Geometrically highly complex ceramic sensor systems (sensor triad)

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Sensors in harsh environmental conditions

The central tasks in sensor technology are the monitoring of status variables, the conversion of sensor signals and their processing as well as communication with higher-level systems. Hardware is adapted to the measurement task required for this. This usually consists of a sensor element, substrate carrier and housing. Harsh environmental conditions with high thermal, chemical and/or mechanical stress are a challenge in nearly all industrial areas. Highly integrated sensor systems with metal or polymer components in these environments quickly reach their limits and complicate real-time-based data acquisition. Functionalized 3D ceramic components, by contrast, meet these requirements for robustness, miniaturization and reliability. Through purposefully selected materials and the combination of additive manufacturing with thick-film technology, these components combine advantages such as chemical and thermal stability, high hardness, low density and specific biological properties with highly complex geometries.

Additive manufacturing of ceramic components

Additive manufacturing processes make it possible to produce geometrically complex and functionalized structures that are difficult or impossible to produce with conventional manufacturing methods. These processes are a game changer especially for hard and difficult-to-machine ceramic materials. Tool-free shaping allows the processing even of individualized single pieces or small series as well as fast iteration cycles in development processes. In addition, only the material that is actually required is used.

Functionalization using thick-film technology

The ceramic components are functionalized with thick-film technology, which is based on the use of pasty materials printed onto the surface of substrates in a structured printing process. Conductor materials, insulators and functional pastes, which are subsequently sintered, are available for functionalization.

Afterwards, additional electronic components or sensors can be assembled or packaged, usually being installed on conductor lines. When it comes to connecting the entire component electrically, typical processes known from electronic packaging are used for assembly:

- Soldering with soft solders
- Wire bonding with aluminum, gold or copper wires
- Sinter assembly of power semiconductors based on nano-silver pastes
- Wire welding for high-temperature applications

Figure 1: Overall setup and ceramic single components of the sensor triad.

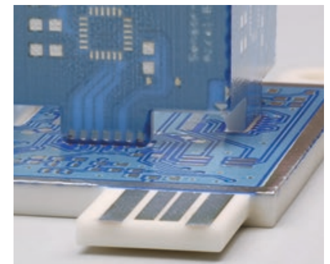

Figure 2: Detailed view of the functionalized single component.

Sensor triad

Within the Fraunhofer-internal project “Sensor triad”, Fraunhofer IKTS, together with Fraunhofer ENAS in Chemnitz, develops highly robust sensor systems which enable determining the position and location in three dimensions. Until recently, the high-precision MEMS sensors from ENAS were installed on polymer PCBs to produce one-dimensional sensor systems, which were then coupled together. Within the novel, patented sensor system, the sensors and components are installed directly on the ceramic substrate, which is functionalized with conductor paths and features orthogonally aligned areas produced through additive manufacturing. Doing without polymer substrates means that the space required and the measurement uncertainty due to thermal stress can be significantly reduced.

The symbiotic combination of the two modern ceramic technologies of “additive manufacturing” and “functionalization of ceramic components using thick-film technology” in a two-step process enables highly complex substrate, sensor and housing variants that were previously unattainable. These in turn offer an approach for optimized measurement procedures in harsh environmental conditions.

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