2D Wrinkled Graphene Oxide-Wrapped 3D Auxetic foam for Sound Wave and Shock Energy Multi-Dissipation

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1 Abstract

Recently, noise pollution has been a serious environmental problem worldwide because the road network is expanded and the number of vehicles is rapidly increasing due to the rapid industrialization and the development of transportation such as automobiles, trains, and buses. Noise pollution can be considered serious especially in densely populated urban environments, which can significantly reduce work efficiency in research areas and schools. There is also the privacy issue in residential areas such as apartments where many households coexist. It is also known to cause disorders such as hearing loss and mental instability.

Therefore, the development of cellular structures has attracted increasing attention in practical engineering applications such as a lightweight sound absorbing panel and shock energy dissipation for preventing noise pollution. Theoretical analysis and experimental verification of sound transmission and acoustic properties through the porous media have been dedicatedly studied.[1-4] Even though cellular structures has gained attention due to their controlled physical and mechanical properties, conventional cellular structures for sound and shock energy absorbers cannot meet demands for high-energy absorbing capacity because of the limited structural properties.[5]

Research on composites foam has been introduced to improve sound absorption performance of porous foam by inserting filler materials. For examples, the enhancement of sound absorption in the entire frequency range was confirmed by inserting natural filler materials such as the tea-leaf fiber, luffa cylindrical, bamboo leaves particle, and rice hull into polymeric foam.[6-8] As interest in carbon materials has increased greatly, many studies by using carbon materials such as carbon black,[9] carbon nanotube,[10] and graphene oxide[11] as filler materials for functionality and enhancement of sound absorbing performance have been widely conducted.

Furthermore, auxetic foam with a counter-intuitive behavior has additional beneficial properties including an indentation resistance [12-14] and enhanced acoustic property [15-18], making it suitable for sound insulation applications. The difference of wave dispersion properties between conventional and auxetic foam was explained by a resonance at a lower cut-off frequency of auxetic foam because of tortuous sound wave path generated by bent struts from thermally compressed and permanently deformed framework.[19] In addition to improving the sound absorption performance in the low frequency band, auxetic porous structure has advantages including a great enhancement of shock energy dissipation and load bearing capability compared to the conventional materials.

Herein, we have suggested a simple, facile and effective method to fabricate two-dimensional (2D) wrinkled graphene oxide (GO)-wrapped three-dimensional (3D) auxetic foam for multi-energy dissipation materials. The suggested auxetic graphene oxide-polyurethane foam (AGPUF) can be fabricated by placing the polyurethane foam into a designated aluminium frame in a hot-pressing machine and compressing it at a temperature of 150℃ for 1 hour to make the auxetic foam, and then dip-coating the auxetic foam on a graphene oxide solution with different ratios.

The proposed AGPUF has been demonstrated to show a superior sound absorbing performance of 99.7% at a frequency of 2,236 Hz and an impact resistance of 189% during a low-velocity impact test. These enhancements could be attributed to the advantage of synergistic effects between 3D auxetic foam with a negative Poisson's ratio and 2D wrinkled graphene oxide as a filler material. The auxetic hierarchically

polyurethane foam has a convoluted structure with a very high tortuosity, which not only greatly improves the load-bearing capacity, but also has the effect of shifting the peak value of the sound absorption coefficient to a lower frequency and increasing the value. The 2D corrugated graphene oxide structures in cellular structures connect between the open-cell frameworks and induce the semi-open cell porous structure with an increase of the tortuosity in the porous media, resulting in a good sound absorbing performance due to the frictional energy dissipation. The advantages of AGPUF's compressibility, light weight, cost-effectiveness, and structural stability are able to open up the possibility of rapid mass production and industrialization by the rational design of heterostructures, enabling the realization of nano-micro multi-scale cellular structures. We believe that it will be promoted in the fields of sound, vibration and shock energy dissipation.

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