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Carbide Derived Carbon (CDC) Micro-Super Capacitors on Silicon Chips

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Abstract: Inter digital on-chip micro-super capacitors were manufactured and tested based on Carbide Derived Carbon (CDC) films. A titanium carbide (TiC) film was patterned and chlorinated to produce a TiC related carbon (TiCeCDC) sheet, accompanied by two forms of current collectors (Ti / Au and Al) deposition utilizing normal micro-manufacturing processes. CDC-based micro-super capacitors used a 1 M tetraethyl ammonium tetra fluoroborate, NEt4BF4, in propylene carbonate (PC) electrolyte were electrochemically characterized by cyclic voltammetry and impedance spectroscopy. A device capacity of 0.78 mF and 1.5 mF cm the specific footprint capacity of the device was measured at 100 mV s for a potential range of 2 V. A specific 3.0 mJ cm energy And 84 mW cm of specific power for the devices were calculated. Such instruments provide a mechanism by micro-manufacturing to produce pure carbon-based micro super capacitors and can be used to drive micro-electromechanical systems (MEMS) and electronic devices.

Keywords: Carbide derived carbon, Micro-super capacitors, MEMS, Electrochemical capacitor.

INTRODUCTION

Micro-Electro-Mechanical Systems (MEMS)[1] development allows portable electronic devices to have new functions without compromising their size. Reducing the size of power sources therefore becomes a key objective for accommodating the compact devices ' operational envelope. The most widely used sources of power today are the Li-ion micro-batteries[2]. Although extensive research has significantly increased levels of performance, their power output is constrained by redox reaction rates. While the use of new designs, such as 3-dimensional and thin-film electrodes, has overcome this shortcoming, there is a demand for higher power devices.

Double-layer electrical capacitors (EDLC or super capacitors)[3], which store energy from the electrolyte through adsorption and desorption of ions powered by an applied potential on the surface of porous active materials, may produce energy in a short time, thus offering high power capacity. Therefore, the implementation of electrochemical micro-super capacitors on a chip has attracted considerable interest as a potential replacement or complementary device for micro batteries to improve the overall power source performance.

Using an organic electrolyte to achieve high energy and power performance, EDLCs operate within a voltage window of up to 3 V. However, as the processing of carbon powders into films using conventional micro-manufacturing processes is difficult, the development of micro-super capacitors remains a challenge. While the proof-of-concept was demonstrated, first carbon-based micro super capacitor tests showed modest performance (specific capacitance of 0.8 mF cm^-2; voltage window limited to 0.8e1 V). Subsequent experiments reported the use of thicker electrodes (up to 50 mm) by adding a binder and novel approaches implementing vertically aligned carbon Nano tube.

Powder electrodes need the addition of a binder and nanotube electrodes have a low volumetric energy density which limits their performance, leading to an improved performance with a specific capacity of 90 mF cm^-2. A binder-free carbon thin film with an

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adapted microfabrication process leads to a scalable production of micro devices directly on silicon. Continuous carbon coatings were produced using high temperature chlorine gas etching from silicon carbide. Bulk TiCeCDC thin films synthesized by TiC chlorination ceramics have proven to be a promising substrate for super condensers with a volumetric range of up to 180 F cm^-3, compared to 50 F cm^-3 for traditional carbon-based roll films.

The current study's objective is to produce CDC electrodes using an already sputtered TiC precursor on a Si substrate. This is a promising technology compatible with micro-devices type MEMS, which has been shown in a sandwich configuration for super capacitors. A volumetric range of up to 180 F cm. The sandwich designs were produced in line with previous results. MEMS systems, however, require micro-super capacitors without any polymer separators or binders in an on-chip planar interdigitated configuration. They must also be produced using technologies that are compatible with the manufacture of electronic devices.

In this research, we study for the first time utilizing traditional microfabrication processes to prepare micro-super capacitors based on TiCeCDC thin films. They present an alternative to carbon-based micro-super capacitors produced using different printing or electrophoresis deposition techniques, with materials of much higher density, higher purity (no organic binders), and the possibility of high accuracy tuning of porosity. Optimization of this process can lead to much higher energy density micro super capacitors compared to previous technologies.

Fabrication Process

The process of fabrication is shown in Fig. 1. To ensure good shielding between the two electrodes, the TiC film was processed on a Si wafer with a 500 nm thick SiO2 coating. As described in our previous work, DC magnetron sputtering was used with a titanium target and acetylene (C2H2) gas. Using picture lithography, the design of interdigital electrodes was added to the light-resistant film and then moved to the TiC film using SF6 as etching gas by RIE. The TiC film then reacted to convert to CDC for 5 min with chlorine at 450. The TiCeCDC film's Raman spectra after chlorination (Fig. 2) are reported using the 514.5 nm wavelength of excitation. Between 1360 and 1600 cm, the two big tops. Confirmed the formation of disordered graphite carbon, representing D-and G-peaks of graphite, respectively. The spectra are characteristic of low temperature amorphous CDC films[4]. The Ti / Au current collectors were evaporated onto the template by means of a built shadow mask with narrower electrode fingers to enable electrolyte percolation during electrochemical characterization.

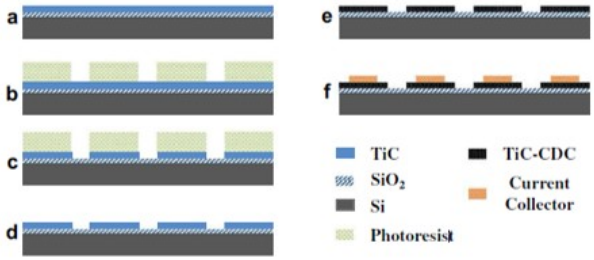

Figure 1: Schematic illustration of the Fabrication Process for Micro-Scale Capacitors

In order to improve metal conductivity and release the mechanical stress between the Ti / Au and the TiCeCDC layers, the deposited current collectors were annealed at 250 #C for 20 min under vacuum. Other samples with a different current collector (Al of 400 nm thickness) were implemented using the procedures described above, except for annealing, in similar devices. Fig 2 shows the Raman spectra test.

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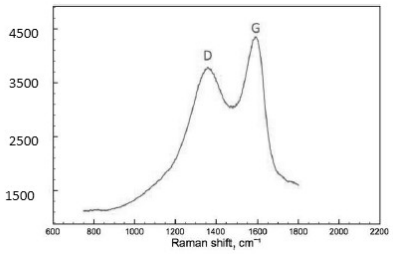

Figure 2. Raman Spectra of the TiCeCDC Film Chlorinated for 5 min.

LITERATURE REVIEW

In this study, experimentally and numerically investigated the fatigue damage behavior of chopped carbon fiber chip-reinforced composite. According to the random distribution of carbon fiber chips, a broad scatter is shown in the S-N diagram and therefore a new analysis technique is introduced to relate the local microstructure to the bulk material's fatigue conduct. Interrupted fatigue testing is also performed so that characterization of the microstructure can be performed on the samples tested to analyze the initiation and propagation of crack[5]. The present author has successfully predicted the formation of chips in carbon steel machining with a model that assumes that all carbon steels have the same thermal flow stress softening and temperature independent strain hardening but are characterized by individual strain hardening behaviors. Thermal softening had to be assumed to be shifted to higher temperatures than was experimentally observed[6]. This study provides a new idea for the treatment of high-strength nitrogen wastewater in wetlands. Nitrification and denitrification were determined by the slag / gravel and wood-chip locations, respectively. Nitrogen removal was efficient in the steady phase before shock loading using combined slag-wood-gravel substrate due to nitrification-denitrification process, while nitrogen removal was efficient due to the ANAMMOX process under shock loading with combined wood-slag-gravel substrate[7]. This paper uses an orthogonal cutting test rig to introduce a comprehensive study on CFRP chip roots for five different unidirectional fiber orientations. Work pieces were deliberately weakened. Thanks to a consistent cut and persistent yet large variety of adaptable cutting speeds, these work parts require truly representative cutting conditions. Chip root analysis is based on light microscopy I electron microscopy (SEM) scanning (ii) and micrographs (iii) scanning. It is capable of understanding the wear mechanisms when machining CFRP in combination with previous in-house studies[8]. This literature discloses about silicon-based chips will play sound and intriguing patterns by feeding alternating currents and audio signals through grooves in the suspended CNT thin yarn arrays. In addition to the thin yarns, further essential elements of processors, groove depth and interdigital electrodes were further discovered in experiments. The sound pressure depends on the depth of the grooves and the thermal wavelength to define the influence-free depth can be introduced[9]. This new Nano-neuron interface can potentially serve as an accurate, informative, biocompatible and dual-mode neural interface for monitoring neuro electrical and neurochemical activity at single-cell and even within the cell. From the Clinical Editor: the authors demonstrate the usefulness of a neural chip with vertically aligned carbon nanofiber electrodes with lithographically defined arrays. The new device can be used to stimulate and/or monitor in vitro brain tissue signals and monitor intracellular and single-cell dynamic neuroplasticity information including neuro electric and neurochemical activity[10].

CYCLIC VOLTAMMOGRAMS

CVs were recorded in 1 M NEt4BF4 in PC electrolyte on-chip micro-super condenser with Ti / Au current collectors. The resume was registered at 100 mVs!1, presents a typical rectangular shape within a voltage range of 2 V, although a shift from

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the ideal capacitive behavior was observed at high voltage due to the redox shuttle (impurities) in accordance with the results of the EIS. The micro-device could also maintain a relative rectangular shape, meaning a small shift from ideal capacitive behavior at a scanning rate of 10 Vs, which even for micro-super capacitors is a very high rate. A capacitance of 0.74 mF was calculated from CV data at 100 mV s for a single on-chip device over a range of 2 V, which results in a specific capacity of 1.4 mF cm!2 (Per system footprint area). Taking into account the thickness of the 1.6 mm TiCeCDC film as shown in Fig. 4, The active content TiCeCDC film volumetric potential was estimated at 35 F cm!3.

While the performance is smaller than that of the TiCeCDC thin-film unit installed in a sandwich configuration measured in NEt4BF4 acetonitrile electrolyte, this is the first proof of the technology principle. For the low capacity obtained, many explanations can be suggested: the first is a somewhat greater transport gap between electrodes of ions, as all ionic transport happens within the aircraft. The device's ability to operate at very high rates, however, suggests that the capacitance is controlled by ion sorption and desorption, rather than between the electrodes. NEt4BF4 in PC has been used in this work as an electrolyte whose viscosity can limit the mobility of ions and prevent good impregnation of TiCeCDC material. PC solvent results in a greater effective ion size compared to acetonitrile-based electrolytes and the 450 #C TiCeCDC pores are too small for the PC-based solvent.

In addition, the leakage current from the system's electrolysis of impurities may also be a cause of capacitance reduction. In future experiments, all these possibilities will be investigated. Fig. 3 presents a contrast of Al and Ti / Au existing 100 mV s CVs for micro devices In an identical electrolyte. The device with the Al current collector has a more distorted CV, as explained above, indicating an increase in the device's resistance. A capacitance of 0.78 mF was calculated from the CV at 100 mVs for the entire device Over a range of 2 V, 1.5 mF cm of specific capacity Standardized by 37 F cm footprint and volumetric efficiency!3 For the substrate of the electrodes. These capacitances extracted are very close to the results obtained with Ti / Au current collectors on the micro-super capacitors.

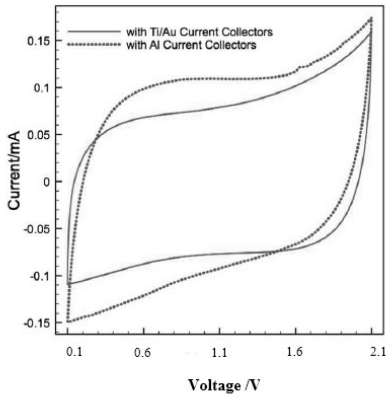

Figure 3: CV Curve

CONCLUSION

The micro-super capacitors prepared by TiCeCDC showed a maximum specific energy of 3.0 mJ cm a maximum of 84mWcm of specific power. The energy and power performance compared to the literature data are within the range of values reported for carbon-based micro-super capacitors with the main advantage of being a simple micro-manufacturing process. Basic power and energy efficiency can be further improved by enhancing the cell configuration, adapting the carbon pore size to the size of the electrolyte ion and refining the interaction between the carbon film and the new collector.

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