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Steel metamaterials for EV battery box protection

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Vehicle safety has improved spectacularly in recent decades with an estimated 25,000 fewer fatalities per year since the 1960s. At the same time, electrification has contributed to a significant increase in vehicle mass in the same period which partly negates any environmental benefit. Improved designs are essential to increase overall structural integrity and reduce weight, to meet future safety standards, extend vehicle range, and reduce manufacturing costs.

One such safety aspect is the protection of batteries during a side impact. In that case there is a severe risk of intrusion and damage to the cells, leading to potentially disastrous thermal run away and spread of fire. To this end we have investigated the potential of mechanical metamaterials with improved shock absorption capacity [1] to improve the resilience of the battery box to side impact. At the same time, by integrating the metamaterials into the chassis design we demonstrate the potential for manufacturers to reduce vehicle mass, thereby improving their energy efficiency, without compromising passenger safety.

We show how by using material plasticity in metamaterial design we can strategically control how metamaterials deform under impact. [2] The resulting metamaterials have a unique combination of strength and stiffness with high specific energy absorption capacity. Finally, we will show how these metamaterials can be shaped into many geometries and sizes; they can be made from a broad selection of materials (any materials that exhibit plasticity, such as polymers, metals or composites); and they can be produced through a wide range of manufacturing methods which leads to their potential for mass production via conventional metal forming processes.

[1] Liu, W. et al. Harnessing plasticity in sequential metamaterials for ideal shock absorption. Nature 634, 842–847 (2024)
[2] Liu, W., Ennis, B. and Coulais, C. Tuning the buckling sequences of metamaterials using plasticity. JMPS 196(50):106019 (2025)

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