



CERAMIC ARMOUR

Shaping Mobility and Protection
in Bullet Proof Jacket (BPJ) Applications



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(BPJ) Applications

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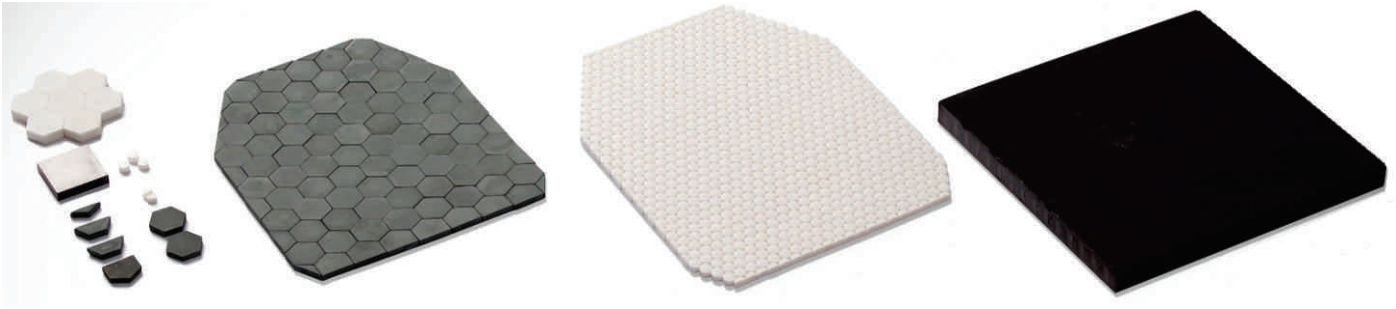
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INTRODUCTION

For centuries now, soldiers and security personnel have relied on body armour to keep themselves safe in dangerous situations. The materials used to produce body armour have been evolving. Our ancestors preferred steel to sculpt armour due to its strength and anti-corrosive properties. However, in response to modern threat levels, armour protection systems are also evolving.

Given that both greater mobility and improved levels of protection are important today, ceramic armour has emerged as a popular option. Ceramics such as Alumina, Zirconia Toughened Alumina (ZTA), Boron Carbide (B4C), and Silicon Carbide (SiC) have proven themselves to increase ballistic performance with an appropriate polymeric backing while also reducing the overall weight of the armour, thereby improving the mobility of the personnel.

Besides, ceramics being much harder, can absorb a large amount of kinetic energy from projectiles through fracture. They can also dissipate a large amount of compressive stress and hence offer better protection against high-impact projectiles.

In this paper, we will briefly examine the challenges associated with existing body armour materials and how ceramic can enhance body armour performance while overcoming these challenges.

OVERVIEW OF EXISTING ARMOUR MATERIALS

The primary objective of body armour is to halt attacking projectiles without causing harm to the human behind it. There are two types of body armour:



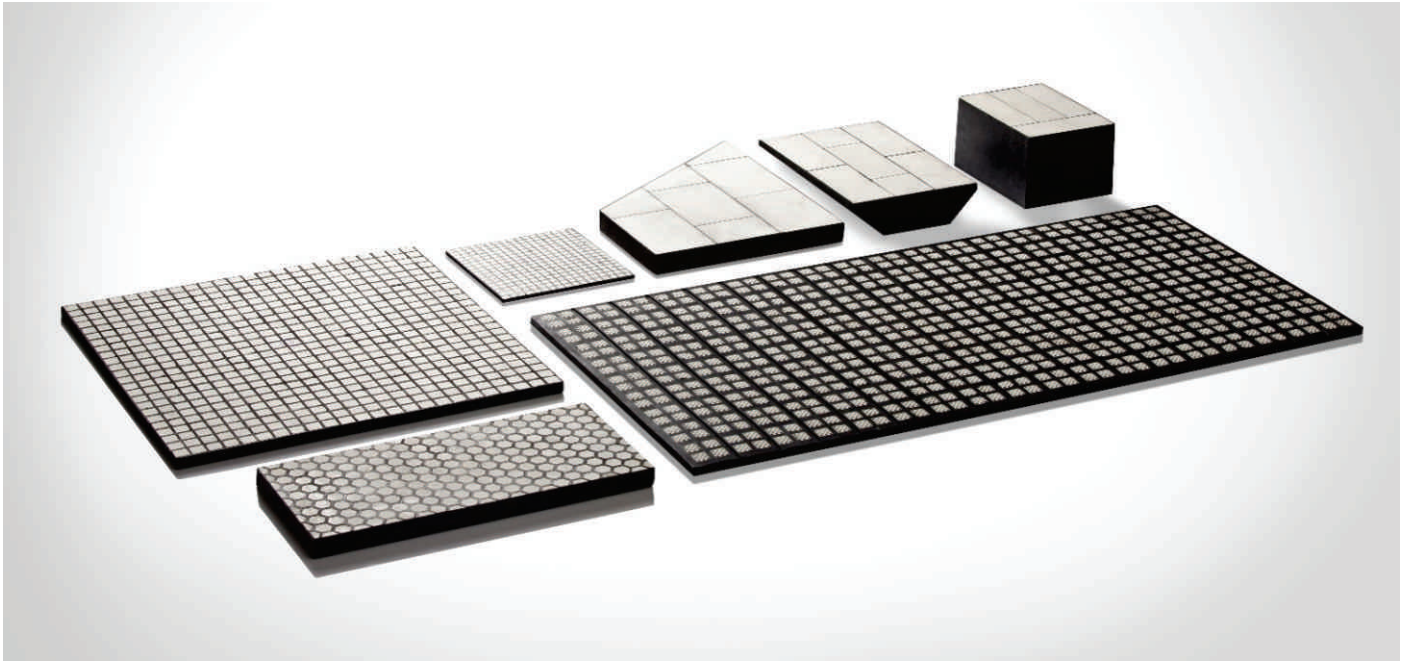
SOFT ARMOUR

Soft armour is predominantly made of polymers like aramid and ultra-high molecular weight polyethylene (UHMWPE). Soft armour can protect the wearer from low-energy threats such as projectiles with a velocity of 500 m/s or lower.

This includes formable technical textile laminates along with high-performance resin. For handgun bullets, a pack of laminated fabrics formed a comfortable wrap around the torso. To protect against sharp objects such as knives or spikes, different packs that contain stiffer materials such as laminated fabrics or metallic elements are used. For high-velocity rifle rounds including armour-piercing (AP) ammunition, it is a common practice to add a Hard Armour Plate (HAP) in front of the system that works together with the soft armour pack at the back to protect the wearer from perforation or blunt trauma. Polymeric fibre-reinforced polymeric matrix composite laminates also offer attractive features such as comfort, strength, and reduced weight.

Disadvantages

Some fibres such as Zylon environmentally degrade due to factors such as heat, moisture, ultraviolet radiation, detergents, friction and stretching. This could cause the vests to underperform, resulting in loss of life. Although fabrics are an excellent ballistic material against high-velocity fragments, they are structurally poor and unsuitable to perform the much-needed energy-absorption mechanism.



HARD ARMOUR - Ceramic and steel

Hard armour, used in conjunction with polymeric laminates, can protect the wearer from higher kinetic energy threats. Hard strike-face materials such as ceramics are used in hard armour. The hardness and strength of ceramic make it suitable for all levels of ballistic protection. The density of ceramic is one-third of that of metal, making it suitable for designing lightweight armour.

Disadvantages of steel armour

Metal-based armour materials have limitations of rigidity and higher weight, which also limits their mobility. Therefore, it is uncomfortable for the person wearing the armour. With the increasing threat levels due to an increase in safety and security against crime and terrorist activities around the world, there is a great demand for ceramic body and vehicle armour for the security personnel of political leaders and high-profile people. For body armour manufacturers today, the challenge is to produce a lighter-weight vest that not only provides maximum comfort but also optimal protection to the wearer. At the same time, the cost and availability of materials would also be of paramount interest.

A Brief Overview of Ballistic Protection Levels and Standards

The National Institute of Justice (NIJ) sets standards for different types of protection vest used by law enforcement agencies, including body armour. The agency conducts independent testing of body armour consisting of bulletresistant clothing and bulletproof material as per the Compliance Testing Program which is administered by the U.S. Department of Justice. These independent tests ensure that the body armour meets the highest standards. A body armour rating system allows consumers to compare products across various brands.

The various protection levels - Level IIA, Level II, Level IIIA, Level III and Level IV, are defined by the type and velocity of the projectile they can resist.

- NIJ IV is the highest-rated level of protection which is capable of resisting armour-piercing rifle bullets. These products are the heaviest in the market and therefore not as comfortable as the lower-rated ones.
- NIJ III stops rifle ammunition and all handgun caliber rounds.
- (NIJ Level III and NIJ IV represent the hard armour or plate inserts and they provide more protection than NIJ IIIA, IIA and II).
- NIJ Levels II and IIA protect against most common handguns. Due to their lower weight and bulkiness, they are more comfortable. NIJ Level IIIA also protects against most common handguns but they are heavier than NIJ II and IIA products. (NIJ Level II, IIA and IIIA are defined as soft armour)

Similarly, there are other industrial standards like STANAG (a NATO Standard for vehicle) and BIS (National Standard Body of India) that are used in armour qualification.

CERAMICS FOR ENHANCED BODY ARMOUR PERFORMANCE

Ceramics have emerged as a popular option for body armour manufacturers in countries like India. These ceramics are effective against hard-core, armour-piercing ammunition. Ceramic offers the following advantages:



Affordability and accessibility

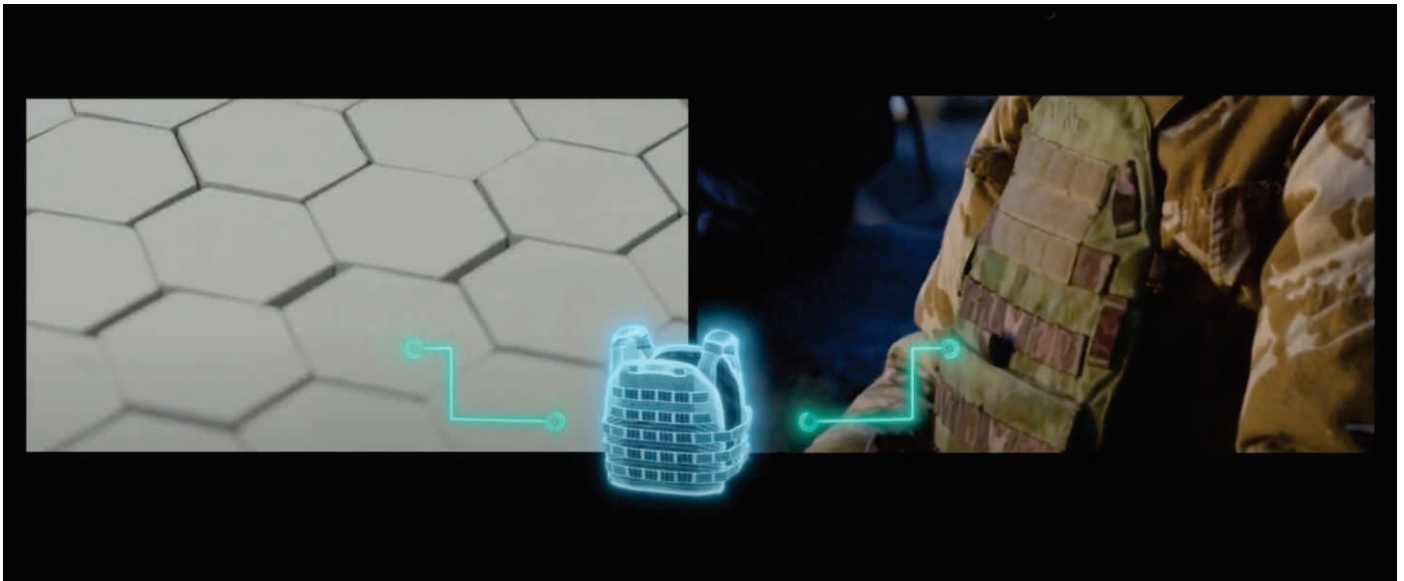
When compared to steel or polymeric laminates, ceramics provide higher protection and also have a lower cost-to-performance ratio while having advantages in terms of hardness, strength and mobility.

Advanced ceramics popularly used for body armour applications are Reaction Bonded Silicon Carbide (RBSiC), high purity Alumina, and Zirconia Toughened Alumina. Usually, RBSiC, sintered SiC, 99.6% and 99.5% Alumina, and ZTA are being used to design armour for personal and vehicle protection. Recently, Reaction Bonded Silicon Carbide + Boron Carbide (RB SiC + B4C) has emerged as a strong contender for high-end ballistic protection. Hot-pressed Boron Carbide (B4C) finds application mostly in helicopters.

While boron carbide's lower density allows for better mobility, it is also the most expensive. The major manufacturing process of making sintered boron carbide involves hot pressing and hence makes it difficult for mass production in bullet-proof jacket applications.

Due to affordability and unavailability issues of B4C, RBSiC is likely to be the preferred material for body armour in mass tenders.

Moreover, manufacturers of body armour systems are increasingly opting to use silicon carbide-based armour products as they perform better than their boron carbide counterparts when it comes to multiple shots.



Greater safety

Body vests or jackets made of ceramics also can reduce the kinetic energy of the projectile through fracture and absorb compressive waves, which minimizes the impact on the person wearing it. Since body armour is made up of several ceramic segments/tiles, in the event of a projectile hitting one tile the crack propagation gets restricted and hence offers a better product for multi-shot application. Also the ceramic cracks and hence reduces the kinetic energy of the projectile while the back-up soft armour absorbs the same. The degree of probability of the bullet hitting the same tile again in a multi-shot situation is practically very minimal. These ceramic tiles come in various shapes – hexagon, cylindrical or diamond shape depending on the amount of area coverage needed.

The future of body armour

Ceramics hold enormous promise as the future solution for body armour. They offer features such as increased hardness, high strength, crack-deflection behaviour and the ability to be designed and used in conjunction with backup materials such as high-performance polymeric laminates/elastomers to enhance the overall ballistic performance of ceramic-based armour products.

In future, hybrids of ceramic materials in ratios that optimize properties of the materials to meet threat levels and affordability could dominate the market. CUMI's lightweight ceramic ballistic solutions engineered with high-purity Alumina, ZTA and RBSiC, are ergonomic and customized into various sizes and shapes for use in bulletproof vests.

CUMI's technical capabilities in ceramic production

Being the leading manufacturer of high-quality ceramics in India and supplying to the Aerospace and Defence sectors, CUMI has exhibited its expertise in producing ceramics for armour applications. CUMI Ceramic has been manufacturing and supplying around 10,000 MT of technical-grade ceramic products including different varieties of alumina, zirconia, aluminium titanate, SiC etc. CUMI is the second largest producer of Silicon Carbide powder globally.

CUMI is also in the process of commissioning one additional tunnel kiln to meet its high-end alumina and zirconia demands. CUMI is expanding manufacturing capacity of RBSiC by fivefold to meet growing demand.

CUMI's ceramic products which are used for personal armour systems in India and abroad, have qualified for NIJ levels III+ and IV application. The company has established itself as the leading manufacturer of high-quality ceramics in India and has all necessary backward integration facility in place to produce ceramics for armour applications.

Conclusion

The global ceramic armour market is growing rapidly due to the rise in demand from the military and law enforcement sectors. The ceramic armour market size is expected to reach USD 3.5 Billion by 2027. This only means that the world increasingly needs lightweight armour to protect against growing threats and new combat situations.

While material development and design across polymers and ceramics will continue to reshape the body armour systems, manufacturers will have to give utmost importance to following the latest body armour standards and producing high-performance products from high-quality raw materials to meet emerging needs and increased levels of protection. Given the multitude of advantages that they bring, ceramic-based armour panels are all set to emerge as the go-to material for bulletproof vests.

References

- National Institute of Justice, “Current and Future Research on Body Armor,” January 1, 2010, nij.ojp.gov:
- <https://nij.ojp.gov/topics/articles/current-and-future-research-body-armor>
- <https://www.m-v-s.de/en/company/news-und-events/ballistic-protection-levels-explained-nij/>
- <https://www.sciencedirect.com/science/article/pii/S2214914718305932#bib16>

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