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1 *Mold core with measurement wires soldered to the two sensor structures. The soldered area has been sealed to make it possible to carry out measurements even at temperatures above the melting point of lead-free solder.*

THIN-FILM SYSTEMS FOR TEMPERATURE MEASUREMENT IN DIE-CAST ALUMINUM

During a die-casting process the molds are subjected to enormous forces and temperatures. Until now it was not possible to obtain data such as temperature curves, which are necessary for a better understanding and above all for allowing adjustments to be made with regard to process simulation. Placing sensor elements as close as possible to the surface of molds in order to achieve a better process control has therefore been a priority objective of the industry. In a project initiated and commissioned by Volkswagen AG and conducted in collaboration with the Fraunhofer IST and G. A. Röders GmbH & Co. KG, success has been obtained in implementing thin-film sensor systems as a coating directly on the mold surface.

Production of the sensorized thin-film system

In the development of the thin-film sensor system on the mold surface, the first step is to add an area to the mold cores for aluminum die-casting which will be used for contacting the measurement wires. Each mold core is equipped with two sensor structures. By means of physical vapor deposition (PVD), the insulation layer of alumina (Al_2O_3) is now added. The next step is to add a homogeneous coating with a chromium (Cr) layer 250 nm thick. This chromium layer is structured with a meander design. To do this, a photoresist is applied manually, exposed with a flexible mask and developed. The unprotected contour areas are etched away wet-chemically after development. Finally, the photoresist is removed and the metallization with sensor structures is left on the surface (see Figure 1). The sensor structures are designed for four-wire technology. The individual conductors are 100 µm wide, increasing to 250 µm locally in the curved transition.

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2 *Mold core with two sensor structures on the surface.*

Following application of the sensor structures, the second insulation layer of Al_2O_3 is deposited, with the contacting areas given an additional layer of copper (Cu) 1.5 µm thick. The wear-resistant coating of chromium vanadium nitride (CrVN) is added in the next step. Finally, the measurement wires are soldered to the contact pads and the whole area sealed. A compound is used for this which adheres well, even at temperatures above 573 K, and is not electrically conductive. Figure 2 shows such a sensorized mold core. The chromium meander structures have a temperature coefficient of $1.24 \cdot 10^{-3}$ K^{-1}.

Verification of functional capability

In order to verify the functional capability of the mold core, it was installed in one half of a die-casting mold, with the measurement cable being taken out laterally. The sensor system consisting of temperature meanders made of chromium makes it possible to realistically reproduce the course of temperature development at the mold surface during the die-casting process. The coating system is functionally capable throughout the 300 die-casting cycles and even after this number of cycles no flaking or loss of sensor quality was detected. The graph opposite documents the course of the 300th die-casting run conducted with the sensorized mold core.

Outlook

This tested technology will in future be used with further molds of complex geometry. One objective here is to improve our understanding of aluminum die-casting processes to create the conditions for optimized resource-efficient production.

Temperature curve for the 300th cycle, measured with a chromium meander on the mold core.