

Self-Healing Behavior of a Graphene-Based Composite Asphalt Binder with Rejuvenated Graphene Nanoplatelets

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Abstract

Two-dimensional materials have emerged as promising building blocks for multifunctional composite systems due to their exceptional mechanical strength, high surface area, and unique thermal and electrical properties. In this work, a graphene-based composite binder was developed by incorporating rejuvenated graphene nanoplatelets (GnP-Rej) into an asphalt matrix to create a microwave-responsive self-healing material. The GnP-Rej structures were fabricated by intercalating a vegetable-oil-based rejuvenator within the porous network of graphene nanoplatelets, enabling the graphene phase to function simultaneously as a reinforcement element and a carrier for a healing agent. The resulting graphene-reinforced composite exhibits energy-responsive behavior in which graphene nanoplatelets act as microwave absorbers that promote localized heating and facilitate controlled diffusion of the rejuvenator throughout the binder matrix. Rheological characterization showed that moderate GnP-Rej concentrations (0.1–0.18 wt.%) significantly enhanced high-temperature mechanical stability, evidenced by increased rutting resistance ($G^*/\sin \delta$) and reduced non-recoverable creep compliance (J_{nr}). Fatigue analysis using the Linear Amplitude Sweep method revealed substantial improvements in damage resistance, with microwave-activated composites exhibiting reduced strain sensitivity and extended fatigue life. In addition, microwave activation enabled efficient structural recovery of the composite, with Healing Index values exceeding 1.4 for optimized formulations. These findings highlight the multifunctional role of graphene nanoplatelets as two-dimensional reinforcement and energy-responsive nanostructures within composite materials. The proposed graphene-based composite system demonstrates the potential of 2D materials for designing smart, durable infrastructure materials with enhanced mechanical performance and autonomous healing capability.

References

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Figures

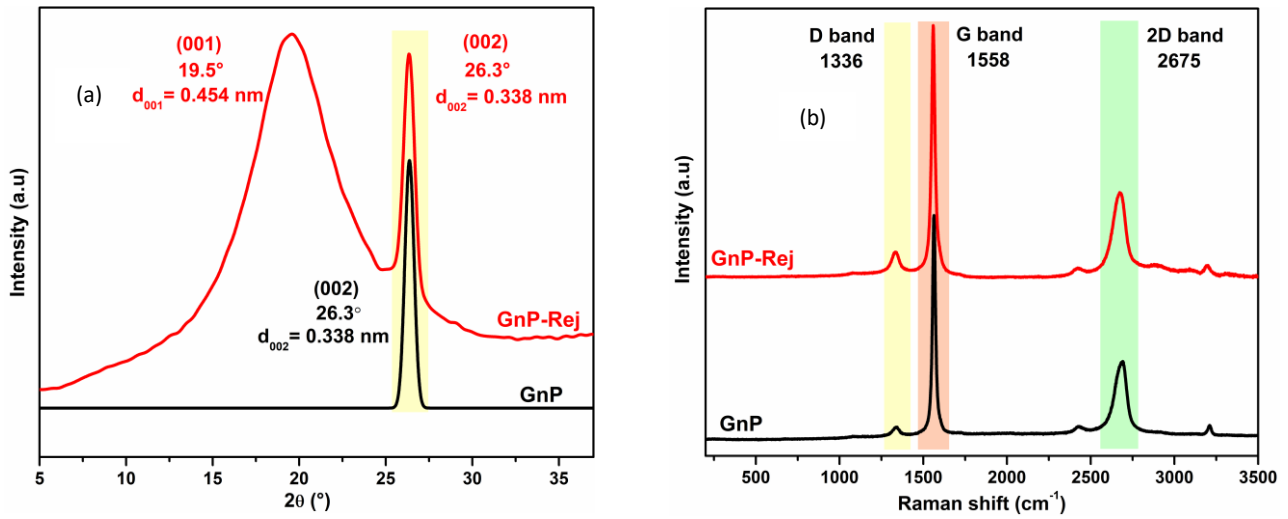


Figure 1: XRD Patterns (a) and Raman spectra (b) of GnP and GnP-Rej and

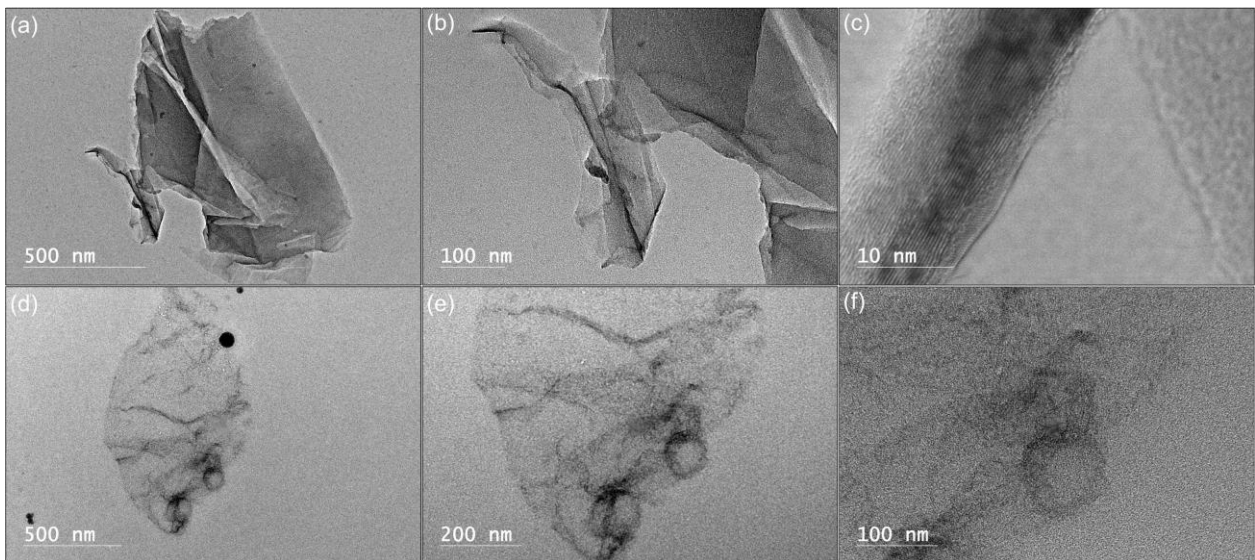


Figure 2: HRTEM images of (a, b, c) GnP and (d, e, f) GnP-Rej