Lightweighting conventional body armor while maintaining the same effectiveness

1. Current state of the art:

There are mainly two types of vests:

- **Soft vests**, used by the police and gendarmerie, for internal security. The soft splinter vest is a soft protection made of aramid such as Kevlar® whose stopping power is limited to handguns and battlefield shrapnel. However, it is often ineffective against long-gun ammunition such as assault rifles, etc.

- **Individual ballistic protection of war**, which is, of course, a protection against handguns and shrapnel from the battlefield, but additional hard plates are added

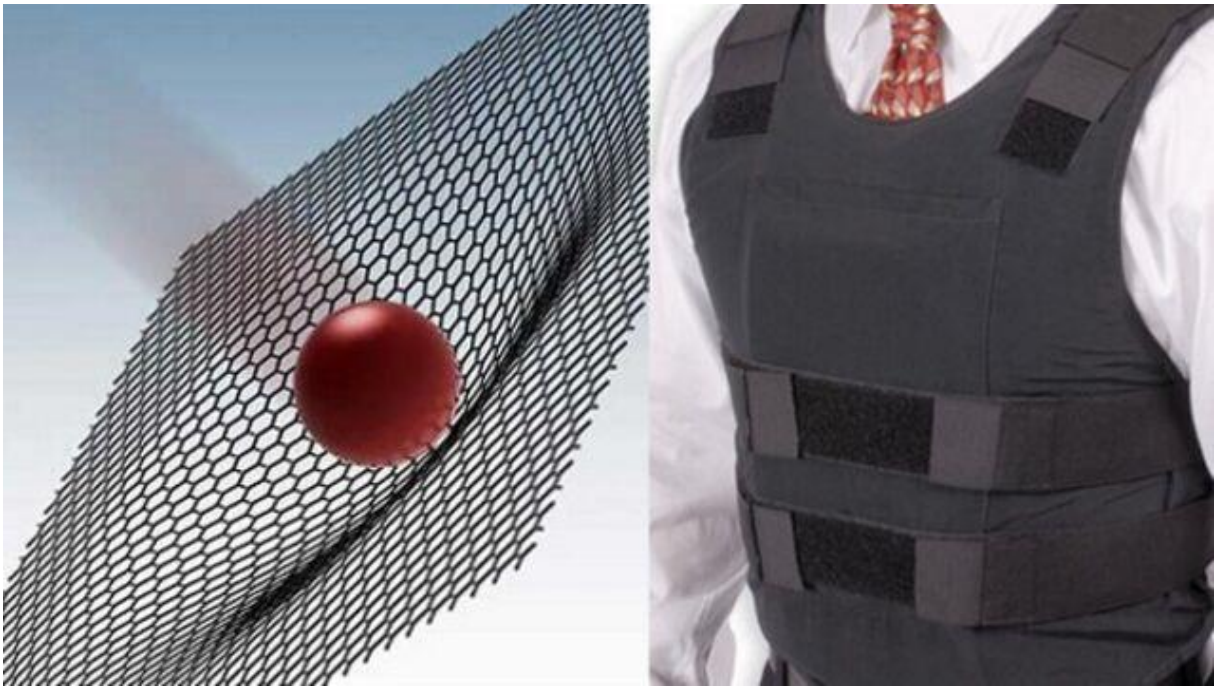
to the outer pockets: front thoracic plate, back thoracic plate, abdominopelvic plate. The choice of materials is guided by the best compromise between hardness, toughness and density. Among the materials, there are two main families: ceramics and polyethylene. The most commonly used ceramics are alumina (Al2O3), silicon carbide (SiC) and boron carbide (B4C). The concept of ceramic/composite assembly tends to replace older and widely used polyethylene materials.

However, these two types of vests have two things in common. They have a very strong canvas on the inside woven with Kevlar® or Twaron® aramid chains.

Example of woven fabric for a type of Kevlar® (Kevlar®1414):

240g Aramid Fiber Woven Fabric for Body Armor (Credit: Alitools.io)

2. **Graphene**:



(Credit: https://www.maxisciences.com/sciences/du-graphene-pour-fabriquer-des-gilets-pare-balles-encore-plus-resistants_art33946.html)

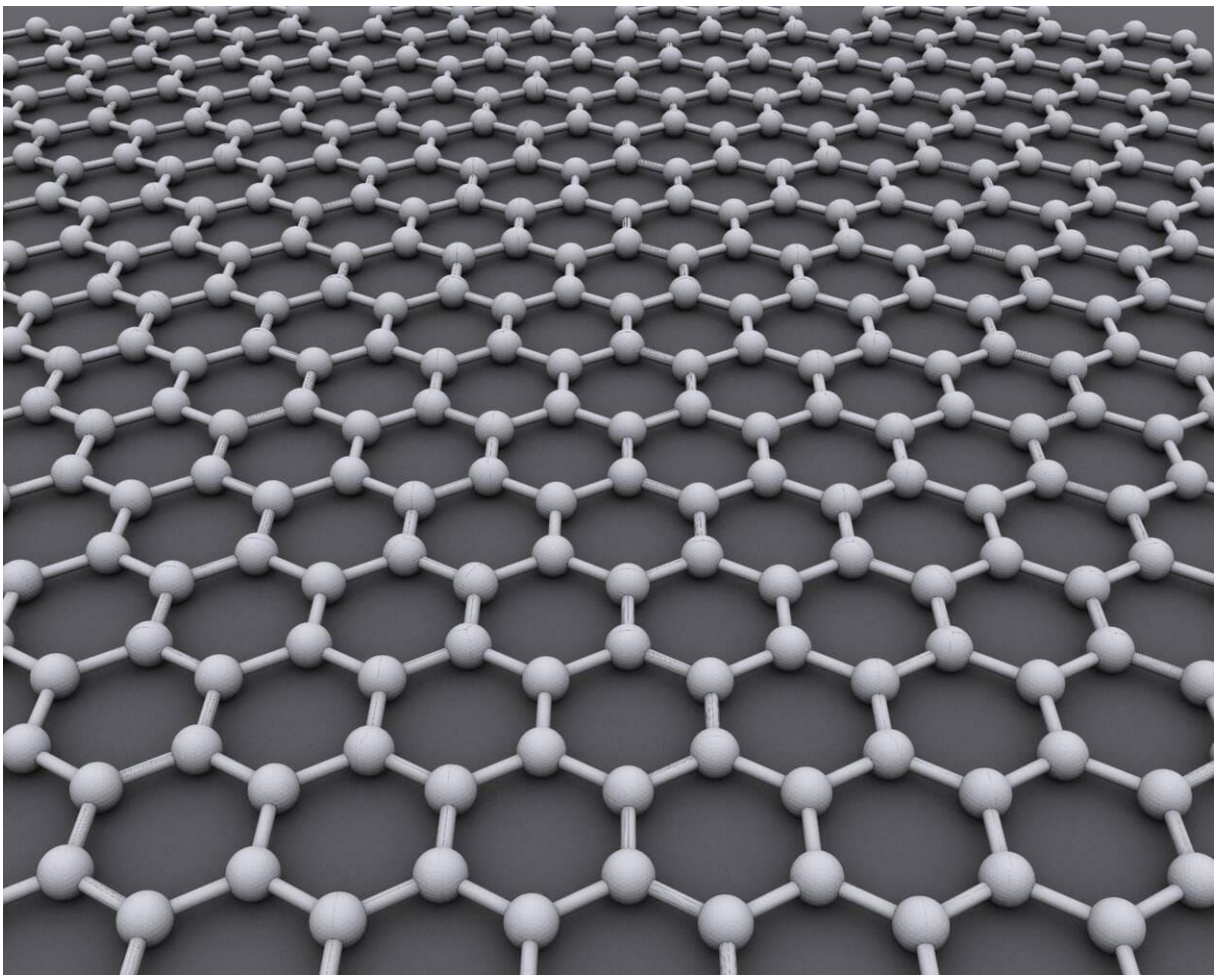
We talk about a miracle material, a revolutionary molecule, superlatives rain down on graphene. It conducts better than copper, **is two hundred times stronger than steel and is six times lighter**, flexible and waterproof. On paper, graphene is first in all categories. It's hard to imagine one day doing without metal or plastic, and yet this new material could soon become established in all fields.

Graphene is a two-dimensional crystal of carbon atoms evenly distributed in a honeycomb-shaped hexagonal lattice. In nature, stacking layers of graphene forms graphite, which is commonly found in our pencil leads.

Graphene was discovered in 2004 by André Geim and Konstantin Novoselov, professors at the University of Manchester, and awarded the Nobel Prize in 2010.

Without really believing it, the researchers used the adhesive strip of a roll of tape to stick graphite debris to it. Then they folded this strip with the adhesive side covered with graphite. By unfolding it, they reduced its thickness. And so on... In the end, only a layer of graphite remained. André Geim had made the discovery that would earn him the Nobel Prize : **the finest carbon crystal, which is only one atom thick.**

Honeycomb-shaped structure of graphene:



Graphical representation of graphene. | BY ALEXANDERALUS — OWN WORK, CC BY-SA 3.0

The important thing to remember is that for the same thickness, graphene is 200X stronger than steel while being extremely light. If you could put an elephant on a needle, it wouldn't go through a single layer of graphene!!

3. Can graphene be one of the answers to better ergonomics ?

Unquestionably, graphene can be one of the answers to a much lighter bulletproof vest with better comfort and skill in gestures and movements. And there is not even mention of the sometimes unbearable heat peaks during heat waves, which must be very inconvenient for the FDO or the military in hot and arid war zones.
"The weight of a bulletproof vest is between 2.5 and 4 kg for classes I, IIA, II and IIIA and between 5 and 16 kg for classes III+ and IV.

We can see that even if a bulletproof vest can indeed save your life, the weight of this vital protection remains a handicap on a daily basis.

Articles mentioning graphene's ability to stop a bullet are legion in the literature, as evidenced by the article below:

Source

Deux simples couches de graphène pourraient arrêter une balle

par **Brice Louvet, expert espace et sciences** • 23 décembre 2017, 12 h 00 min

Crédits: iStock

Attention !

Graphene is not intended to improve the chances of survival but only to provide a considerable gain in the weight of the vest and therefore better ergonomics.

Even if the bullet does not pass through the protection, the energy and formation of the dynamic cone will still be present with significant damage to the internal organs. These are known as "back effects"

Figure 1 – Absence de traumatisme pénétrant thoracique et abdominal chez un militaire porteur d'effets de protection au moment de l'agression

(Source : https://sofia.medicalistes.fr/spip/IMG/pdf/Interets_et_limites_des_effets_de_protection_blessures_de_guerre_.pdf)

What are « back effects » ?

"When the protection performs its bulletproof function, it absorbs a very large part of the energy provided by the impact of the ammunition against the vest. The latter brakes and then captures the ammunition at the cost of deformation and breakage.

So not all the energy is absorbed, some of it will be transmitted to the underlying body segment. The ammunition indirectly causes non-penetrating wounds called "rear effects" meaning injury effects behind the impacted protection.

The impact is transmitted through the vest to the chest wall. First, the shock wave passes through the wall in less than 200 µs, followed by the formation of a very localized dynamic cone under the impact. This deformity induces local injuries to the chest wall but also pulmonary haemorrhagic injuries. These injuries are called **Behind Armour Blunt Trauma (BABT**).

They consist of tissue destruction with haemorrhages with morbid consequences on major respiratory and cardiac functions. The lesions included a skin contusion, rib fractures and pulmonary hemorrhage. Injuries are functionally manifested by transient respiratory distress and then by cardiovascular disorders depending on the intensity of the haemorrhage."

In conclusion, graphene, whether or not combined with Kevlar® (or other materials), could provide a very significant weight gain. **This weight could be halved or tripled**, all with a thinner thickness and the same protection as the vests currently in use!

On the other hand, with the same mass and thickness as traditional vests, graphene could also drastically reduce the BABT and therefore increase the chances of survival.

These two alternatives are both of interest and possibly avenues to explore more closely...

L'article est unique et a été rédigé par un bénévole expert de chez ADESS, ayant une grande expertise dans sa thématique de prédilection. Il a accumulé une expérience professionnelle significative et des diplômes qui lui sont associés. ADESS n'a aucune intention d'approuver ou d'infirmer les opinions exprimées dans les publications, qui restent la propriété de leurs auteurs :

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