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Printed sensors produced via thick-film technology for the use in monitoring applications

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Abstract

Supervision of systems and devices has become more and more important with regard to maintenance requirements and quality management. To achieve these monitoring requirements many different kinds of sensors are needed. At the Fraunhofer IFAM different sensor types have been developed on the basis of thick-film technology and especially by screen-printing. The development of sensor structures spread over a wide field of measurement categories like temperature, humidity, forces, rotational speed or positioning. Here the focus is on thermocouples and magnetic sensor structures for rotational speed and position measurements. Investigations on the functionality of the sensor structures have been performed like correspondence of electrical properties with literature values, comparisons in performance in relation to conventionally produced sensors.

Keywords: Printed sensors; thick-film; monitoring; thermocouples; magnetic sensor; rotational speed

1. Introduction

Today sensors have found their way into many different kinds of devices and whole systems. Smartphones, automats, cars and other things of daily life can be mentioned here as well as production machines like industrial robots, presses, printers and more. Increasing complexity of devices or systems and their target specifications lead also to advanced or changing requirements to sensors.

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Upcoming requirements for future sensors beneath size, price and performance are multi-functionality or the ease of integration into a device. Thick-film technology and here especially screen-printing offer possibilities to meet these challenges in sensor development. With this printing method powder-filled pastes can be applied on different substrates such as metals (additional insulation if necessary), ceramics or plastic material as well as directly onto a part. After the printing process the sensor structures get their functional properties during a following heat treatment. Advantages of the use of screen-printing as an application method are the high diversity of materials that can be processed, cost efficiency and high throughput rates combined with a structure width down to 100 µm. Another aspect is the possibility of printing a combination of different sensors onto the same substrate or part.

2. Experimental details

Substrate materials were alumina and stainless steel sheets. If needed an additional dielectric layer was also screen-printed on the substrates for electrical insulation. Beneath the sheet material also powder metallurgically produced gear wheels were used.

The powder-filled pastes that finally result in the sensor structures consist of a binder system, elemental or pre-alloyed powders and if necessary further additives. Particle sizes of the powders used were in the range of 1-30 µm. Homogenization of the pastes was performed by a 3-roller mill. Screening of the right powders and the composition of the ingredients are some of the critical parameters for the resulting sensor performance.

The application of the pastes was made by screen-printing. A schematic diagram of the process is shown in Fig.1.

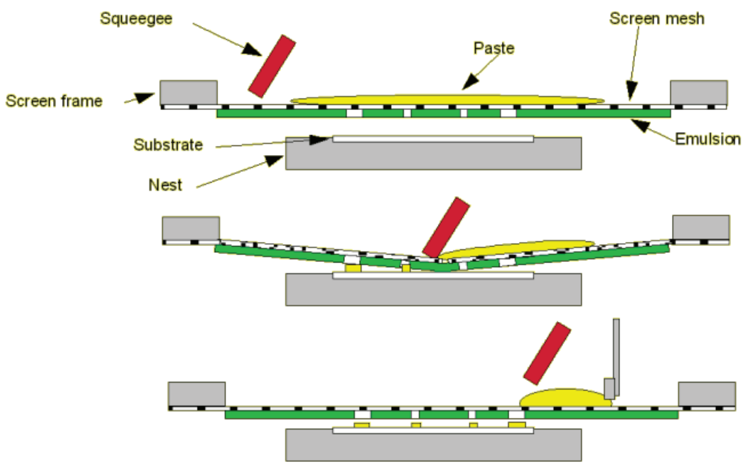

Fig. 1. Schematic diagram of the screen-printing process [1].

The paste was deposited on a screen and then transferred by a flood bar passing over it. This flooding step fills the mesh openings of the screen with paste. In the following printing step a squeegee overcomes the screen pressure to apply the paste onto the substrate. While printing the viscosity of the paste is reduced by velocity and force of the squeegee. This thixotropic behavior of the paste is necessary for a good printability [2]. For each type of sensor one or more screens were used with structure and interspace width of minimum 100µm. Multilayer-printing was performed with accuracies in the range of 2-20µm.

After printing a drying of the structures at 125°C was performed, followed by the functionalization of the sensor structures in a sintering process. Sintering temperatures varied from 750°C to 1300°C with atmospheres were mainly nitrogen and hydrogen, depending on materials used.

The performance of the different thick-film sensors has been evaluated by specific testing methods. Thermocouples were tested on their electrical properties like conductance and test runs in direct comparison with