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**DE-B3- 10 303 351**  
**US-A1- 2009 217 813**



**Description**

The invention relates to components made of ceramic materials for ballistic protective applications. In particular, such components are used for vehicle armoring and

5 protective vests.

Ceramics have been used for many years in combination with other materials for ballistic protection of persons and objects (DE 1 578 333 A1). The decisive advantage of ceramic armoring is a significant reduction in weight of the ceramic composite systems by more than 50% compared to conventional armor steels. The properties of a ceramic material for ballistic or similar protective applications can be varied by the selection of the raw materials used, their composition and the process parameters during production (hardness, strength, toughness, density). However, an optimum protective effect, especially under multi-hit loads, can only be achieved by a combination of materials with high hardness (front) and high toughness (back) (US 2009/0217813 A1). The hard layer in the front area has the task of deforming or breaking the projectile. The layer or layers behind it serve to intercept the projectile or its remnants and the fragments of the destroyed ceramic. The decisive factor is that the complete kinetic energy of the projectile is converted into work and heat by the shattering of the material during penetration into the ballistic protection equipment. So far the problem has usually been solved by a sandwich construction of ceramic materials and/or synthetic fibers and/or metals. DE 103 03 351 B3 discloses such a component made of a metal/ceramic composite material with an intermetallic matrix, its use as an armoring material and the process for its manufacture. EP 0 260 235 A2 discloses a shaped body consisting of alternating layers of hard and tough (preferably steel) materials, which is produced by an extrusion process. The pulverulent ceramic hard materials of the hard layer are filled into a metal tube. The hard materials are distributed in a metallic matrix by extrusion or isostatic pressing. The layer structure in the shaped body is not formed by a sintering process. Metal must always be used as the matrix.

The problem underlying the invention is to provide a component for ballistic protective applications that guarantees more effective protection than the prior art. The object of this invention is therefore a method for producing of a component with a front and a

back side in accordance with independent claim 1. Furthermore, a component produced using this method for ballistic protective applications in accordance with claim 2, or claims 3 and 4 which refer back to it, is another object of this invention.

5 The core of the invention lies in the fact that two or more ceramic materials are joined in the manufacturing process in the form of a layer, wherein stresses are specifically induced in the layer structure. Thus, the proposed component combines both functions (destruction of the projectile and interception of the fragments) in one composite and an optimal energy destruction or impulse transmission takes place. The advantages  
10 achieved by the invention are, in particular, that the first layer of material facing the load (e.g. projectile) has a high hardness and leads mainly to deformation, fragmentation and erosion of the impacting body. The material or materials lying behind it have a higher toughness and thus hinder the propagation of cracks and thus limit the damaged volume of the armor.

15 The primary impulse of an impacting projectile is transferred, due to the preservation of the impulse, to the protective body consisting of layers or material gradients and is split into as many small individual impulses as possible with different directions (billiard ball principle). The compressive and tensile stresses introduced into the layer structure  
20 contribute to increasing the mechanical strength of one or more layers. By releasing or becoming free of stresses, a targeted distribution and deflection of the impulse of the impacting body onto the layer structure or the resulting fragments can take place. The stressed shaped body built up from layers or material gradients assumes an active function, so to speak. The mechanical energy is converted into work for shattering or  
25 crushing the composite in the vicinity of the impact. The smaller the fragments produced in a specific volume, the more energy can be absorbed. If a curved, non-planar geometry is specifically generated by stresses, this can also be used to deflect the primary impulse. This behavior can improve the energy conversion and thus the protective effect, especially under multi-hit loads, and can lead to a reduction in the  
30 material thickness or the weight per unit area of an armor, for example.

According to the invention, the different material layers are already formed during shaping in the green state before sintering. The component can consist of dense and

porous material layers. After sintering, porous layers can be filled or infiltrated with plastics, glasses or metals so as to modify specific properties.

Shaping can be carried out by uniaxial dry pressing or other shaping processes  
5 common in the ceramic industry (e.g. casting, foil casting, injection molding, isostatic pressing, printing).

During shaping, the different materials can be introduced into the tool or mold  
separately or successively and can be simultaneously formed into the green body.  
10

Production may also be carried out by two or more successive shaping processes.

It is also possible to combine different forming processes.

15 According to the invention, the stresses are introduced into the layer structure by the green densities of the layers set during shaping and the subsequent sintering process.

In the ceramic shaping of a material, for example, the green density can be influenced  
by the pressing power or the binder system before sintering. A higher green density  
20 reduces shrinkage during the sintering process, a lower green density leads to higher shrinkage. By adjusting the green density, the shrinkage can be varied in the range of almost 0% to 5% without significantly affecting the final density after sintering. If the green densities of one or different materials are influenced as described during the shaping of the layer system, tensile or compressive stresses can be specifically  
25 adjusted by the different shrinkages.

The generated stresses must be "adjusted" in such a way that they do not lead to cracks or delamination in the layer system.

30 The applied stresses can be used during sintering or in joining processes to form curved contours of the finished shaped bodies. The resulting geometry contributes to the targeted impulse deflection.

The invention will be explained in more detail below with reference to exemplary embodiments and drawings. In the Figures: Fig. 1 shows a component consisting of three layers, Fig. 2 shows a component according to Fig. 1 with another layer and Fig. 3 shows a curved component.

5

Figures 1 to 3 show components with different layer structures. According to Fig. 1, the component consists of a first layer 1, a second layer 2 and a third layer 3. The first layer 1 and the third layer 3 consist of different ceramic materials. The second layer 2 consists of a mixture of the materials of the first layer 1 and the third layer 3. The first  
10 layer 1 is thus functionally the particularly hard layer which destroys the projectile and the following layers intercept the fragments. In addition to the structure according to Fig. 1, the component according to Fig. 2 has a porous layer 5 which is connected via a joining zone 4 and filled with a plastic material. The stresses are introduced into the component according to Fig. 3 in such a way that a curved geometry of the layer  
15 structure is produced. The geometry designed in this way contributes to targeted impulse deflection.

## List of reference numerals

- |   |   |              |
|---|---|--------------|
|   | 1 | first layer  |
|   | 2 | second layer |
| 5 | 3 | third layer  |
|   | 4 | joining zone |
|   | 5 | porous layer |

**P a t e n t k r a v**

- 5        **1.** Fremgangsmåde til fremstilling af en komponent med for- og bagside til ballistiske beskyttelsesanvendelser bestående af en kompositdel, hvor kompositdelen fremstilles i form af lag af to eller flere keramiske lag, hvor forsiden funktionsmæssigt udviser en stor hårdhed og trykstyrke i forhold til erosion og reducere af indtrængningsdybden af et projektil og et bagved liggende lag i retning mod bagsiden til opfangning af resterne af projektilet og materialesplitterne, **kendetegnet ved, at** den keramiske formgivning af kompositdelen sker ved en opbygning i lag af keramiske materialer med lagvist forskellige grønne massefylder, og kompositdelen efterfølgende sintres til komponenten, hvor der målrettet induceres mekaniske spændinger i komponenten gennem de forskellige grønne massefylder.
- 15        **2.** Komponent til ballistiske beskyttelsesanvendelser med for- og bagside, bestående af en flerlaget keramisk funktionskompositdel, fremstillet ifølge det foregående krav, **kendetegnet ved, at** tilgrænsende lag af funktionskompositdelen har enten indførte trykspændinger eller trækspændinger.
- 20        **3.** Komponent ifølge krav 2, **kendetegnet ved, at** funktionskompositdelen har en bølget geometri.
- 4.** Komponent ifølge krav 2, **kendetegnet ved, at** grænsefladerne af lagene ikke forløber parallelt i forhold til for- eller bagsiden.

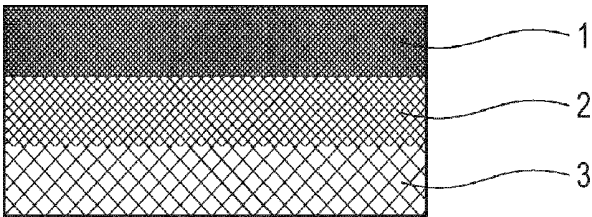


Fig. 1

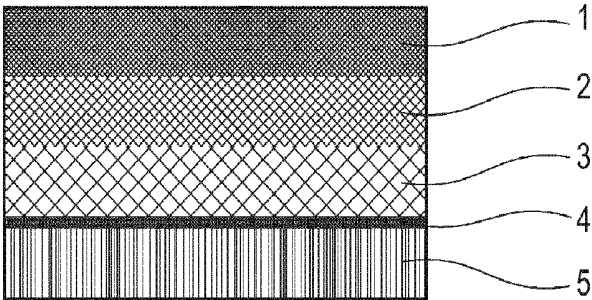


Fig. 2

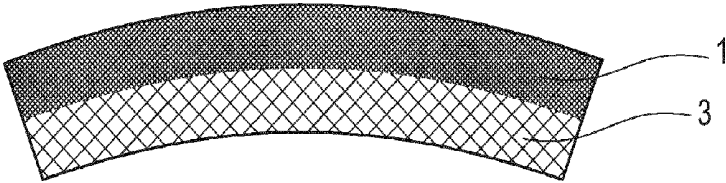


Fig. 3