POSITIVE TEMPERATURE COEFFICIENT EFFECT OF NANOCARBON/POLYMER COMPOSITES

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ABSTRACT

We used commercial carbon nanotubes (CNTs) and graphene as raw materials to fabricated high-performance positive temperature coefficient (PTC) thermistors. We found that the CNTs and graphene are beneficial to greatly improving PTC effect of nanocomposites, which is closely associated with high intrinsic electrical conductivity, entangled structures of CNTs, and crumpled morphology of graphene. There are great potentials for these nanocarbon materils to be used as novel functional fillers in the field of thermistors.

1 INTRODUCTION

Positive temperature coefficient (PTC) effect is a phenomenon of remarkable increment in electrical resistance at elevated temperature, and the PTC thermistors have been widely applied in electric industry for over-current protection and self-regulating heating. However, the typical polymeric PTC materials, carbon black (CB) filled high-density polyethylene (HDPE) composites, has intrinsic disadvantages of high loading and low thermal cycle stability, greatly hindering their application in some critical circumstances of high temperature and high electric current. In this work, we used carbon nanotubes (CNTs) and graphene as conductive fillers, and investigated their PTC effect at elevated temperature and applied voltages, in order to explore the advantages of these nanocarbon/polymer composites in comparison with CB/HDPE composites.

2 EXPERIMENTALS

We used commercial CNTs and graphene as raw materials. All the nanocomposites were fabricated using conventional melt-mixing and hot-press methods. Electrical resistivity and PTC effect of nanocomposites were investigated.

3 RESULTS AND DISCUSSION

we prepared CNT/HDPE composites using conventional melt-mixing methods, and investigated their PTC effects in detail.We found that the CNT/HDPE composites could bear much higher hold current and hold voltage, increasing by 129 % than the CB/HDPE composites(Figure 1), implying satisfactory availability for the CNT-based thermistors in some critical circumstances. Such high current-bearing and voltage-bearing capacity for the CNT/HDPE thermistors is mainly attributed to high thermal conductivity and heat dissipation of entangled CNT networks[1]. Moreover, the CNT/HDPE thermistors exhibit rapid electrical response to applied voltages, comparable to commercial CB-based thermistors.

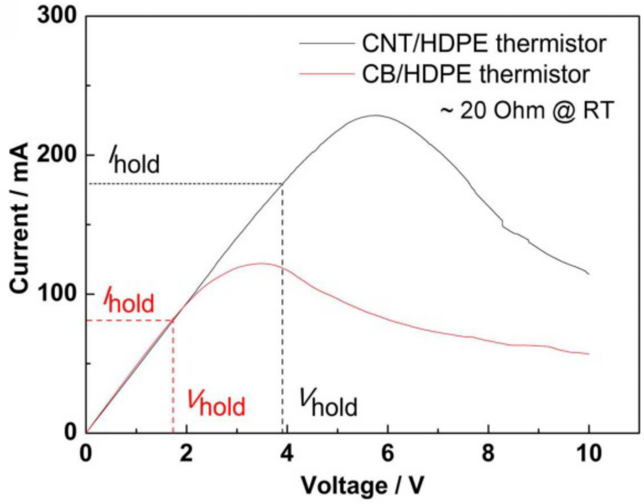

Fig. 1 V-I curves of the CNT/HDPE and CB/HDPE thermistors

Furthermore, we investigated PTC effect of graphene/HDPE composites in this work. Comparing with CNTs, the graphene have some advantages of lower cost, less entanglement, and larger lateral surface area, indicating that the graphene can be used as novel conductive fillers in PTC materials[2]. We prepared the graphene/HDPE composites using melt-mixing and hot-pressing technique. We can see from Figure 2 that the graphene/HDPE composites exhibited not only satisfactory low electrical resistivity at room temperature due to the excellent conductivity of graphene, but also high PTC intensity (ratio of maximum resistivity to room-temperature resistivity) of over 4, much higher than that for CNT/HDPE composites. Such satisfactory PTC effect of the graphene/HDP composites is mainly attributed to high electrical conductivity and high thermal stability of the crumpled graphene. The interconnected graphene network can be easily broken down during melting of semi-crystalline HDPE at elevated temperatures, resulting in remarkable increment of electrical conductivity and high PTC intensity. Moreover, the graphene/HDPE composites also exhibit satisfactory thermal stability during repeated heating-cooling cycles. In light of their high current-bearing capacity, quick response, and high PTC intensity, the CNT- and graphene-based composites have great potential to be used as high-performance thermistors in practical application.

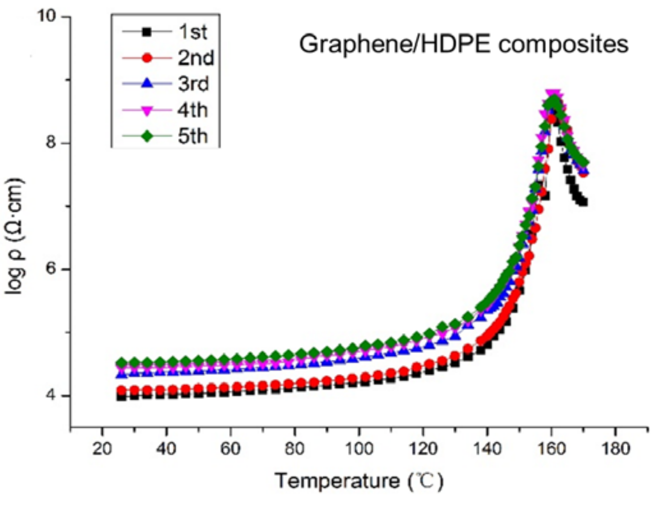

Fig. 2 Positive temperature coefficient effect of grapheme/HDPE composites.

4 CONCLUSION

In our work, we found that both of the CNT and graphene-based thermistors exhibit significant PTC effects, which is mainly attributed to high thermal conductivity and heat dissipation of entangled nanocarbon networks. In light of their high current-bearing capacity and quick response, the nanocarbon-based thermistors have great potential to be used as high-performance thermistors in practical application, especially in some critical circumstances of high temperature, large applied currents, and high applied voltages.

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