Improving Surface Uniformity and Performance of Supercapacitor Electrodes Through Roll Coating

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In the conventional wet electrode manufacturing process, after the slurry coating is completed, a phenomenon occurs during the pressing and drying stages where the polyvinylidene fluoride (PVDF) binder, which is dissolved in organic solvents such as N-Methyl-2-Pyrrolidone (NMP) and Dimethylformamide (DMF), partially leaches out. NMP is a solvent that has a strong ability to dissolve various polymers without providing hydrogen ions, while DMF is also a similar type of solvent commonly used in the production of plastics and so on.

The leaching phenomenon negatively impacts the performance of the electrode, particularly leading to a decrease in the adhesion between important components, such as the electrode, current collector, active material, and conductive additives. As a result, the mechanical stability of the electrode is compromised, and its electrochemical performance is adversely affected. To address these critical issues, we propose an innovative solution that incorporates the roll coating process.

Roll coating allows for the large-scale production of electrodes with a uniform surface. This uniform electrode surface significantly enhances performance and improves ion mobility through the compression of active materials. Additionally, by utilizing large-area slitting techniques, it offers the advantage of mass-producing products with consistent quality.

In this study, electrodes were fabricated using both carbon-based slurry and MXene-based slurry, The carbon-based slurry utilized functionalized activated carbon, which offers advantages over regular activated carbon by reducing the potential for both large and small cracks, as well as minimizing issues related to the detachment of active materials from the surface. This leads to improved surface adhesion to the substrate.

A detailed comparative analysis was conducted to evaluate the differences between electrodes coated manually with the slurry and those processed through our proposed advanced coating technique. To assess the uniformity and surface roughness of the electrodes, we employed Field Emission Scanning Electron Microscopy (FE-SEM), which provides high-resolution images of the surface characteristics.

Furthermore, we investigated the electrochemical properties of the electrodes using Cyclic Voltammetry (CV) and Galvanostatic Charge Discharge (GCD) tests, which help to measure the capacitive behavior and charge-discharge performance. In addition to these assessments, we performed Electrochemical Impedance Spectroscopy (EIS) analysis to analyze the resistance characteristics of the devices. We also calculated the Specific Capacitance of the electrodes to further evaluate their performance. This comprehensive approach allows us to gain valuable insights into the performance of the electrodes and their suitability for supercapacitor applications.

The insights gained from this study are expected to play a crucial role in developing optimized design methodologies that mitigated the inherent issues of the wet coating process and achieve improved surface uniformity, ultimately enhancing the performance of supercapacitors. This multifaceted approach, which combines advanced coating techniques with methods to enhance adhesion, has the potential to lead to more efficient supercapacitor designs.