



## FINEST STRUCTURES FOR PRINTED ELECTRONICS

### THE TASK

“Printed electronics” refers to electronic components, devices and applications fabricated by printing technologies. In this context “printing inks” are electronically functional materials. Printing electronics reduces costs and also offers to fabricate electronics on flexible substrates. This opens up new application fields for electronics, which are inaccessible for conventional devices. Today’s examples of printed electronics include organic solar cells, RFID tags (radio frequency identification) or sensors.

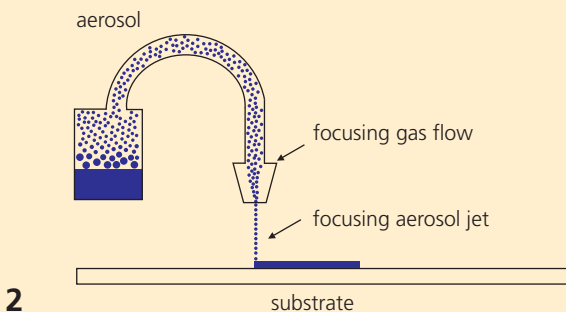
A growing application field is the direct printing of functional structures without the need for masks. Structures such as contacts, conducting lines, electrodes, antennas and sensors can be directly printed onto various substrates. Challenges include the increasing demands for the spatial resolution of the structures and also the required flexibility with respect to ink materials and substrates. The various technology components have to be compatible and optimized such as printing process, printed materials and substrate tolerable sintering processes. This optimization process is the core working area in printed electronics development.

### OUR SOLUTION

Fraunhofer IWS engineers are developing functional inks and associated printing and sintering processes for high-resolution structure printing. The basic Aerosol-Jet® technology can print metals, semiconductors, polymers or liquid etchants. Printing also requires substrate surface cleaning steps for which we have plasma and laser based processes that do not harm the substrates. These processes activate and functionalize the

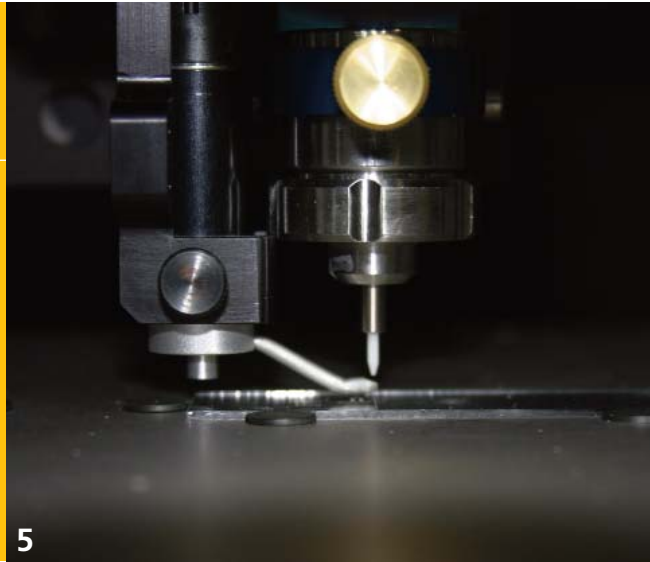
substrate surfaces. We print with in-house developed as well as commercial inks and adapt them to the particular application. Printed structures are then cured by heat. Heat sensitive substrates are treated in an RTA furnace (rapid thermal annealing) or with the help of lasers to keep the heat loads low on the substrates.

*Schematics of the Aerosol-Jet® technology*



### RESULTS

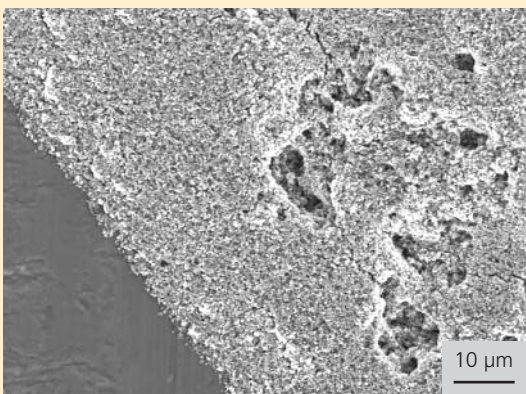
The Aerosol-Jet® process provides noncontact printing of fine structures with minimum line widths of 10 µm. The usable inks are manifold including pure liquids, dispersed systems such as conductive nanoparticle containing inks, carbon nanotube based inks, etchants and polymers. Inks are used extremely sparingly and are very efficiently utilized.



The ink's viscosity ranges from 1 - 1000 mPa s. It is pneumatically sprayed or ultrasonically transformed into a fog so that a dense aerosol forms. An inert carrier gas then transports the aerosol to the coating head. An enveloping curtain gas shapes the aerosol into a jet. The ink is never in direct contact with the nozzle, which avoids clogging. The distance from the coating head to the substrate can be varied from 1 - 5 mm. Due to this variable distance structured surface can be printed on. Selected examples are described in the following paragraphs.

Special inks were developed to use the aerosol pressure process to print electrodes for Li ion batteries.  $\text{LiFePO}_4$  was printed onto aluminum foils and subsequently sintered. The structure has very good edge sharpness (Fig. 4). The high resolution of the print pattern enables the direct integration of secondary batteries in electronic devices.

Detail of a printed  $\text{LiFePO}_4$  electrode structure



Other ink materials were developed to fabricate electrically conducting paths. Various conductive inks were evaluated with different viscosities including those based on silver nanoparticles, doped metal oxides and dispersions from single wall carbon nanotubes. The printed conducting paths are used as RFID antennas or heating elements (Fig. 3).

A KOH based ink and an adapted etching process using aerosol printing were developed to isolate the edges of silicon wafers for photovoltaic applications. A key advantage of the process is the minimized use of etchant. The silicon wafer is preheated to 200 °C when the etchant is printed. This directly initiates the etching process. An etching width of less than 200 μm was achieved.

- 1 Printed SWCNT ink
- 3 Printed heater element on glass
- 5 Printer head with shutter

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