Why not Using Ceramics – Trends from Ceramics Research

Within the Fraunhofer AdvanCer Alliance/DE, four institutes have pooled their capabilities to form a coordinated range of services aimed at using advanced ceramics in the creation of individual system solutions for industrial partners. Below, two examples are presented from the successful project work showing the advantages of advanced ceramics in specific industrial applications.

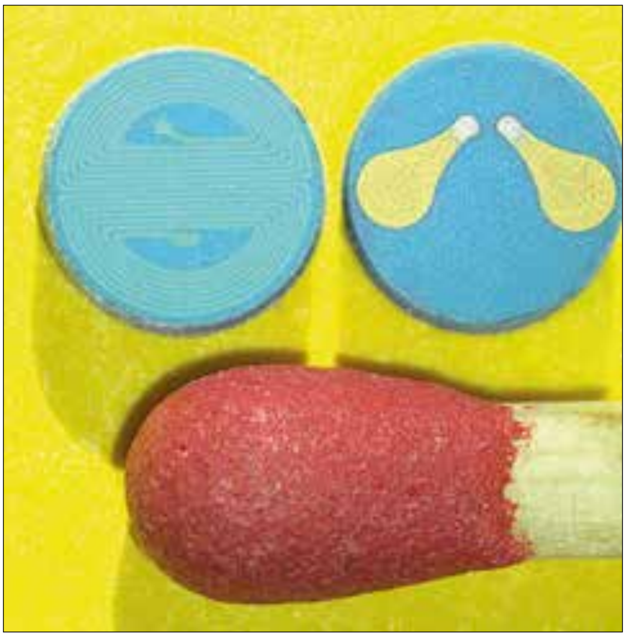

Fig. 1
Sintered and separated LTCC double-D coils, size compared with matchstick

Ceramic-integrated miniaturized coils for speed measurement in turbochargers

Speed measurement is crucial for supplying vehicle engines with the optimum air flow and thus minimising fuel consumption. For these measurements, eddy-current sensors are usually used enabling the non-contact detection of rotational speed.

As these eddy-current-sensing coils are subject to high temperatures, it is advantageous to produce them in ceramic multilayer technology (LTCC). Furthermore, LTCC offer an ideal platform for integrating tailored eddy-current-sensing coils into very small components. Together with the Jaquet Technology Group, Fraunhofer IKTS has developed miniaturized LTCC coils (diameter 4 mm) for speed measurement that can be operated in very rough environments at high operation temperatures.

A crucial element for the coil's performance is its quality factor. Thanks to new LTCC manufacturing processes, the lateral winding distance of the printed multilayer coils could be reduced to 30 µm with line widths of 70 µm. That allows a high inductivity value of 1 µH. The metallization thickness was simultaneously enhanced (50–90 µm) which reduces the internal resistance. Thus, the inductivity and the ohmic resistance achieve an obvious optimisation which results in significant improvement of the quality factor of the novel coils as compared to standard technologies. The result was an improved, precise measuring signal much easier to demodulate.

In addition to miniaturization with optimised quality, the integration of a tailored coil design in LTCC was also a big driver of development. Coils of this type are typically produced as wound coils with a spiral-like shape. The LTCC double D-coil developed at Fraunhofer IKTS/DE delivers a narrow-band magnetic field thanks to the tailored design and thus a clearer measuring signal on turbocharger blades, for example on those made of aluminium or titanium.

Moreover, using the ceramic multilayer technology, stacked coil structures with a metallization distance of up to 50 µm can be realised. These innovative microcoils in the tailored LTCC double D-design with optimised quality and an aspect ratio of >1 (height to width ratio of printed conductor paths) stand out from the current state of the art.

Fraunhofer IKTS has extensive experience and design tools for multilayer ceramic-based components and systems. A complete technology line for developing and producing LTCC/HTCC components is available. Additionally, IKTS offers functional characterisation of ceramic microsystems as well as reliability studies.

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Fig. 2
Sintered aluminium oxide components machined using grooved grinding pencils with inner cooling channels and optimised clamping systems allowing at least four times higher material removal rates (machining time <5 min) than conventional grinding methods

Low cost ceramic components by the application of efficient grinding methods

The constantly growing requirements on complex ceramic components with regard to surface quality, dimensional accuracy, manufacturing flexibility and cost reduction are current manufacturing challenges. In addition to innovative machine technology and process design, the appropriate choice and design of used tools and tool clamping systems can make a decisive contribution to fulfil these requirements.

Structured grinding tools have great potential concerning the required high material removal rates with low tool wear at the same time. These innovative tools include, for example, laser-structured grinding wheels, grinding wheels with selective positioning of abrasive grains and grooved grinding tools with internal cooling. They are characterised by the regularly distributed height change of the abrasive coating over the peripheral surface of the grinding wheel. That reduces the static density of the cutting edge and the number of kinematically and instantaneously involved cutting edges on the grinding process. As a result of the intermittent grinding process lower grinding forces and temperatures cause a higher grinding ratio. However, the interrupted cutting process generates a characteristic vibration. To reduce these vibrations and to stabilize the process modern tool clamping, spindle and machine systems are used. In this case, a high degree of damping, a high static and dynamic stiffness as well as a good concentricity <3 µm can be achieved at the grinding tool.

Current investigations of Fraunhofer IPK/DE have successfully shown that using grooved diamond grinding pencils with inner cooling channels can maximize the chip removal rates of the grinding process of high-performance aluminium oxide ceramics (Al_2O_3). Based on the state-of-the-art, feed rate v_f and depth of cut a_e could be increased by more than a factor of 4, resulting in a specific material removal rate of Q'_w = 8,33 mm³/mms. After the machining process, no macroscopic fractures on the workpiece and only minor tool wear were observed. Furthermore, the increased effect of the cooling lubricant because of the included cooling channels could be proven.

Fraunhofer IPK offers the integrated view and optimisation of machining processes of advanced ceramics. This includes the scientific analysis of the current state, the design and qualification of tools, process and process chains as well as the support while transferring these processes into industrial scale. For technological investigations various modern machining systems are available at IPK the performance of which significantly exceeds the potential of conventional production machines.

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