PRODUCTION OF ELECTROCHEMICAL MICRO-POWER SOURCES WITH LASER ENGINEERING

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We are developing a laser engineering technique to make energy storage and delivery components on the characteristic length scale of micrometers to millimeters. Our goal is to produce different types of electrochemical micro-power sources (pseudocapacitors/ultracapacitors, alkaline batteries and lithium batteries) for integration with individual passive elements and/or microelectronic systems. A laser induced forward transfer technique is used to deposit commercially available hydrous oxides, metals, polymers and corrosive electrolytes. Subsequent laser processing and machining allows us to achieve desired electrochemical characteristics and intricate geometries without resorting to any processing steps under vacuum conditions. Motivation for our approach includes the versatility to accommodate rapid processing and a variety of chemistries to make micro-power sources customized to the device requirements.

A schematic of the Matrix Assisted Pulsed Laser Evaporation Direct Write (MAPLE DW) process is shown in Fig. 1 (1). An “ink” containing a material for the electrochemical power source is forward transferred from a “ribbon” onto a desired substrate. Electrolytes are incorporated with the inks of the electrode materials and transferred in a single step. Different materials can be sequentially deposited to build a planar or stacked structure having all of the needed components of a battery or pseudocapacitor, including separator, current collector, and packaging materials. Specific form-factors of the deposited power sources are accomplished by moving the stage in three dimensions, depositing multiple layers, and laser machining. Subsequent thermal or laser processing is used as necessary.

A wide variety of electrode materials have been transferred, shaped, and processed. The optical micrographs in Figure 2 are of laser-deposited and machined pads of hydrous ruthenium oxide (RuO_2 0.5 H_2O) that serve as electrodes in planar pseudocapacitors. The electrode spacing of 18 μm and uniform interfaces are exemplary of the capabilities of the laser machining. The electrochemical characteristics of pseudocapacitors charged to 1V at 50μA and discharged at various currents are shown in Fig. 3. The specific energy and power achieved using a 100μA drain are 21 mWh/g and 950 mW/g, respectively. These values are comparable to those achieved with other processing techniques and are at the upper bounds of the specific energy expected for this type of pseudocapacitors (2). These laser-engineered pseudocapacitors demonstrate high specific capacitances and good cycling behavior, indicating that the laser processing is not deleterious to the electrochemical properties of the RuO_2 0.5 H_2O. Development of lithium and alkaline batteries by this laser engineering approach will also be discussed.

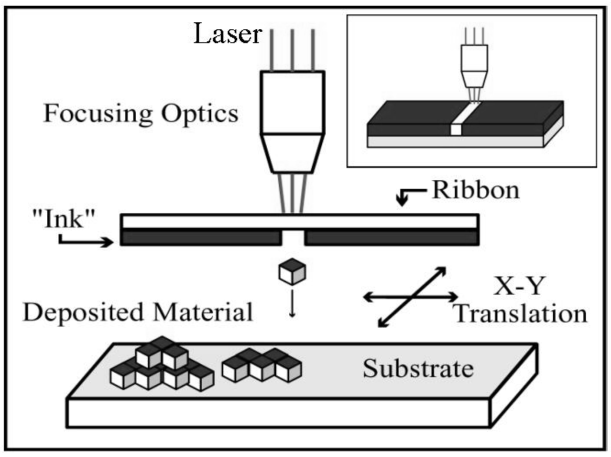

Figure 1: MAPLE-DW forward transfer process of materials for electrochemical power sources. Inset: The ribbon is removed for laser processing and machining.

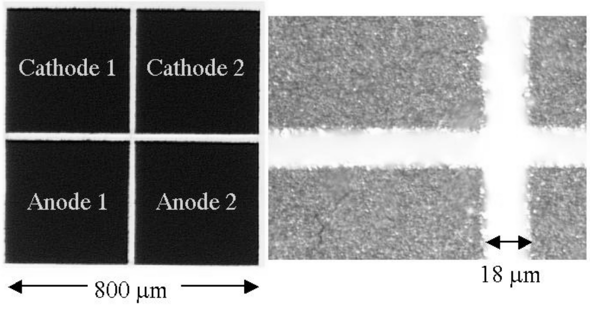

Figure 2: Optical micrographs of the feature length scale of laser deposited and machined pads of hydrous ruthenium oxide for planar pseudocapacitors.

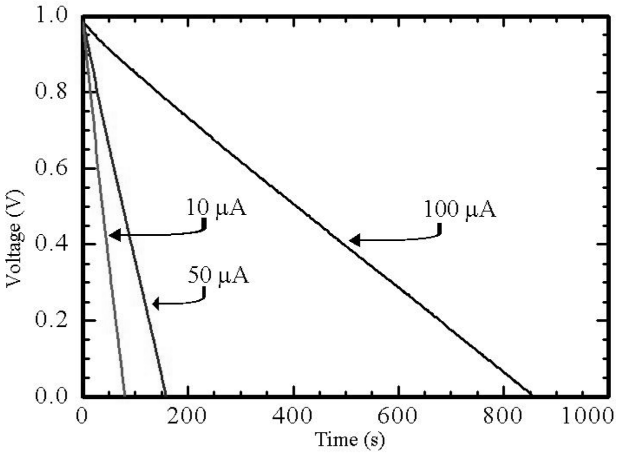

Figure 3: Discharge profiles of hydrous ruthenium oxide pseudocapacitors (~100 μg) with 5M sulfuric acid electrolyte.

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