Enabling Multi-Functional Performance
through Multi-Material Additive
Manufacturing

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Integration of electrical conductors into light metal components by means of generative modules

Modern additive manufacturing technologies allow an energy- and material-efficient realization of multi-material designs. MULTI-FUN R&D activities with focus on Direct Energy Deposition technologies to produce demonstrators with different integrated functionalities ranging from locally placed thermal conductors to insulated electrical conductors and embedded optical fibres for measuring temperature and strain.

LKR is working intensively with INOCON to realize electrically conductive copper integrated by DED in aluminium structural components. Both partners combine their expertise in the application of different, complementary AM technologies. INOCON uses its InoCoat process to create several, approx. 10µm thick individual layers. Masking is used to limit the lateral dimension of the tracks.

The core element of this atmospheric plasma powder coating process (APPD) is the IC3 plasma head, in which a plasma beam with a temperature of several 1000 degrees is generated. Argon gas carries the particles through the head onto the substrate's surface, after being heated up to the melting point. The spherical grains are preferably applied in a range of 5-20 microns in size to prepare a layered stack of up to 500 microns.

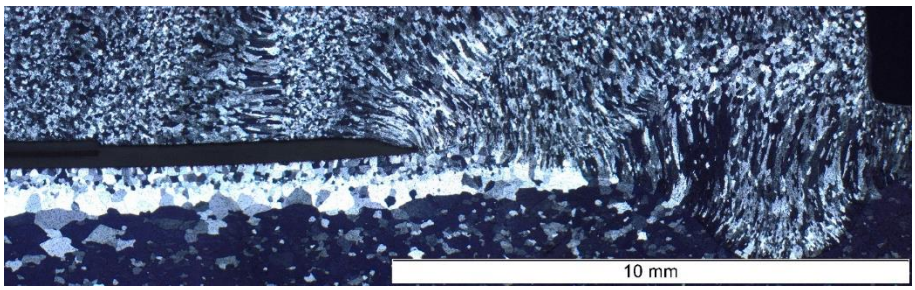
For the use of conductive tracks – embedded in electrically conductive, metallic components – an electrical insulation has to be generated as well: InoCoat can process a variety of materials up to a melting point of 2000°C – therefore aluminium oxide can be applied as an insulator.

Specifically, in the MULTI-FUN research project, LKR and INOCON have investigated several types of tests that have the following similarities in the production sequence: Application of a first multi-layered alumina stack to isolate the substrate from the subsequent copper stack. Subsequently, multi-layered aluminium oxide provides insulation again.

However, the insulation capability of Al_2O_3 is a challenge for the next process step: the embedding of the whole setup with metal inert gas welding and electrode wire. An electrical short circuit must be possible between the wire and the workpiece where the filler metal generates the metallic layer. LKR has therefore developed a deposition strategy that makes it possible to integrate non-conductive areas. For this purpose, the 2-axis tilting table is brought into inclined position and the next WAAM layer is applied to the previous one without being affected by the insulation zone. These AM manufactured aluminium layers rest on the ceramic zone, but without damaging it.

Under mechanical conditions, the embedded copper conductors showed a significantly increased internal resistance compared to classic drawn wires, but also a high degree of robustness against mechanical loads. Both in the elastic range and after high plastic deformation, the level of Ohmic resistance remained within its narrow limits. Even after >50 million oscillations in the fluctuating tensile regime with peak values of up to 50% of the nominal yield point of the aluminium solid, thermal effects were more significant on the measured Ohm value than mechanical influences.

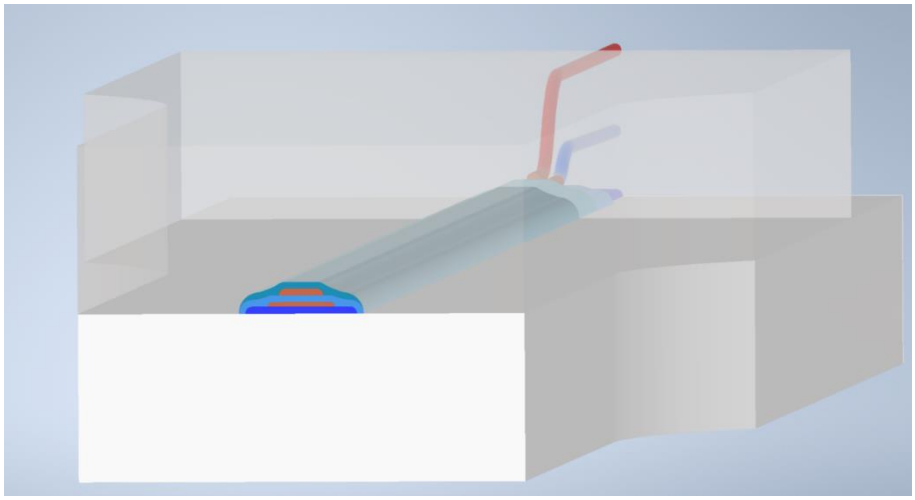
Based on these results, applications in automotive components are now being developed.



Macro grinding in cross-section through a layer structure with embedded layered stacks of Copper and Aluminium oxide structure (appearing as a black zone in the middle of the left half of the image)

Cross-section through a multi-layer composite with aluminium as substrate (bottom) and WAAM structure (top), the (dark grey appearing) aluminium oxide insulation structure around the central copper zone.

Conductor concept (half-section of the transparent rendered CAD model) showing Cu conductors (in orange colour) together with insulation (dark & light blue plus green) as well as the indicated connected cables.



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