Final Report

Project acronym: *EcoPrint*

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http://www.ecoprint.co.at

2. Publishable project summary

The EcoPrint project has set its focus on developing AM in-line applicable, electrically insulating, low-temperature-processable materials for cooling (power)electronic components. Due to miniaturization and steadily increasing power densities, waste heat deduction has become a crucial issue. Metal based cooling solutions still can cover most application scenarios, but there is a need for electrically insulating cooling materials in order to maintain a freedom of design and further increase integration densities.
Three different material approaches were examined in this project. Any approach consists of a base material which is combined with filler particles in order to increase its thermal properties. Base materials were selected from three different materials groups, each requiring a different AM-technology. Depending on the chemical structure, rheologic behavior and application conditions an optimum filler combination has been worked out.
The following material combinations were selected as final concept approaches are have been characterized regarding electrical, thermal and application properties:

(1) TPE-PA12 with carbon fibers and Cu-particles (up to 40 vol.%) for MEX application
(2) Acrylic resin (Precision by Cubicure) and alumina-particles (up to 67 vol.%) for application in Hot Lithography
(3) Alumino-silica-epoxy-acrylic-hybrid and alumina-/aluminiumnitride-particles (up to 75 vol.%) for SLA application

In order to allow direct application on electronic devices or components a minimum break through voltage of 1 kV/mm and a resistance of more than 10^8 Ω had to be achieved. All approaches met the requirements regarding surface resistance (2 TΩ or above) while a sufficient dielectric strength was only achieved by (2) and (3) (15 – 35 kV/mm). During the phase of material optimization thermal conductivity measurements were performed on 1x1cm sample plates via laser flash analysis. Up to 2 W/mK were measured for approach 1, up to 3 W/mK for approach 2 and up to 15 W/mK for approach 3. Subsequently, pin coolers were printed with the respective AM method directly on a heat source (thermal resistor) and compared to an Al-based cooling reference mounted via a thermal paste. Calorimetric measurements in a custom setup showed, that the hybrid approach (3) was able to keep up with the reference regarding thermal flow. Furthermore, application properties were characterized especially regarding substrate adhesion and stress. Cu-substrates were used to determine material adhesion via micro sheer testing. Adhesion forces of 3MPa (2) and 6MPa (3) were measured as is and up to 4MPa (2) and 5 MPa (3) after thermal shock testing.
The EcoPrint project has demonstrated, that AM-applicable material combinations can be used to deduct waste heat from electronic devices. The key to achieve cooling results which are comparable

to state of the art aluminium cooler solutions applied via a thermal paste is to incorporate a sufficient amount of thermally conductive particles into the base material. The possibility to form chemical bonds between the base material and the filler is as important to the thermal behavior as the avoidance of shrinking induced micro cracks and delaminations on the base material – filler – interfaces. The ability to apply cooling structures by AM without the need of an additional thermal interface material (thermal paste) is a benefit, which does not only include the potential to achieve higher integration densities in production but also will influence life time and reliability of electronic systems as thermal pastes are no longer needed.