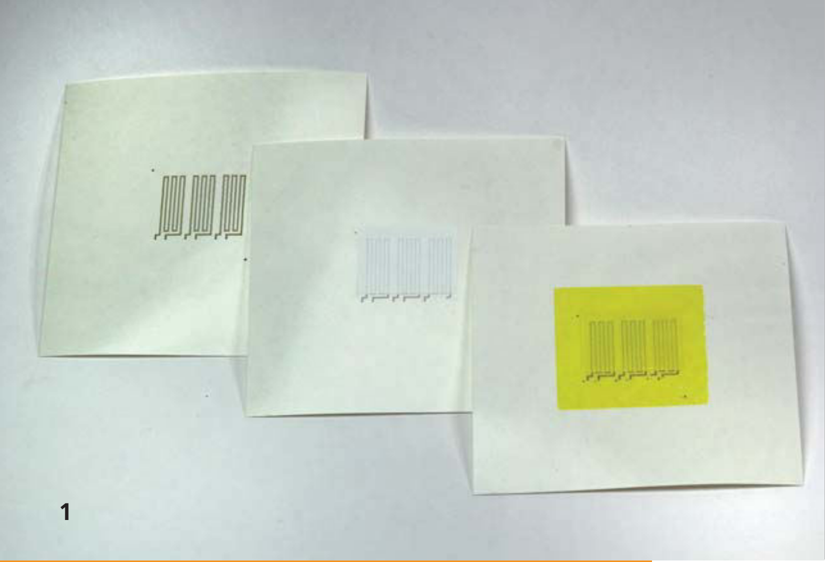

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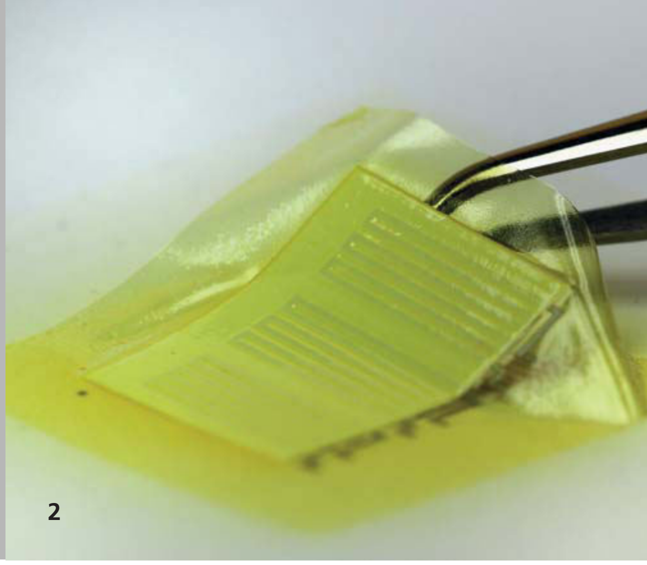


2

PREDESIGNED THICK-FILM SENSORS FOR VARIABLE COMPONENT SURFACES

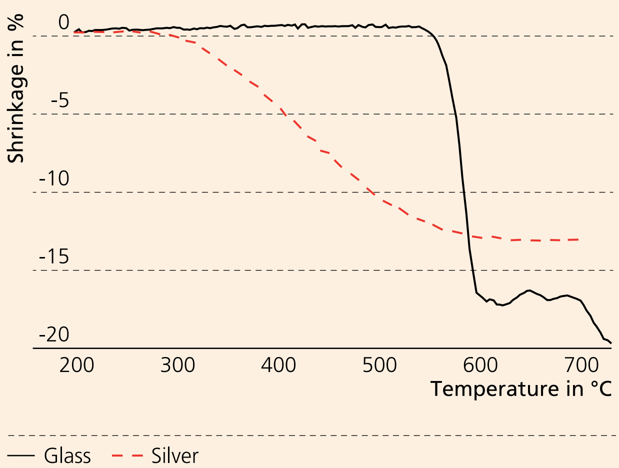
Dipl.-Min. Thomas Seuthe, Dr. Markus Eberstein

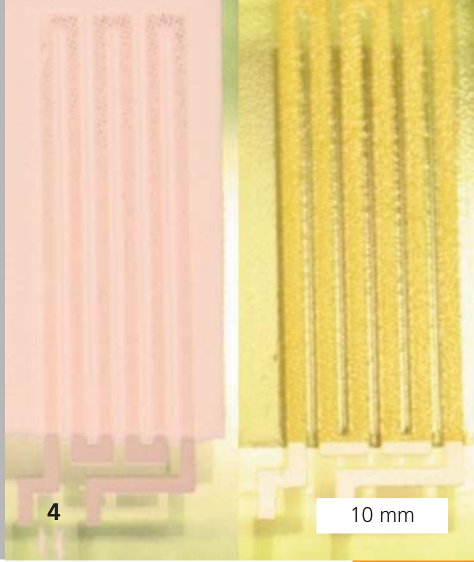
The production of functional ceramic multilayers via deposition methods, such as screen printing, dispensing and aerosol printing is a common practice today. However, in some cases significant effort is necessary in a production environment in order to perform the printing and firing process with required precision and reproducibility (clean rooms, staff). The application areas are also limited by the size of the substrates to be processed. Thus, printing on substrates exceeding an edge length of one meter is difficult to realize with a conventional laboratory printer. To avoid these effects, a decal method was analyzed where the issued structure, fulfilling all requirements for layer thickness and contour characteristics, was first printed on a non-sticking pad with a multilayer structure, then dried and, finally, transferred to substrates of any size using a transport layer as it has already been used for the color design of decorative ceramics. This type of substrate processing allows transmission of thick-film sensors on substrates of various size and shape, whereby the scope of thick-film technology is expanded. Therefore, a two-layer safety circuit for tempered safety glass could be realized within a research project.

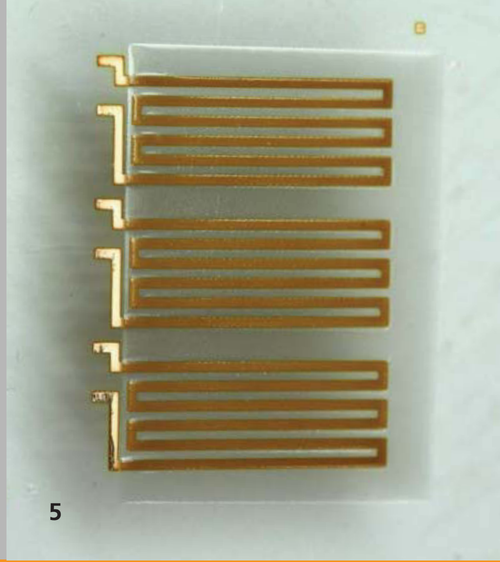
The production of tempered safety glass is carried out by a heat treatment process, where a conventional float glass plate is rapidly heated in a tempering oven above its transformation temperature (T_g) and is then chilled to room temperature. Thus, the frozen thermal stresses lead to a significant hardening of the glass. Tempered safety glass can be applied for, e.g., sliding glass doors, glass tabletops, wall cladding, car side windows and safety glasses for shopping windows. Here, the need for two-layered alarm circuits arose, consisting of a conductive path covered with a glass insulating layer, which are co-sintered during the short heat treatment inside the tempering furnace. The first challenge was the precise deposition of both superimposed layers on a coated paper substrate by screen printing. An extensive optimization of the printing parameters allowed for the exact and flawless deposition of the superimposed layers (conductive path, glass insulation, transfer paint). These layers must adhere to each other and be transferable from the paper substrate to the glass substrate without damaging either of the layers, which would affect their functionality. Because tempered safety glass must not be reheated above T_g, the second challenge consisted of sintering the assembled circuit directly inside the tempering furnace at high heating rates of up to 100 K/s.

Furthermore, the decal-applied layers must densify sequentially and non-simultaneously during the co-sintering process, so that escaping gases in the lower layer (conductive path) can evaporate through the upper, still porous, layer (glass insulation). In order to meet this requirement, the silver and glass powders used to create the layers were adjusted in their sintering behavior, so that the firing during the co-sintering process with heating rates up to 100 K/s can gradually take place and the layers do not need to be processed post-firing.

Shrinkage behavior with increasing temperature of the used glass powder (black line) and the silver powder (red line) using hot stage microscopy







The optimized sintering procress of the silver powder and the glass powder used are shown in Figure 1. The sintering of the silver powder starts at about 300 °C and is almost completed at above 550 °C. Then, the sintering of the overlaying glass paste (insulation layer) begins. Decals optimized for the firing process in the glass tempering furnace allow for the production of robust and defect-free layers for alarm circuits. The specific resistivity of the conductive paths nearly reaches values of pure silver. The insulation layer shows dielectric strength of more than 1 kV at a thickness of about 20 µm.

The new decal process for the production and transmission of technical ceramic multilayer structures ensures reproducible quality and easy handling of high-resolution multilayer constructions and also avoids the limitations of the printable substrate size. Therefore, it is suitable for the realization of high quality active and passive electrical elements (sensors, antennas, smart labels) on substrates of variable sizes or curved surfaces, completely opening up new areas of application of thick-film technology.

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1 *Functional multilayers printed on paper consisting of conductive path, insulation layer and varnish layer (from left to right).*
2 *Separation of the functional layer from the carrier paper.*
3 *Multilayer ceramics before sintered on a drinking glass with a curved surface.*
4 *Conductor loop with insulation layer on tempered safety glass before (left) and after (right) firing.*
5 *Conductive path with insulating layer on tempered safety glass after firing.*

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Contact Markus Eberstein • Phone +49 351 2553-7518 • markus.eberstein@ikts.fraunhofer.de