Laser Propulsion of Three Dimensional Graphene Structures For Space Applications

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Abstract

Progress in space exploration not only deepens our knowledge of the universe but also drives innovation across various technological fields [1]. Among emerging propulsion technologies, photonic propulsion—which leverages the momentum of light to produce thrust—stands out as a compelling alternative to conventional methods [2]. It enables higher speeds, better thrust-to-weight performance, and greater efficiency while reducing spacecraft mass by eliminating the need for onboard propellant, making it especially suitable for extended space missions [3]. Recent research emphasizes the promise of graphene and related materials (GRMs) in light-driven propulsion due to their outstanding characteristics; graphene aerogels, in particular, exhibit ultra-low density (>0.16 mg/cm³) [4], high electrical conductivity (>100 S/m), and a notable Young's modulus (>20 MPa) [5,6]. In this study, we fabricate three-dimensional graphene architectures through a novel process combining intercalation, thermal expansion, and liquid-phase exfoliation. Directional freezing was applied to enhance pore orientation and microstructure, tailoring the materials for laser propulsion, which was tested under simulated space conditions using an advanced in-house experimental setup. Our findings indicate that aerogels of densities 16.3 ±0.2 mg/cm^3, subjected to freezing by liquid nitrogen under a vacuum level of 10^{-5} exposed to a 3.5W laser, exhibited superior thrust of 36 μN (which is the highest thrust achieved in the literature using graphene aerogels). To mimic the space environment, these tests were further executed in parabolic flights to study for the effect of microgravity and some preliminary results were obtained.

References

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Figures

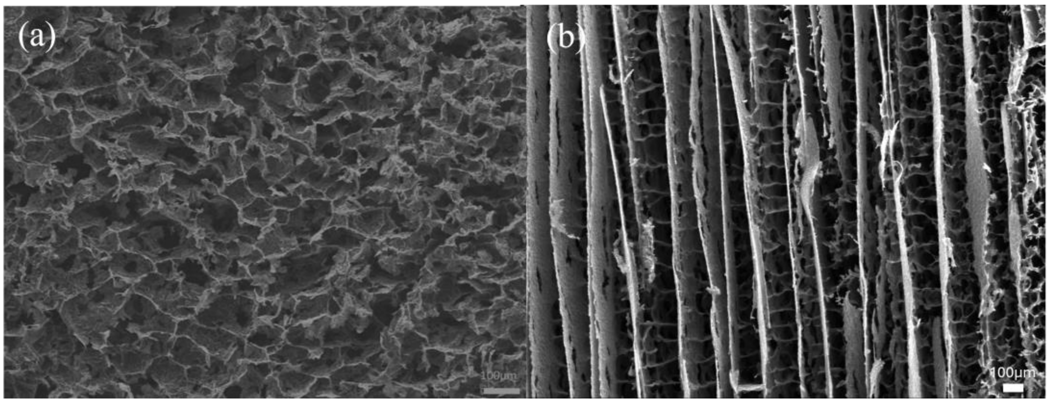

Figure 1: (a) Random-pored aerogel, **(b)** Tailored aerogel with aligned microstructure

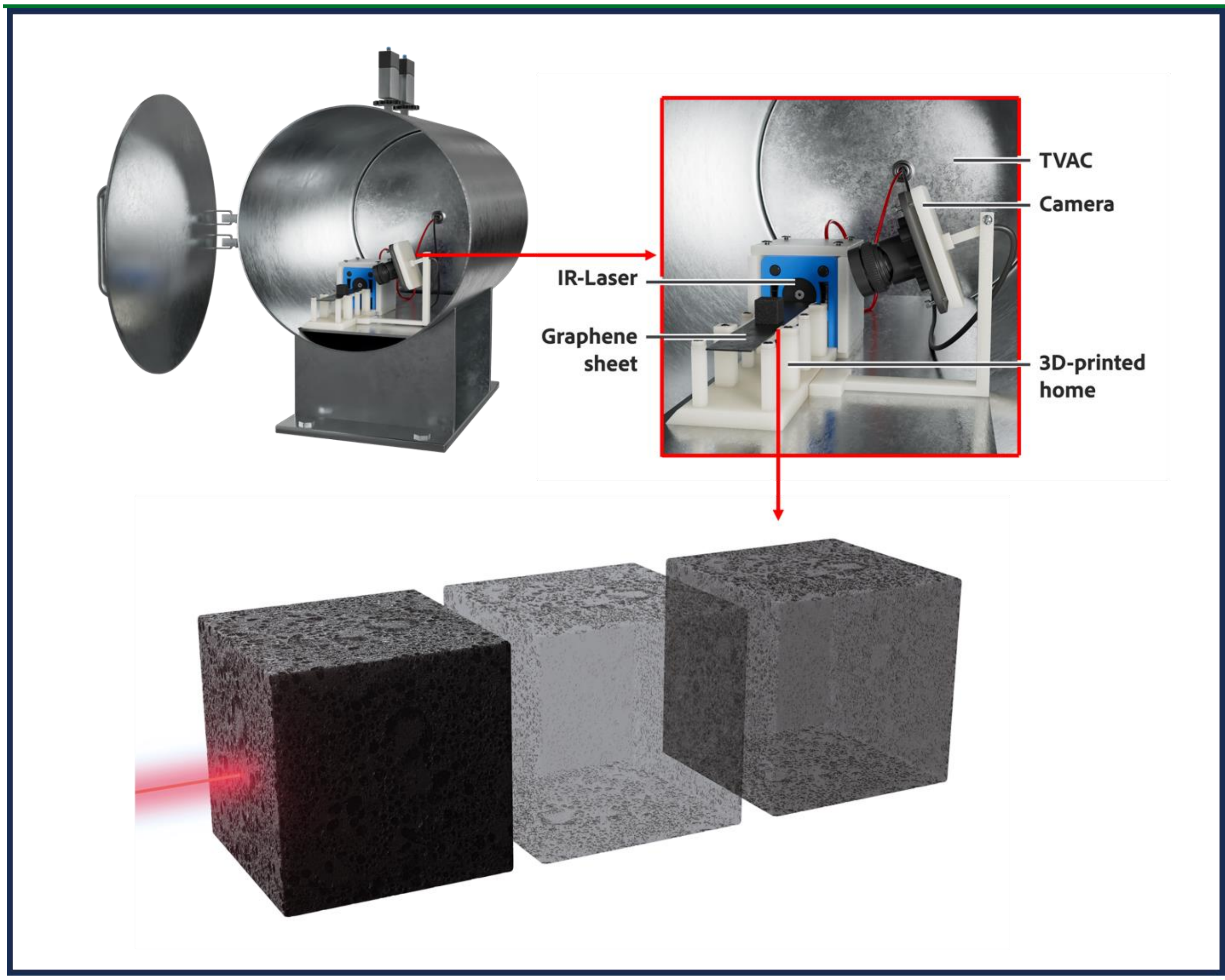

Figure 2: (a) Graphene aerogel testing setup and propulsion schematic