LIFT for printing and assembly – a study on optimized water-based inks for batteries

Ulrich Rist

U. Rist[1], **W. Pfleging**[1]

[1] *Institute for Applied Materials-Applied Materials Physics (IAM-AWP), Karlsruhe Institute of Technology (KIT), Kaiserstraße 12, 76131 Karlsruhe, Germany*

ulrich.rist@kit.edu

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The laser-induced forward transfer (LIFT) is a digital direct additive manufacturing tool, so changes in the geometry or the process parameters can be fast applied. Furthermore, it is a nozzle-free printing technique [1], enabling the process to be integrated into a wide range of possible applications in both research and industry. In research the technique is used for printing proteins [2], biological cells [3], suspensions [4], and solid materials mostly metals [5]. Furthermore, whole components can be transferred what has been demonstrated in research with resistors, capacitors, and diodes [6] to name a few and is applied for example for printing µLED for displays in the industry [7]. A functional circuit can be printed by applying the LIFT process with conductive material, e.g. solid copper or silver nanoparticles to connect the printed components. For the power supply of these printed circuits lithium-ion batteries can be printed as well. In the battery research the LIFT-process can provide a versatile tool to boost the development by rapidly manufacturing prototypes. To further optimize the lithium-ion battery advanced electrode architectures and high capacity materials as silicon are under development. The high capacity material silicon (3579 $mAh \cdot g^{-1}$) has one order of magnitude higher theoretical specific capacity than the commonly used graphite (372 $mAh \cdot g^{-1}$) but during lithiation silicon undergoes a volume expansion of up to 300 %, which leads to fast mechanical degradations of the electrodes. Advanced electrodes architectures can help to overcome this challenge and can increase the power density, energy density, the cycling stability and the electrode wettability.

In this work, a tripled frequency UV-laser with a pulse width in the nanosecond range was used to perform the LIFT-process. First, the composition of the electrode ink was optimized. For this purpose, polyacrylic acid (PAA) was introduced as a suitable binder for silicon-containing electrodes in electrode printing, as polyvinylidene difluoride (PVDF) has mostly been used so far for electrode printing, but the binding forces from the PVDF to the particles are too weak to withstand the volume expansion of the silicon during cycling. For the printing process with an electrode ink with a protic binder (PAA) a solvent with lower vapor pressure as water is required, which leads to the introduction of a glycerol-water mixture. First the influence of the glycerol content on the electrochemical properties of silicon was investigated. For the silicon a specific capacity of more than 3000 $mAh \cdot g^{-1}$ was reached. Additionally, the influence of different conductive additives with different particle sizes were investigated with the focus of reached specific capacity of silicon and the cyclability. Furthermore, for different glycerol contents in the solvent process parameters were identified at which the edge quality of the printed electrode areas is improved.

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