

1 Printed magnetic nonius structure for measuring rotational speed or position.

THICK-FILM SENSORS – CONDITION MONITORING DIRECTLY AT THE PART

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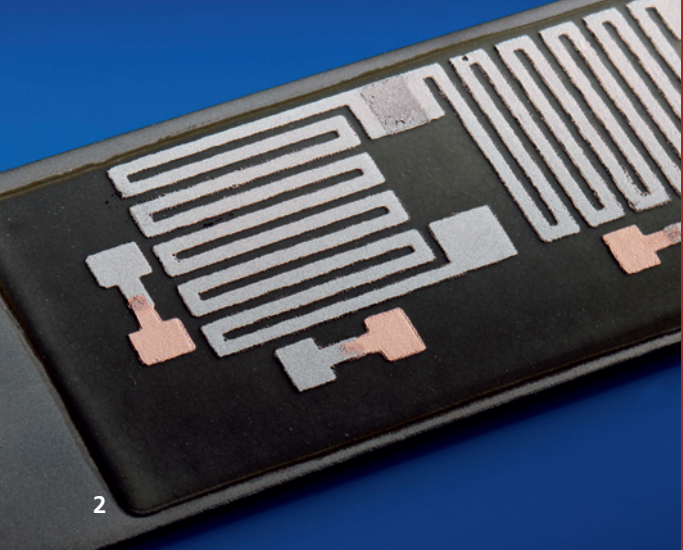
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Due to the complexity of systems or production lines, condition monitoring or health monitoring of equipment and parts is important for system supervision as well as for optimizing the maintenance rate. To achieve an efficient health monitoring, many different kinds of sensors are needed.

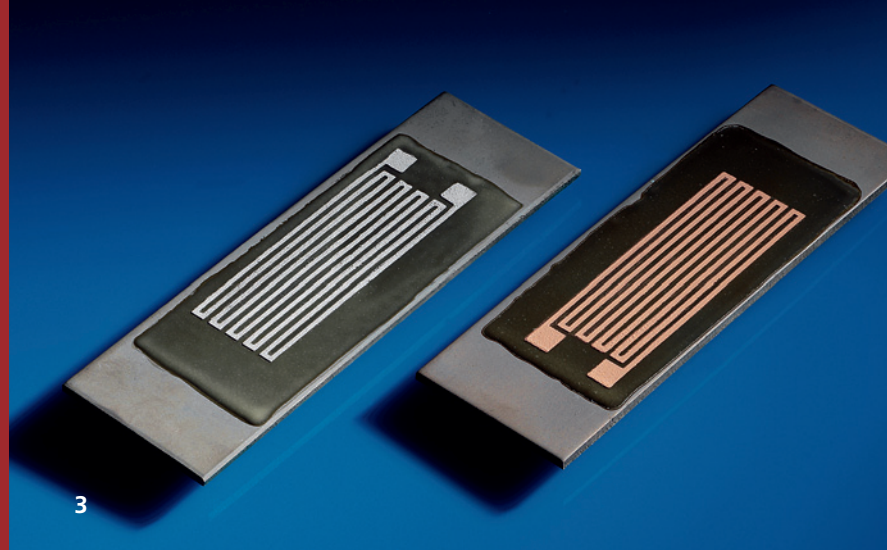
Fraunhofer IFAM has developed a variety of sensors using powder-filled pastes which can be applied directly onto a part. The main advantages of powder-filled pastes are the material diversity and the use of established manufacturing methods, like screen or stencil printing processes. These allow a cost-effective and rapid production of complex geometries in large lots.

Process

The first process step is selecting applicable materials for the desired sensor properties and mixing them with additives to obtain a printable paste. This paste will be applied onto part surfaces via screen or stencil printing, then dried and sintered subsequently. By adjusting the sintering parameters, the sensor's properties can be influenced. When a sensor is applied onto electrically conductive surfaces, an additional electrical insulation between sensor and part is required. This is realized by the application of an enamel layer. With regard to the high resistivity (10^{10} to 10^{14} Ohm) of the enamel, insulation layers can be produced that show high temperature and corrosion resistance, as well as good adhesion properties.



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Possible applications

A big field of application for sensors is the equipment condition monitoring of systems and components. Below, the functions of sensors already developed at Fraunhofer IFAM are explained.

Due to the use of powder-filled pastes it is possible to apply **magnetic sensorial structures** onto devices. Hard magnetic structures made of NbFeB or other hard magnetic materials can be printed upon components, e.g. to gain information about the rotational speed or to determine its position in relation to magnetic field sensors.

It is also possible to apply soft magnetic materials onto nonmagnetic substrates which can be monitored by an external field coil. So-called nonius structures (Fig. 1) make it possible to determine both rotational speed and angular position simultaneously. Additional tracks, printed with an offset, improve the metering precision. Magnetic materials are used e.g. in the drive and automation technology.

A different application field is the monitoring of part overloads. This can be managed with thick film **strain gauges**. For this purpose different materials with temperature-independent resistances (e.g. a CuNiMn alloy) can be printed directly onto the part. A mechanical load on the part produces an elongation of the strain gauge, resulting in a change of resistance that can be measured.

Due to the good adhesion of the electrical insulation and the powder-filled paste, it is also possible to determine the maximum deformation or overload.

Temperature monitoring in operating systems is also very significant. Depending on the temperature range of an application, all current types of **thermocouples** (e.g. type T: Cu–CuNi) can be applied onto the locally insulated part. The thermoelectric voltage can be measured precisely, indicating the momentary temperature of the part.

Our offer

Fraunhofer IFAM offers the development, modification and production of directly printable sensor elements. This means e.g. the modification of paste compositions and the evaluation of sintering cycles for the adjustment of the desired sensor properties.

- paste development and production
- development of part-specific sensors
- consultation on suitable application processes
- functionalization of surfaces
- integration into existing manufacturing processes
- consultation / planning of new production lines

Our equipment

At Fraunhofer IFAM, the complete line for preparation and processing of powder-filled pastes is available:

- mixing device, agitator (Turrax)
- roll mill
- dissolver, (temperature-controlled, under vacuum)
- screen/stencil printer
- dispenser
- dryer
- several sintering furnaces with different process atmospheres: air, inert gas and reducing atmosphere
- layer thickness gauge
- electrical and magnetical characterization
- metallography and analytics

2 Close-up view of a screen-printed strain gauge with thermocouple Type T (Cu-CuNi).

3 Printed strain gauges (sintered strain gauge - left; unsintered strain gauge - right).