Special Materials for Miniaturised Assemblies in Electronics

Miniaturised assemblies for electronic applications require highly resilient materials – thermally, mechanically and tribologically. Specially formulated high-conductivity ceramics, such as Rapal® 1000 ZA developed by Rauschert, are ideally suited for this purpose. In combination with a processing procedure adapted to the respective component, it is possible to reproducibly produce filigree parts that reliably fulfil their function.

Introduction

High-performance ceramics are always used when conventional materials do not provide the required performance in the application. In the past, these wear-resistant materials have been used in a wide variety of applications: paper machine industry, textile machine construction, pump construction, sanitary sector, etc. They can show their advantages especially in small and complexly designed assemblies, where lubrication of the material pairings is often no longer possible (ceramic high-performance materials are also suitable for non-lubricated systems). In most cases, it is sufficient to use material pairings with different hardnesses. Sometimes, however, there is a need for the tribological system to have the same hardness but a different material base.

In some applications, for example in electronic assemblies, the standard ceramics available on the market today reach their limits. The filigree components are often geometrically highly complex and may only have minimal wall thicknesses in some cases. This places high demands on the materials: they must have a certain mechanical strength and, in particular, a high fracture toughness. These requirements can often no longer be met with conventional standard materials. An example is yttria-stabilised zirconia (Y-TZP). Although this material has a high mechanical strength, it can only be used in a humid environment to a limited extent.

In order to arrive at technical solutions nevertheless, new materials with high fracture toughness are required on the one hand, and new, innovative processing technologies are needed on the other. In the following, the interplay of product design, material development and technology adaptation is explained in more detail using a technologically highly demanding sleeve (Fig. 1).

Fig. 1
Miniaturised and resistant ceramic sleeve made of Rapal® 1000 ZA

Design requirements

Fig. 2 shows the drawing of the sleeve with a wall thickness of 35 µm, a diameter of 4 mm and a length of 12 mm. It is used as an insulation component in an electronic assembly. In order for such a component to be technologically feasible, not only a highly resilient material is required, but also suitable processing machines, moulds and tools as well as appropriate clamping technology. Especially for a suitable clamping technology, fixtures have to be built with which the series production can be reliably carried out. The handling of such filigree components is also very demanding. For

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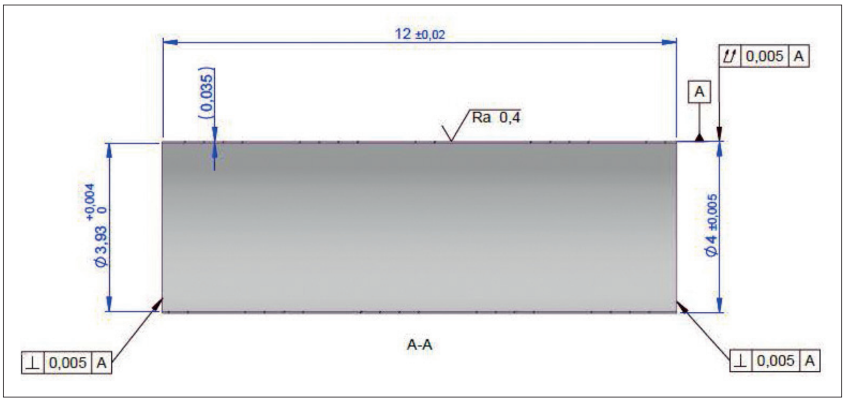

Fig. 2
Geometric requirements for the sleeve

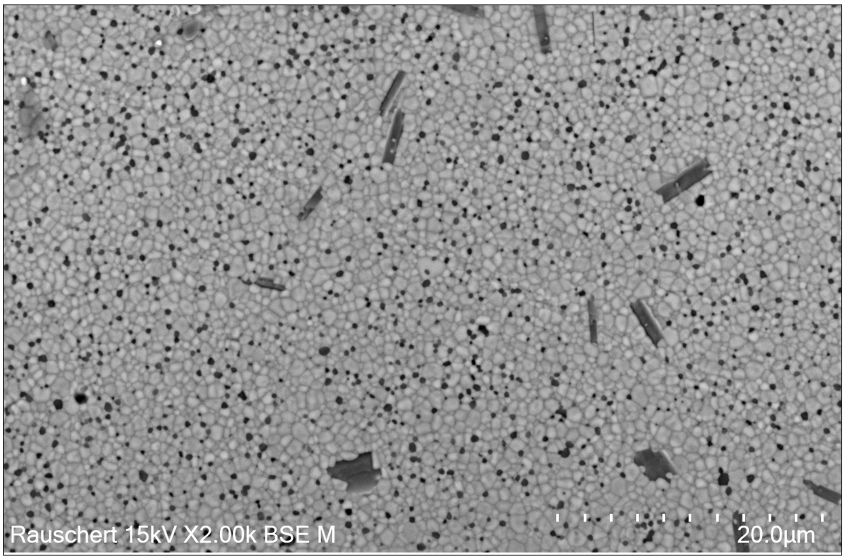

Fig. 3
Microstructure of Rapal® 1000 ZA

series production, a clamping and handling system must be developed that works largely automatically and is equipped with an "in-process" control of the geometric dimensions.
The "in-process" control is of high importance, insofar as the cutting tools to be used, with diamond-bonded abrasive grit, are subject to significant wear.

Development of the material formula
The sleeve shown in the drawing in Fig. 2 has a wall thickness of only 35 µm. This corresponds to the typical grain size of magnesium oxide stabilised zirconia (Mg–PSZ)! It is therefore obvious that the sleeve can only be produced with a much finer material. A prerequisite for the development of such a component is a material with a submicron structure, as found in Y–TZP ceramics. However, since the component is used in a humid atmosphere, this material – as already mentioned above – is also not suitable for the planned application. What is needed is a material that has high fracture toughness, flexural strength and hardness, but also high hydrothermal stability.
Based on this, Rauschert has developed a material for this application that meets all requirements. The basis for the new material Rapal® 1000 ZA is an extremely fine zirconium dioxide powder with a particle size of 0,3–0,4 µm. In order to maintain the tetragonal phase after the sintering process, this powder is alloyed with yttrium oxide (Y_2O_3) and cerium oxide (CeO_2). Aluminium oxide (Al_2O_3) and lanthanum oxide (La_2O_3) are then added to the powder mixture as additional components. For the production of a homogeneous mixture, which is adjusted accordingly by the addition of defined chemical substances, a detailed knowledge of the colloidal chemical relationships is required. In the subsequent grinding process, deagglomeration and homogenisation take place.
After adding an organic binder system, the suspension is converted into a ready-to-press powder by spray drying. After shaping has taken place, the property characteristics of the ceramic material are generated via solid-state chemical reactions during the sintering process. This results in the creation of a solid solution of yttria and zirconia dispersed in the zirconia lattice. In addition, the aluminium oxide reacts with the lanthanum oxide under suitable process control. It forms hexagonal platelets of lanthanum aluminate ($LaAl_{11}O_{18}$) as well as globular aluminium oxide. The typical microstructure of the material is shown in Fig. 3. Tab. 1 summarises the typical properties.

Realisation of the component
To realise the component, an isostatically pressed moulded body is first produced. This is then pre-machined – taking into account a special clamping technique – into a near-net shape, sintered and then subjected to a grinding process so that the required geometric dimensions, as per the drawing, can be adhered to. Fig. 4 shows a stereomicroscopic image of the component; in Fig. 5 the wall thickness is measured in the scanning electron microscope at 1000× zoom.

Tab. 1
Typical properties of Rapal® 1000 ZA

Density	ρ_E [g/cm³]	6,01
E-module	E [GPa]	210
Flexural strength	σ_{4B} [MPa]	1050
Vickers hardness	HV_{10}	1170
Fracture toughness	K_{Ic} [MPa√m]	7,9

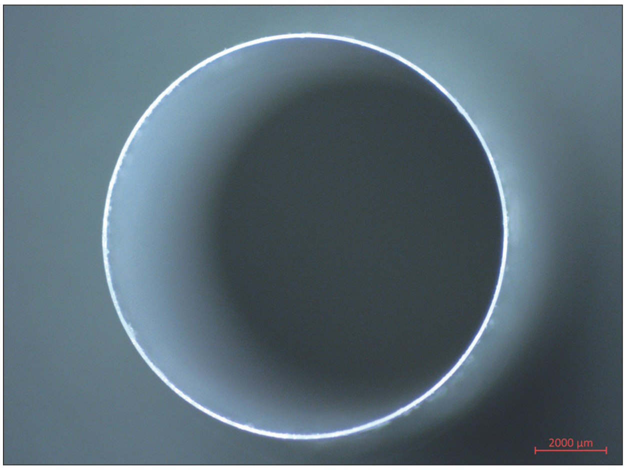

Fig. 4
Stereomicroscopic image of the component

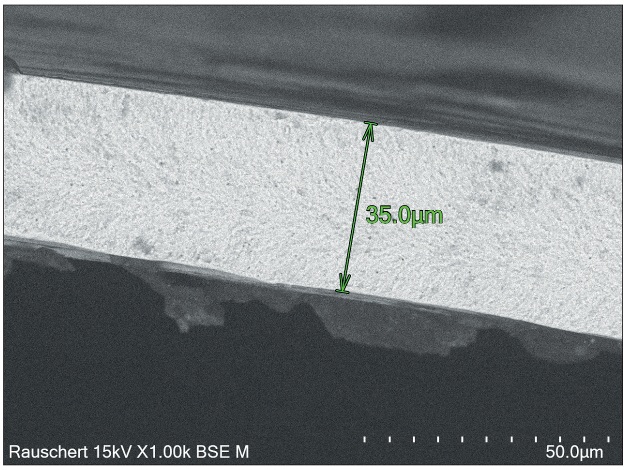

Fig. 5
SEM image of the wall thickness at 1000× zoom

Outlook

The described example shows the importance of the symbiosis of material, manufacturing process and application in solving customer requirements.

In the present case, the classical press-milling process is suitable for manufacturing the components. If the geometric requirements become much more complex, then ceramic injection moulding has the highest priority. Reliable components made by injection moulding require even more precise coordination between material, binder system, injection moulding tool and process control compared to the press-moulding process – and that in an application-specific manner. For each component, not only the material formulation must be adapted, but also the plasticising recipe. The mould concept must also be closely coordinated with this. Experience shows that own, customised formulations are indispensable, especially for the plasticising of modern high-performance ceramics.

Conventional, commercially available binder systems no longer meet the requirements. In addition, the tools must fit the plasticised granulate, the so-called feedstock, very precisely so that the components meet the dimensional specifications precisely after the sintering process. This requires years of experience in the design and construction of cavities for ceramic components.

In conclusion, customer and application-specific solutions made of ceramic high-performance materials in miniature design require a high level of manufacturing expertise.

With its consistent material and manufacturing technology, Rauschert is a competent partner for the realisation of miniaturised assemblies.