Silicon carbide offers strength and versatility as an armor material to protect personnel and infrastructure assets.

Figure 1. Sintered SiC Hexoloy® body and vehicle armor tiles by Saint-Gobain.

Figure 2. Hardness of various types of ammunition and armor materials. Note that Vickers hardness of the lead antimony core 7.62 mm NATO ball is only 10 HV.

We have all seen body armor in the movies: a gunfight erupts, bullets fly, and one of the protagonists is knocked over backwards. She has been hit! Is she mortally wounded? No—predictably, she regains consciousness and opens her jacket to reveal an intact bulletproof vest with a shiny bullet perfectly mushroomed from impact. Impressive? Yes. Accurate? Not at all.

Bullet-resistant vests, or “body armor,” have become standard equipment for law enforcement and military. Maximum protection at minimal weight is the ever-advancing goal for body-shielding gear. High hardness makes ceramic materials like silicon carbide (SiC) an ideal candidate for stopping rifle bullets. In fact, SiC inserts, like those made of Saint-Gobain Hexoloy® sintered SiC (Figure 1), when combined with adapted backing materials and inserted into protective vests, are the most common ceramics in top-performing hard body armor protection systems against high-velocity “armor-piercing” (AP) projectiles.

The hardness (Figure 2) and impact resistance characteristics of SiC lend themselves well to the requirements of stopping a bullet—and saving a life. Here is what really happens when a bullet strikes ceramic body armor.

First, let’s have a closer look at bullet and body armor structure and interaction. For the most part, a bullet is composed of a case, powder charge, and projectile. Modern armor piercing projectiles have a jacket, which is a sheath of metallic alloy around a generally denser, harder core often made of steel or other very hard (tungsten carbide) or dense materials. When a gun is fired, the powder charge is ignited, introducing energy into the projectile. When the projectile impacts a properly configured body armor system, its kinetic energy is dispersed and spreads across a much greater area than the projectile’s original cross section. The armor system prevents the projectile from penetrating into the body of the wearer.

The kinetic energy in a 7.62 mm AK-47 round is about 2,000 joules, which is equivalent to being hit by fourteen 100 mile-per-hour professional fastballs in a cross sectional area of 0.07 square inches. When a projectile comes in contact with a ceramic armor plate, the projectile’s jacket is stripped away. The violent impact of a projectile core with the much harder ceramic erodes and deforms the core and shatters the ceramic (Figure 3). The armor system absorbs the energy and all of the projectile and ceramic fragments. The ceramic panel and supportive backing incorporated behind it spread the force across the area of the vest, and then transmit the energy to the wearer at a level that is survivable. Ultimately, the wearer is protected from penetration and deadly blunt force trauma during a ballistic event.

Edward Acheson discovered SiC 125 years ago while trying to make synthetic diamonds. Hexoloy®, a special sintered SiC manufactured by Saint-Gobain Ceramics, is one of the hardest materials after diamond, but weighs nearly 2.5 times less than steel (Figure 4)—properties perfect for stopping high-velocity, armor-piercing projectiles as described above.

The manufacturing methods for sintered SiC ceramics allow for custom designed shapes, including complex curvatures and
other advanced geometries, to provide specific levels of ballistic protection to sensitive targets. Mastery of green shaping through pressing or casting and machining of fired and unfired components are critical to ensure the level of performance and quality required for protection in a ballistic event. One-piece helmet designs are an example of the exceptional levels of complexity that can be achieved with advanced ceramic processing technologies (Figure 5).

Continued development efforts within Saint-Gobain Ceramics are focusing on the next generation of ceramic body armor. New chemistries that produce multiphase microstructures are being developed to increase the level of protection offered and grant the opportunity to reduce the weight required to meet a specific protection level. These advances enable ceramic armor technology to keep pace with new emerging ballistic threats. While military and law enforcement body armor have used ceramic insert panels for some time, new applications, including architectural, structural, vehicle, and civilian security, are taking advantage of this technology more frequently.

Specifically for vehicles, the light weight advantages of SiC armor are becoming more important as modern militaries place greater emphasis and value on mobility. These include wheeled, fixed and rotary wing, and waterborne strike and transport platforms. In some situations, a ceramic armor system may be modular to further enhance flexibility of the vehicle platform to be adapted to the situation at hand. Saint-Gobain offers reaction-bonded SiC armor solutions that enable monolithic panel constructions with excellent multihit capabilities—a perfect fit for vehicular installations.

Whether civilian, military, or law enforcement, at home or abroad, SiC is the strike face material chosen for its adaptability to the threat level encountered. Manufacturers such as Saint-Gobain Ceramics continue to invest in this application, and these products continue to save the lives of service men and women of all countries, in all locations, around the world.

About the authors

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References