Ultrasonic emitter based on photoacoustic polymer graphene nanocomposites

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Focused high amplitudes and high frequency ultrasounds pulses are difficult to achieve with a traditional piezo-electric based technologies. A photoacoustic approach, employing pulsed optical excitation of photoacoustic materials or nano-absorber sandwiched with a polymer, results in ultrasound pulses with high amplitudes as well as high frequency [1,2]. This minimizes the electrical components and cabling usually used in a traditional piezoelectric approach and creates new opportunity for the integration of miniaturized optoacoustic devices. In a photoacoustic lens the ultrasound can be generated by light-induced material ablation [3] or thermoelastic effect. Moreover, if a focusing geometry is adapted, due to the acoustic gain, the achievable transient pressure can exceed 40 MPa and the negative pressure can easily lead formation of cavitation bubbles.

Here, we present a single-laser-pulse-induced ultrasound wave through thermoelastic effects. The photoacoustic nanocomposite was made of few layers graphene nanoflakes (FLG) and Polydimethylsiloxane (PDMS) polymer matrix. The excitation photon energy (1.1 eV) is absorbed by the FLG and is immediately transfer (within tens of ps), through acoustic phonon, to the polymer matrix that expands and successively contracts, giving rise to a high frequency ultrasound (Fig. 1). Despite the others method that used nano-absorbers sandwiched between two polymer layers [2], the challenge here was to embed the nanoflakes (absorber) into the PDMS (expander) and create a thin film with sufficient optical density. For the purpose, a controlled protocol was developed to obtain well dispersed FLG in the polymer matrix at different weight percentages, form 0.7 wt% to 1.1 wt%, and with different values of optical density (up to 94% light absorbed and less than 3% of scattered light) and thickness (from 4 to 22 µm). The measured ultrasound frequency was >15 MHz, with a maximum amplitude of 10 MPa in a planar geometry. The signal amplitude linearly depends on the laser fluence, and it shows an onset of saturation at higher fluence, up to 350 mJ/cm2, probably associated to the dependency of Grüneisen parameter on temperature. The maximum optoacoustic efficient conversion estimated was 1.2×10^{-3}, comparable to others carbon-based nanomaterial directly grow on a substrate. The FLG composite (freestanding) was easily embedded in an optical lens to produce high amplitude focused ultrasound and cavitation microbubbles in free field with lifetime of few tens of µs. These results bear the scope for compact, high-efficient, and inexpensive photoacoustic components for biomedical application or sonochemistry.

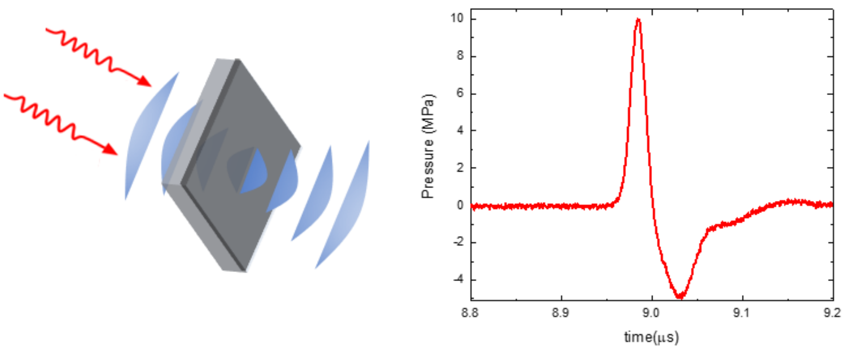

Fig. 1. Schematic illustration of the optical excitation (1064 nm) of the photoacoustic FLG composites (left panel). Ultrasound wave recorded with a hydrophone needle (right panel).

References

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