ω, respectively. We applied 20V to each heater and monitored the temperature variations as shown in figure 3(b). We could achieve high heating temperature even with low voltage supply.

As far as we know, this is the first trial of CNT heater capable of heating up to 500℃ and this technique will be able to applied to relevant industrial applications which need high power film heater.

References

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Figures

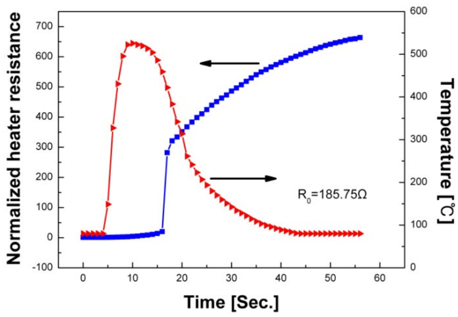

Figure 1. Temperature and resistance variations of heated CNT film.

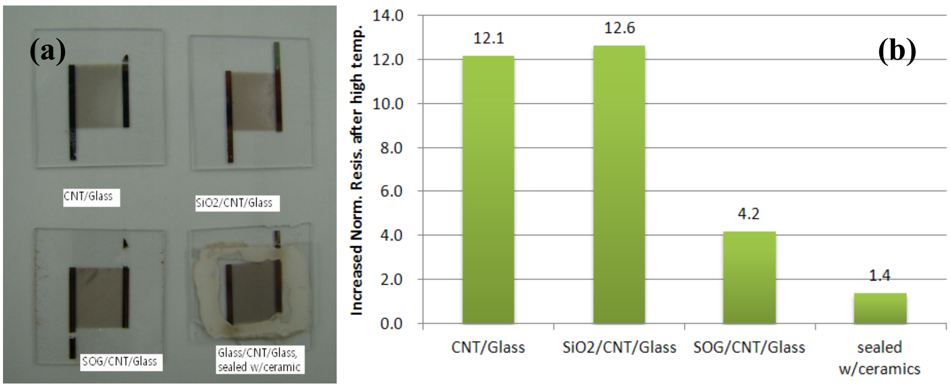

Figure 2. (a) CNT heaters coated with different methods. (b) Normalized increase of CNT film resistance after 10-minute annealing in the air at 500℃.

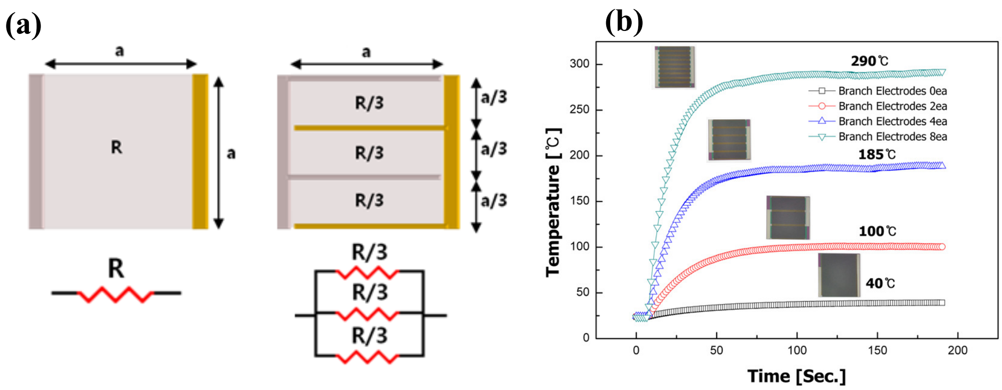

Figure 3. (a) Film resistance reduction by using branch electrodes. (b) Temperature rise due to operation of heaters with different number of branch electrodes (applied voltage: 20V).