Graphene-reinforced PVDF Nanocomposites with Enhanced Electrical Conductivity via Controlled 3D Printing

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This study provides a comprehensive analysis of the thermal and electrical properties of poly(vinylidene fluoride) (PVDF) and its nanocomposite reinforced with 6 weight percent graphene nanoplatelets (GNP). The primary objective is to elucidate how the incorporation of GNP affects the material's overall performance, with particular attention to its suitability for thermal and electronic applications. The research is driven by the growing demand for advanced materials in additive manufacturing, especially for 3D printing technologies that require enhanced thermal stability and electrical conductivity.
Electrical conductivity tests revealed a pronounced influence of the printing orientation on the material's performance. The GNP/PVDF nanocomposite exhibited its highest electrical conductivity, reaching 98 S/m, when printed in a parallel orientation relative to the current flow (3DP 0°). This value decreased to 67 S/m at a 45° orientation and further dropped to 62 S/m when printed at 90°, indicating that the alignment of the material during the printing process plays a critical role in determining its electrical efficiency.
Joule heating experiments further demonstrated the material's capability for efficient resistive heating. When a voltage of 2 V was applied in the parallel configuration, the composite achieved a maximum surface temperature of approximately 65 °C. Moreover, the repeatability of the heating performance was confirmed through multiple cycles of heating and cooling, with consistent peak temperatures recorded across all trials, suggesting excellent reliability and thermal response consistency.
Heat flow analysis provided additional insights, showing a linear decline in thermal diffusivity as temperature increased. At the same time, thermal conductivity was found to be highest in the parallel orientation due to the more effective alignment of the graphene nanoplatelets along the direction of heat transfer, which facilitated improved thermal pathways.
In conclusion, the findings from this study highlight the significant improvements in thermal stability, orientation-dependent electrical conductivity, and Joule heating efficiency achieved through the addition of GNP to PVDF. These enhanced properties position the GNP-reinforced PVDF nanocomposite as a highly promising material for next-generation applications in 3D printed electronics and thermal management systems.
Keywords: polymer composites, 3D printing, graphene

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