Understanding the mechanism of positive thermal coefficient in conductive polymer composites

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Extended Abstract

Conductive polymer composites (CPC) are materials with conductive filler dispersed in sufficient quantities in polymer resin. CPC have found applications in various fields including electromagnetic interference shielding, electrostatic dissipation, direct platable plastics and sensing applications [1, 2]. However their unique pyroresistive behaviour with high positive temperature coefficient (PTC) makes them useful for self-regulating heating and over current protector applications [3]. Although there is a lot of work in literature explaining the large PTC effect in CPC mainly based on mismatch in thermal coefficient of expansion between polymer matrix and conductive fillers, the effect of different size or shape of the filler, mixed filler systems and polymer blends on the PTC intensity on the composites in poorly understood [4-6]. Also there is no direct evidence in literature which confirms the PTC mechanism in CPC.

In the present work model CPC systems were studied to understand the effect of filler size and shape on the PTC intensity of High density polyethylene (HDPE)-Silver coated glass sphere (AgS) and Silver coated glass flake (AgF) composites. CPC with different concentrations of AgS and AgF were prepared by melt compounding with HDPE. It was found that PTC intensity of the composites increased with decreasing filler concentration and increasing filler size for both the composites suggesting low surface area fillers to be the ideal choice for getting high PTC intensity.

This is consistent with the view that small size fillers have more conductive pathways therefore it is difficult for conductive pathways to be disrupted at the PTC temperature hence low PTC intensity of the CPC **(Figure 1)**. As suggested in the literature the main mechanism for PTC effect was expected to be mismatch in thermal coefficient of expansion of the filler and the polymer. **Figure 2** shows the relation between filler size, filler content and PTC intensities of the CPC. It can be seen both decrease in filler size and increase in filler content increase in robustness of the conductive network in CPC resulting in decreased PTC intensity. So by tuning the filler size, shape and content PTC intensity of CPC can be tuned.

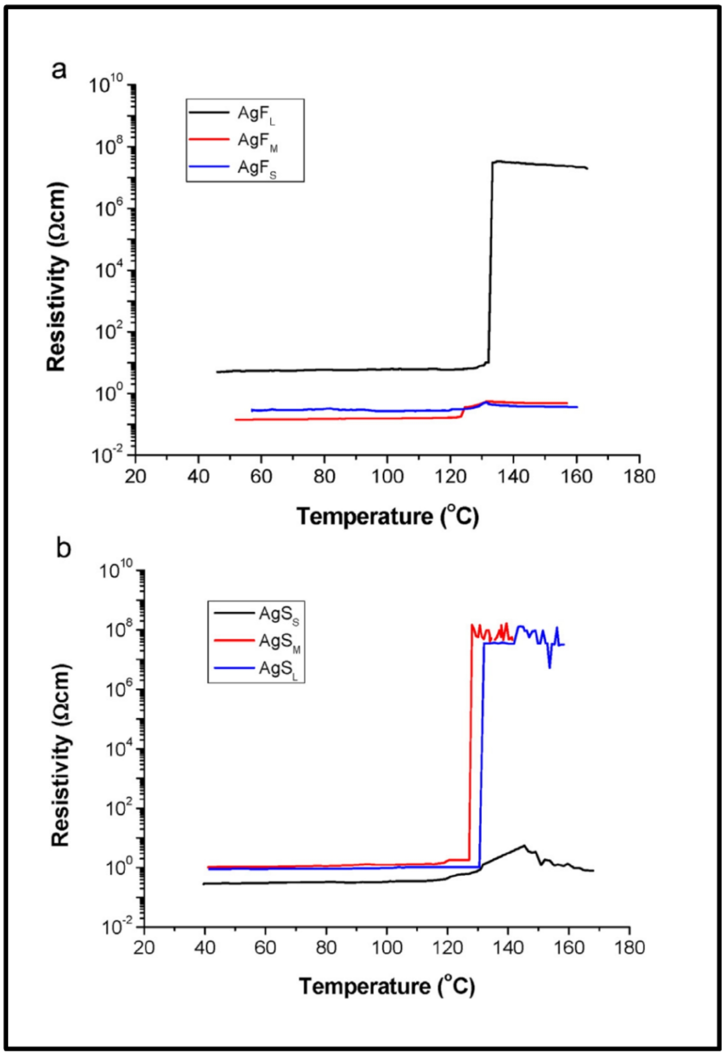

Figure 1 PTC behaviour of HDPE filled with different size: **a)** Ag coated flakes and **b)** Ag coated spheres.

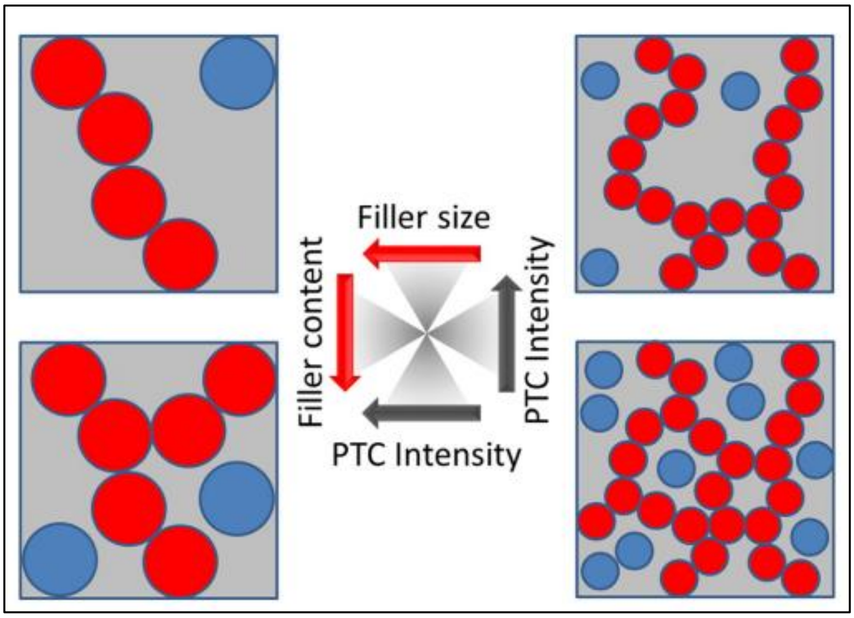

Figure 2 Schematic of how a reduction in filler size and an increase in filler content increases the number of conductive pathways in a conductive polymer composite, therefore improving the 'robustness' of the network, leading to a smaller PTC intensity.

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