Journal of Interdisciplinary Science Topics

Are We Bulletproof?

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12/04/2024

Abstract

The Korean Pop group BTS is known as Bangtan Sonyeondan in Korean (방탄소년단) which translates to bulletproof boy scouts. By investigating the carbon-based materials used in producing bulletproof vests, this article explores whether the members of the group really can be bulletproof without bulletproof shields or clothing.

Keywords: *Music; Chemistry; Materials Properties; Carbon Nanotubes; BTS*

Introduction

The Korean Pop group BTS is also known as Bangtan Sonyeondan. This translates from Korean as "*bulletproof boy scouts"*, and the group have made being bulletproof part of their identity, particularly in their early years. On their first album, one of their first title tracks was *We Are Bulletproof pt 2* [1] as a sequel to their SoundCloud exclusive *We Are Bulletproof pt 1*, and on their Map of the Soul:7 album, released the third part to the trilogy called *We Are Bulletproof: The Eternal* [2]. But the seven members are humans, and humans are not bulletproof by nature. So, how can the seven be made bulletproof?

What bulletproof materials are there already?

Bulletproof materials and armour have been constructed since the Elizabethan times, where doublets were produced from plates of iron sewn between folds of cloth [3]. Torso armour was produced in the First World War that was made of steel and fibre layers but was impractical as it was too heavy for general use [3]. Modern bulletproof vests are made from nylon fabric, with usually 16-24 layers of heavy weave fabric. The layers dissipate the kinetic energy of the bullet. 16-layer vests can stop submachine gun or pistol bullets, and 24-layer vests can stop magnum bullets [3]. However, the wearer is generally bruised after impacts when wearing these vests, and so sustains at least some damage. How can the material be improved to prevent damage, and how can the material be formed on the skin?

Carbon-based materials

The human body, as with other life on Earth, contains carbon as the most important structural element [4]. As approximately 12% of the body's atoms are carbon, investigating carbon-based bulletproof materials is a good starting point for making humans bulletproof.

Carbon based composites used in the defence industry are sorted into two categories. The first is classical carbon materials, which includes char, carbon blacks, and activated carbons [5]. The second is nanostructured carbons, including graphene, graphite, fullerenes, and carbon nanotubes [5]. Carbon nanotubes, pictured below in figure 1, are the material we will focus on.

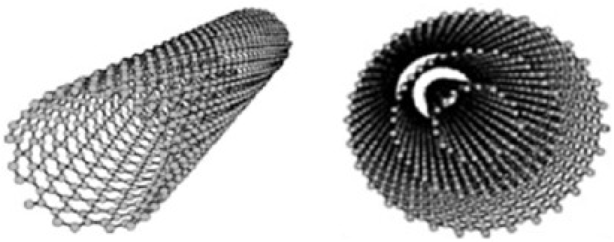

Figure 1 – A single walled, and a multi walled carbon nanotube. The carbon structure is shown, and carbon rings form a tube that can be considered one-dimensional. Modified from figure 1 [5].

Carbon nanotubes are seamless cylindrical sheets of graphite, and they have a very small diameter so that the aspect ratio is large. From an electrical point of view, they are considered one-dimensional structure [6]. The diameter is between 1-20 nm, and the length is of the order 1 µm or longer [6]. Each carbon atom within the structure is bonded to three neighbouring atoms through orbital hybridsation, and carbon nanotubes can be considered as tubular microcrystals of graphite [6].

Are carbon nanotubes bulletproof?

Prabha et al. [7] compared carbon nanotubes to Kevlar, which is one of the materials most commonly used in bulletproof vests and performed ballistic analyses on both. Kevlar has a high strength to low weight ratio, as do carbon nanotubes, but, with a Kevlar vest, the wearer has to absorb some of the blunt force trauma. This can be reduced with additional layers but requires an increase in weight [7].

Carbon nanotubes have a high strength, are lightweight, high ballistic resistance, and are 5-6 times stronger than Kevlar. The comparative data from the research is presented below in Table 1.

Property	Kevlar 29	Carbon nanotubes
Total deformation (mm)	87.909	37.751
Minimum deformation (mm)	3.4325	0
Maximum Von-MISES stress (MPa)	2800	14958
Minimum Von-MISES stress (MPa)	11.876	15.393

Table 1 – A comparison of the deformation and stress-resistant properties of Kevlar 29 and carbon nanotubes when fired with ballistic missiles. The Von-MISES stress determines if a material will give way or fracture under a certain pressure. Adapted from table 4 [7].

From figure 2, carbon nanotubes have better properties than Kevlar 29 in every aspect. The penetration of bullets is much lesser in nanotubes, and they can withstand a higher force of stress. Carbon nanotubes seem to be a good option, as they are derived from elements already commonly found in the human body and have bulletproof properties. The next problem to address is coating the body in them.

Forming carbon nanotubes

Carbon nanotubes can be formed from several methods. The carbon arc method is the simplest, and uses two carbon rods in an inert atmosphere, like helium. A direct current is used to initiate an arc between the two electrodes, and carbon deposits form on the negative electrode [6, 8]. The issue with applying this method to humans is that the nanotubes would either need to be spread across human beings, or the skin would need to be the negative electrode.

Another method of formation, which is the preferred method of synthesis, is using chemical vapour deposition. A carbonaceous gas is passed over a transition metal catalyst at elevated temperatures, and nanotubes form [8]. The problem with this method is that carbonaceous gases are not good for humans, and the elevated temperatures could lead to severe illnesses or death.

A third method is high pressure carbon monoxide conversion, which relies on the Boudouard charcoal reaction:

$$2CO \rightarrow C + O_2$$

This uses transition metal carbonyl catalysts to form the nanotubes [8]. Carbon monoxide is toxic to humans and, additionally, this method produces radical hydrogen species [8] which can interfere with skin cells and induce mutations that lead to cancers.

Another reaction that can form nanotubes is the vapour-liquid-solid mechanism. Carbon/catalyst vapour is co-condensed to form liquid catalyst-carbide nanoparticles, and the continued adsorption of carbon vapour onto the particles leads to a supersaturated phase where solid carbon nanotubes begin to grow [8]. The catalysts promote the formation of localised and highly reactive carbon species, which can again interfere with normal cellular processes and can cause the human being problems during the application process.

So, can we make bulletproof boy scouts?

While humans contain carbon that can be used to make bulletproof materials, trying to form a layer of a bulletproof covering on a human can prove difficult. Classical bulletproof materials require several layers which reduces moveability and increases the weight. While the bulletproof properties of carbon nanotubes have applications in defence, trying to apply them to human beings and coat people in a layer of the nanotubes to create a bulletproof covering on a person is not feasible. For now, the best way for the members of BTS to be bulletproof, is to use bulletproof vests, and to have good security.

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