Development of Graphene-Enriched Intumescent Coatings for Enhanced Fire Resistance

Sinu P, Nimmi C Sekhar, Sreeparvathy V S, Alex P James
India Graphene Engineering and Innovation Centre, Digital Science Park, Kabani Building, Technopark Phase 4, Thiruvananthapuram, Kerala, India- 695317
E-mail: sinup@igeic.org

Abstract

Graphene-enriched intumescent fire-resistant (FR) coatings were developed to investigate the role of graphene as a nano-reinforcing additive in passive fire protection systems. Graphene nanoplatelets (GNP) were exfoliated and dispersed in an ethanol–water mixture to prepare a stable master dispersion, which was subsequently incorporated into an ammonium polyphosphate (APP)–pentaerythritol (PER)–melamine (MEL)-based intumescent formulation, followed by integration with the acrylic polymer binder. Coatings containing 0.01–0.05 wt.% GNP were applied on structural steel substrates (10×10cm) at controlled dry film thicknesses (DFT) (1.2 ± 0.1 mm) and evaluated through lab-scale flame exposure at a fixed distance of 15 cm from the coating surface. Compared to the reference coating, GNP-modified formulations exhibited increased char expansion (≈15–30%) and delayed flame penetration. Fourier transform infrared spectroscopy (FTIR) analysis of the residual char indicated enhanced carbonaceous and phosphate-based char formation in graphene-modified coatings. The enhanced fire-retardant behavior is attributed to graphene-induced barrier effects and char reinforcement during thermal degradation. The results demonstrate the feasibility of graphene incorporation at ultra-low loadings for improving intumescent coating performance, representing a successful preliminary screening of GNP as a nano-reinforcing FR additive.

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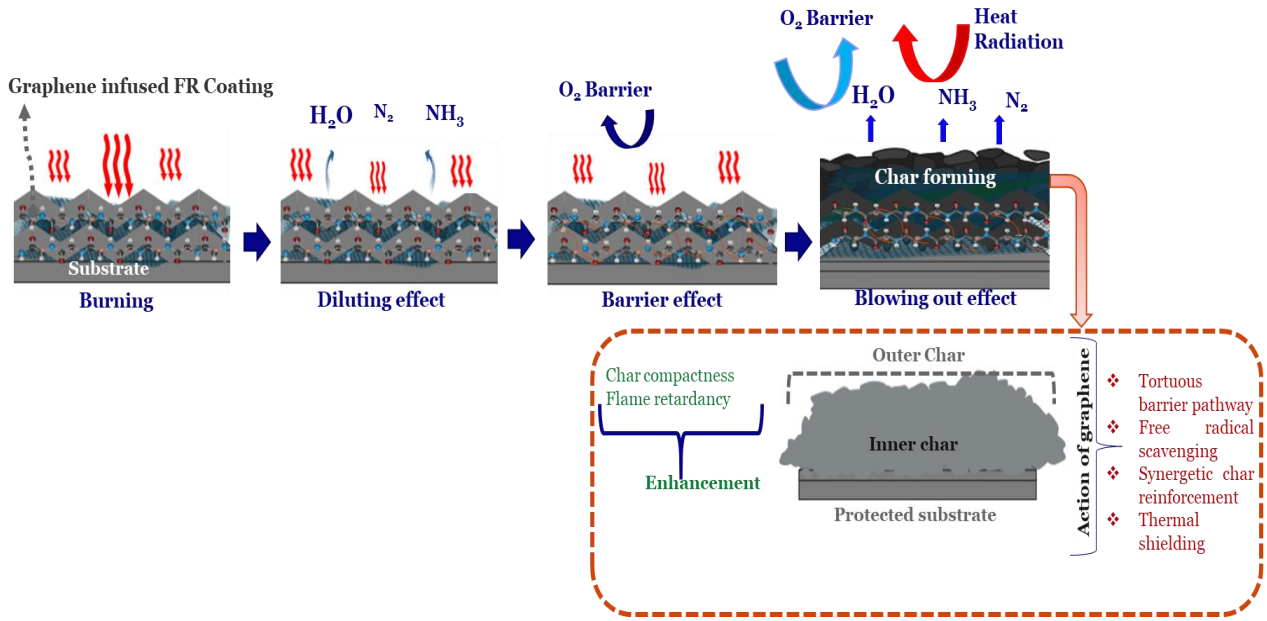

Figure 1: Mechanism of Graphene on FR