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Coupling Metal Oxide and Dendritic Gold Current Collectors for High-Performance Hybrid Supercapacitors on Silicon Wafer

Abstract

Hybrid supercapacitors have gained significant attention in recent years due to their potential to combine the advantages of both batteries and capacitors. In this study, we investigate the use of metal oxides materials in a hybrid supercapacitor using a dendritic gold current collector, the device was implanted on a silicon wafer. Metal oxide materials, such as iron Oxide (Fe_2O_3) and manganese oxide (Mn_2O_3), are known for their high pseudo-capacitance and excellent electrochemical performance in water based electrolyte.

By integrating dendritic gold current collectors with these materials, we aim to enhance its energy storage capacity and cycling stability. The silicon substrate provides mechanical support and pave the way for on-chip application, while the dendritic gold current collector offers a high surface area for efficient ion adsorption and desorption along the electrode-electrolyte interface. The metal oxide is coated onto the porous gold electrode using a simple and low cost-effective method, the electroplating, by mean of a solution based on $FeSO_4$. The performance of the hybrid supercapacitor is evaluated through various electrochemical tests, including cyclic voltammetry, galvanostatic charge-discharge cycling, and electrochemical impedance spectroscopy, adopting neutral water based electrolyte. The results show that the enhanced hybrid supercapacitor with metal oxide materials exhibits significantly improved electrochemical performance compared to the device with a flat metal oxide electrode. The Fe-coated dendritic electrode exhibits a high specific capacitance over 20 mF cm^{-2}, while the MnO_2-coated flat electrode demonstrates similar specific capacitance over 25 mF cm^{-2}. Additionally, the hybrid supercapacitor shows excellent cycling stability with negligible capacitance loss after 1000 cycles.

In conclusion, this study demonstrates the potential of mixing dendritic current collectors with metal oxide materials can enhance the performance of planar hybrid supercapacitors. The results suggest that mixing micro-structured current collectors with metal oxides can lead to simplified area's balancing technique for planar electrochemical cells, destinated to the development of on-chip devices with large operating voltage window, high energy storage capability and efficiency.