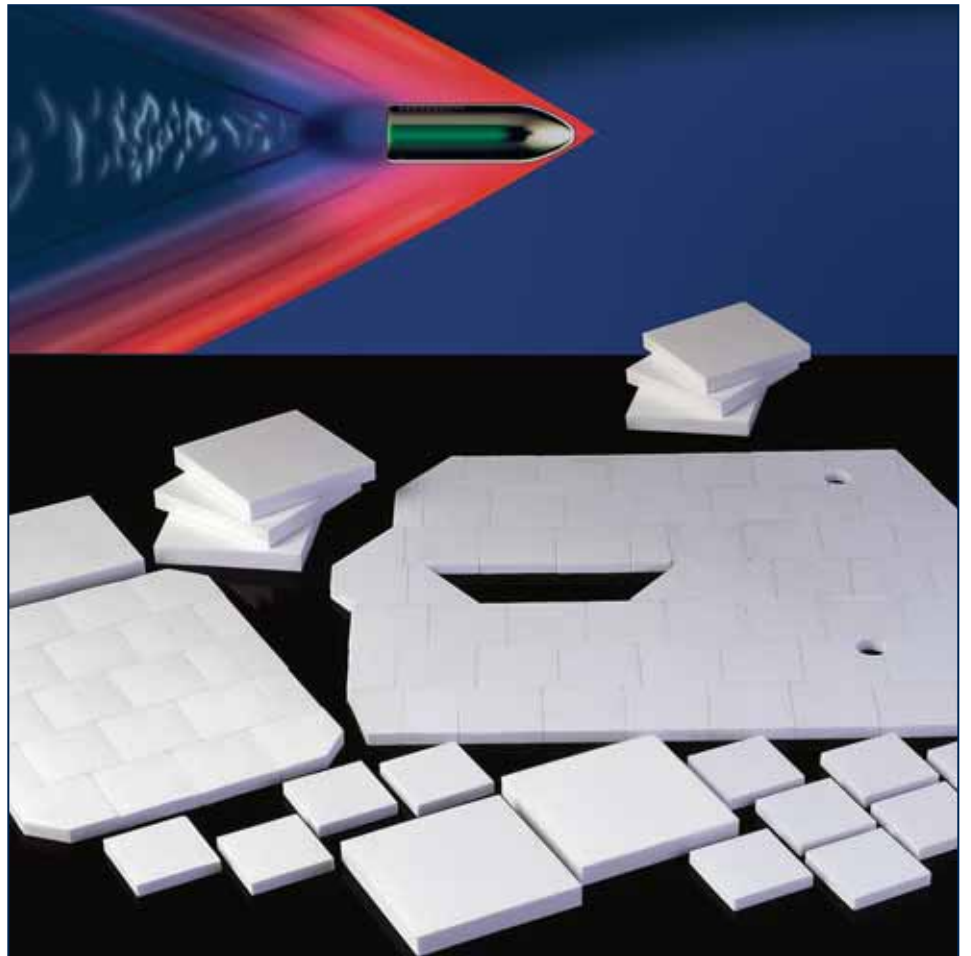


ALOTEC®

HIGH PERFORMANCE ALUMINA
FOR PERSONAL AND BODY PROTECTION



HIGH PERFORMANCE CERAMIC, THE SUPPOSITION FOR . . .

Ceramic Materials are brittle and therefore, they are susceptible to impacts. In spite of this, ceramic is being applied in the field of armor protection. Ceramic materials alone only provide limited protection against bullet impacts, however, when combined with other materials, within a composite construction, the advantages of ceramics become evident. Particularly in the field of body protection, but also for armoring motor vehicles, ceramic materials have been successful to a large extent in replacing previously used steel plates.

For ballistic application of ceramic materials the following properties are required:

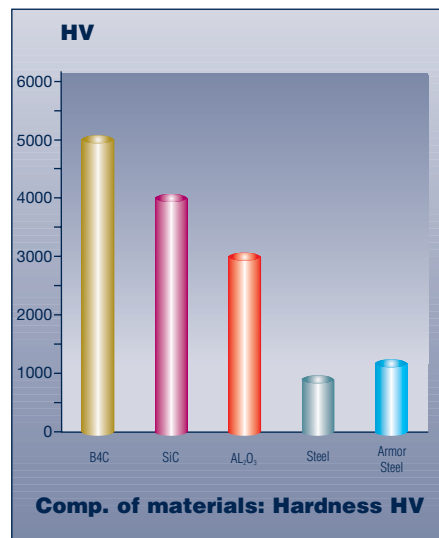
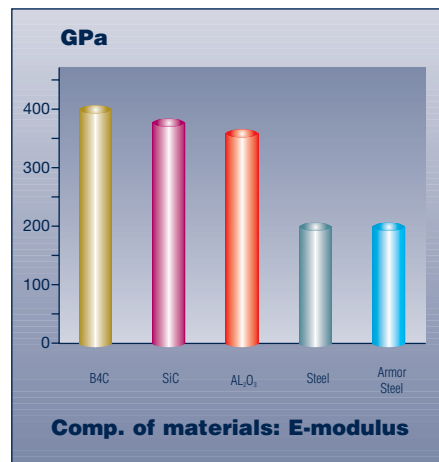
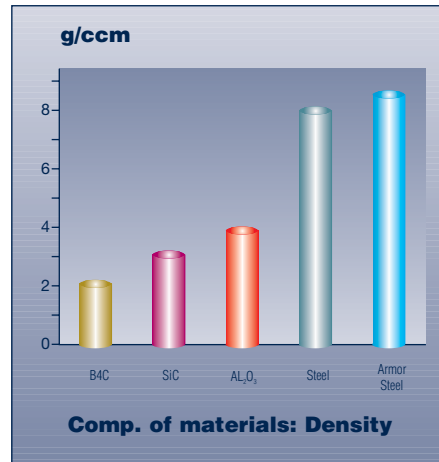
- **High hardness**
- **High fracture resistance**
- **High E-modulus**
- **High sonic velocity**
- **Low weight per area**

These requirements are met by several ceramic materials. Below the most important materials:

- **Boron carbide**
- **Silicon carbide**
- Silicon nitride
- **Alumina**
- Aluminium nitride
- Fiber-reinforced ceramic
- Ceramic/metal composites

Due to its excellent price-efficiency ratio, the most important one among the above mentioned materials is alumina. Only when extremely low weights are required, are boron carbide or silicon carbide used, such as in helicopter applications. Fiber-reinforced ceramic materials and ceramic-metal composite applications are very limited.

For ballistic applications, ceramic pro-



duction technology must be carefully controlled. It is absolutely necessary that all components are free from cracks and pores, and the tiles are only allowed to show very few chips on edges and corners. A bulk density of at least 98% of the theoretical density must be achieved for optimum ballistic performance. Equally important is the uniformity of all ceramic tiles, with the following features: tight dimensional tolerances, surface parallelism, defined angles and flatness of surfaces. Only when all these requirements are met, can close-joint laying of the tiles be made. Joint gaps of more than 0,3 mm are apt to become a weak point with regard to the ballistic strength of the whole system. Adherence to all relevant physical properties is required.

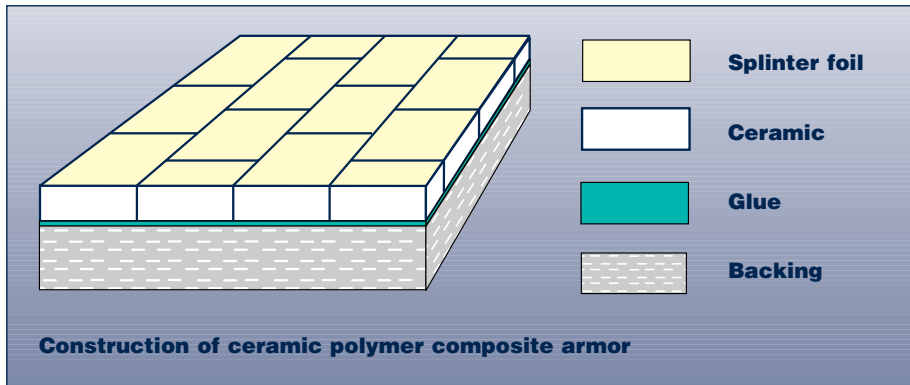
Following are the prerequisites to meet these requirements:

- **Careful selection of raw materials and additives**
- **Controlled and reproducible preparation of raw materials**
- **Absolute expertness concerning the forming and sintering technology**
- **Complete Quality Management during all production stages – from the powder stage until the finished product**



Nearest tolerances guarantee smallest joints

... CERAMIC COMPOSITE ARMOR SYSTEMS

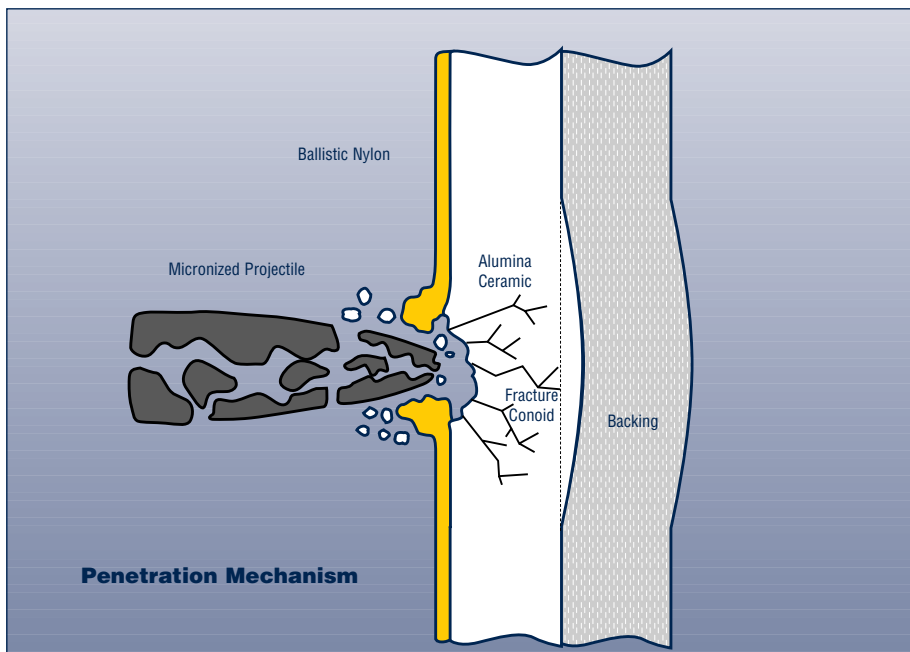


The basic principle of these light-weight systems is based on a composite construction composed of ceramic and polymers. In these systems the four components have different functions: The front side of the composite armor consists of ceramic tiles, which, due to their favorable cost, are generally made of alumina.

For the **backing**, high-performance and high-elastic polyaramide (e.g. Twaron) or polyethylene fibers are used.

By impregnation with rubber or curing polymers with a specified shore hardness desired rigidity and ductility are achieved.

An alternative to polyaramide materials are glass fiber composite materials. The joining technique between ceramic and backing is of critical importance for the whole system. Exclusively high-performance adhesives are used, and additionally a spall liner is fixed on the front side of the ceramic.



Protection mechanisms

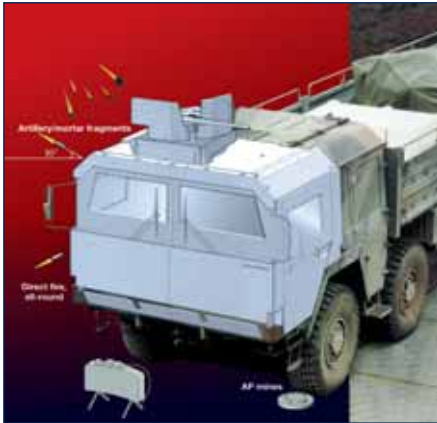
The protective effect of **metals** is based on their plastic ductility, causing a transformation of kinetic energy of the bullet into a deformation process.

The ballistic performance of **ceramic composite armor** is based on a totally different mechanism. When the bullet strikes the ceramic surface, initially a deformation of the bullet tip takes place and thus, an enlargement of the cross section. When penetrating the ceramic, the ceramic is pulverized. Possible reasons are:

Impact and friction processes, but above all reciprocal effects between the longitudinal shock wave and the reflected wave. This is the reason why after penetrating the ceramic there only remain bullet fragments. Due to the low mass of these fragments, their kinetic energy is considerably lower and they are entrapped by elastic/plastic deformation within the backing. When this mechanism takes place, only a relatively small share of kinetic energy of the bullet is transformed into fracture energy.

Each component within the composite system has a particular function. In addition to the quality and homogeneity of the ceramic, a further decisive parameter is the adhesion. It must be ensured that bullets striking the ceramic will not cause any loosening of the ceramic from the backing, yet permit the shock waves to be transferred.

LAYOUT AND ASSEMBLING

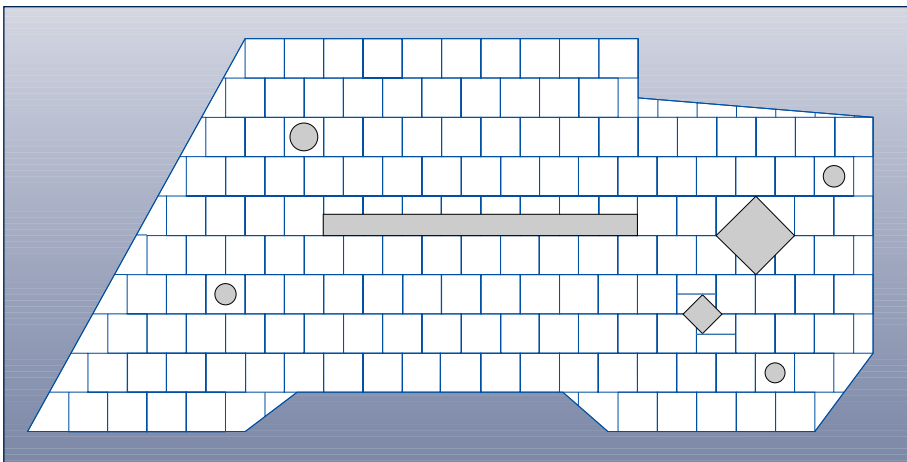
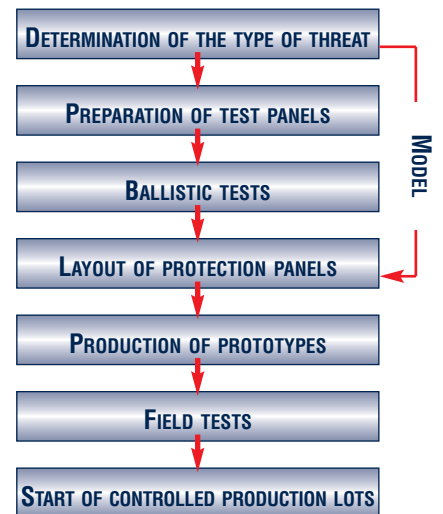


Ceramic composite armor protect from direct fire, against mortar and bullet fragments as well as against ground mines. It should be emphasized, however, that these panels will not be able to correctly function unless the composite system has been properly engineered. The following criteria are to be taken into consideration:

- ceramic quality and dimensions
- backing quality and thickness

- proper mounting of the assembled panels

The following procedure has proven to be adequate for the engineering of light weight armor:



Layout for front side of a vehicle



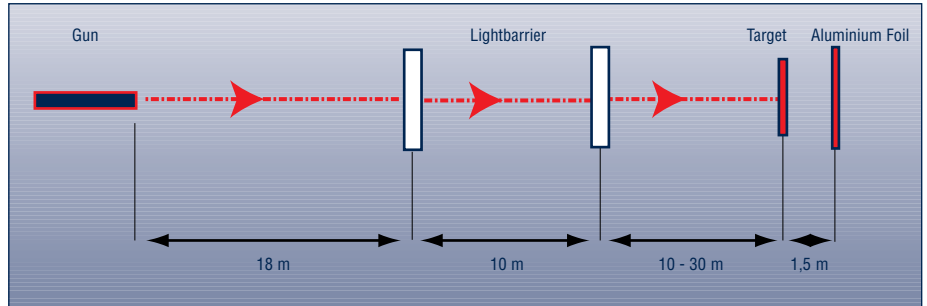
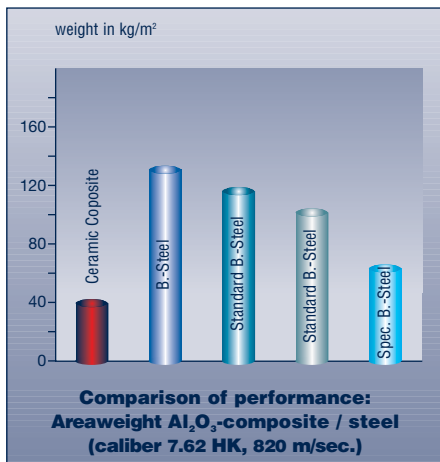
Pre-engineered and assembled ceramic have shown to be desirable at numerous projects, thus making unnecessary the expensive diamond cutting and drilling of the tiles forming the ceramic panels.



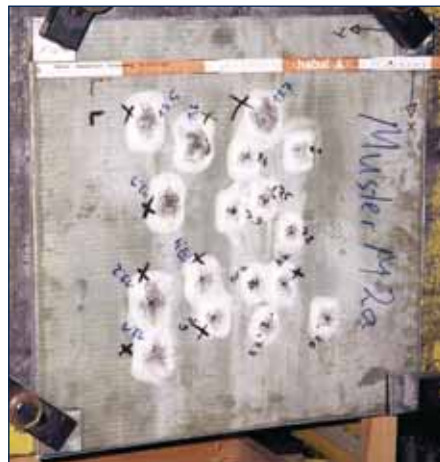
Protection panel for vehicle door UNIMOG – interior armor ALOTEC – 96 SB / Twaron composite

BALLISTIC TESTS

Based on type, caliber, weight and speed of the bullet, the threat levels are divided into different protection levels. The most common standards in the U.S. are the NIJ standard (National Institute of Justice) and the European Standard – C (Euronorm). For the lower protection level range, comprising bullet speeds of less than 450 m/sec and kinetic energies of up to approx. 1500 J, the so-called "soft armor", based on polyaramide, ensures a sufficient degree of protection. However, these systems are not suitable to absorb higher quantities of energy. Solutions involving steel have meanwhile been displaced by ceramic composite armor, enabling a weight reduction between 30-50%. Alumina-polymer composites with a weight per area of less than 50 kg/qm provide protection from hardcore bullets of caliber 7.62 mm (NATO rifle, Kalashnikov, Dragunov) with kinetic energies of up to 4500 J. There are also properly designed systems available for the protection against artillery, mortar and grenade fragments. Composite armor systems have also proven to perform successfully against mines. An even higher degree of pro-



Design of a testing stand



Ballistic test: gun fire

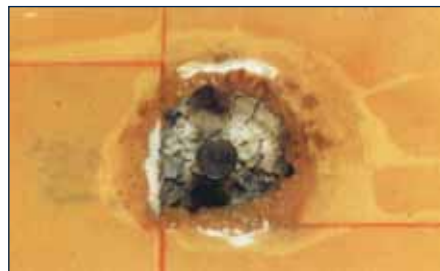


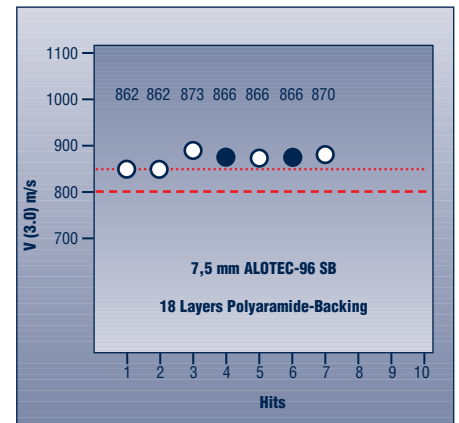
Illustration of cracked ceramic caused by direct gun fire



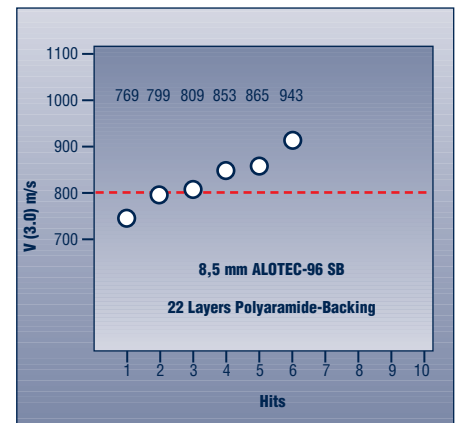
Illustration of cracked ceramic caused by fragment fire

tection, e.g. against machine gun and light artillery fire, can be achieved by thickening the ceramic (up to 30 mm) plus backing.

There exist interesting test results for armor protecting from high velocity bullets.



Certificate of shooting (V 50 value)



Certificate of shooting (threshold value)

BODY PROTECTION

Conventional armor protection vests provide inadequate protection from direct gun fire. According to the type of threat, the vests can be upgraded, that means, by inserting polymer-soaked polyaramide fiber plates as protection against hand guns, or by ceramic-polymer composites against rifle fire. The requirements of the upper protection levels can be fully complied with by using ceramic-polyaramide inserts, e.g. DIN 52290 level 4 and 5, NIJ Standard level III and IV, European Standard level B5, B6, B7.

Today, mostly ceramic monolith plates are used as inserts for armor vests. They can be adapted to the body shape to a great extent by means of double-curved levels, giving additional comfort to the wearer. Depending on the requirements of the individual protection levels, the plate thickness can vary accordingly. ETEC supplies a number of standard tiles – ranging from "single curved" to "multi-curved". Thanks to the variety of production technology for ceramic materials, it is also possible to produce designs according to customers' specifications. The multi-hit resistance can be improved by utilizing new composite systems.

Inserts based on single-curved ceramic tiles, with radii between 200 and 400 mm provide an improved multi-hit protection. The dimensions of the tiles are generally 50 x 50 mm. For special applications it is also possible to produce larger dimensions.

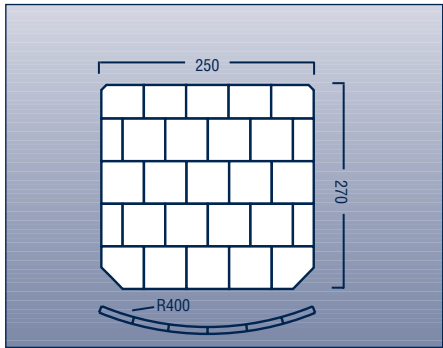
The improvement of multi-hit resistance, however, can be disadvantageous to the wearer's convenience.



Ceramic inserts for armor vests



Special designed inserts for large 380x320 mm, R = 200 mm vest



Standard tile 300x250 mm, R = 400 mm

OBJECT PROTECTION



Armored personnel carrier M 113

High-tech ceramic composite panels have upgraded protection levels as add-on armor for vehicles. Other applications include mobile functional containers, e.g. used as evacuation hospitals or command centers.



Evacuation hospital

IBD (Mexas system)



MB 2638 KMW / IBD (Mexas system)



MAN KAT 1 KMW / IBD (Mexas system)



Protection for tracked vehicles/ Leopard KMW / IBD (Mexas system)



EAGLE

Tissu



German transport tank FUCHS

(IBD / Mexas system)

COMPETENT IN ARMOR CERAMICS



Providing of layout by 3D - CAD.



Automatic hydraulic presses are the guarantee for nearest tolerances and equal high quality.



Computer-controlled high-temperature kilns ensure defined sintering processes.



Quality control attends production from powder till delivered components.



ETEC Gesellschaft für Technische Keramik mbH is a company with a great research potential and high flexibility. The basis of the success is the orientation on customers requirements, continual innovation and the total Total Quality Management in accordance to ISO.

The ETEC production program covers:

- Ceramic linings for wear- and corrosion protection
- Ceramic components for machines and plants

- ceramic for high temperature application
- ceramic or composite armor

Especially in the field of composite armor standards has been set by ETEC in regard of ballistic performance, observance of nearest tolerances and realization in terms of delivery. Assumptions to fulfil these requests are the TQM-system, an integrated VPPS-system and the application of modern shaping and sintering equipments.

ETEC Gesellschaft für Technische Keramik mbH

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