Introduction
Interconnects are an important cost driver in advanced 3D chip packaging. This holds for Through Silicon Vias (TSV) for chip stacking, but also for other integrated Si-technology. Especially in applications with a low number (<100 mm-2) of relatively large (10-20 µm diameter), high aspect ratio (1:5-1:20) interconnects, conventional wafer level plating processes are slow and become cumbersome with increasing aspect ratio, thus becoming cost ineffective. Hence, industrially feasible alternative deposition processes are of interest for advanced interconnects.

LIFT is a maskless direct-write process with industrial potential. It is a single step, dry process under atmospheric (clean room) conditions. It is suitable for different types of interconnect fabrication, without the need for wet chemicals or high temperatures. The following reports on the investigations towards application in micro-electronics manufacturing.

LIFT as a manufacturing process
Laser induced deposition processes have been investigated widely, as extensively described in a review by Banks [1]. Many varieties of the LIFT process exist [1,2,3]. However, as yet no attempts have been made to apply the LIFT process in an industrial setting. The purpose of our research is to investigate and consequently develop the industrialization of the LIFT process to create micron-sized electrical interconnects. Therefore we investigated the electrical resistivity of the deposited material as well as the geometric capabilities.

A pure metal donor on a transparent carrier as well as ultra-short picosecond (ps) laser pulses were selected for the experiments (Figure 1). The downward facing donor layer is positioned close to the substrate surface. The thickness of the resulting air-gap between donor and substrate is typically 10-50 µm. In this way, metal deposits in the µm range can be formed using a ps-laser with a spot size of 5-20 µm focused onto the metal layer.

Experimental results
Using a straightforward laboratory-scale donor set-up, experiments have been performed in green and UV light using the picosecond laser machining facility at the University of Twente.

2D line conductivity
Conductivity of copper lines produced using this set-up was measured to be 5.8 times the electrical bulk resistance of copper using a 4-point resistance measurement. Such a resistivity is comparable to other direct-write technologies and is sufficient to generate functional interconnect structures [4].

3D feasibility
The same settings as in Figure 2 were also applied to deposit droplets inside high aspect ratio TSVs (Figure 3). Droplets visually appear to reach the bottom in a molten state, given the splash shaped deposits. Also, the deposition accuracy is maintained over this larger distance i.e. the majority of the droplets landed within a diameter of about 20 µm. Hence, filling high AR structures with copper using LIFT appears to be a feasible approach.

Conclusion and outlook
Manufacturing feasibility of LIFT has not been published before on this scale. Hence, the results currently achieved are a unique first step towards industrial application of LIFT as a micro-manufacturing technology. In the near future, vias with a smaller diameter will be used to study the complete filling of vias. Also, conductivity of the deposited material will be optimized. In parallel TNO is working on machine concepts that allow cost-effective interconnect manufacturing using LIFT.

References