Supplementary information

On-chip integration of bulk micromachined three-dimensional Si/C/CNT@TiC micro-supercapacitors for alternating current line filtering

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Note S1: Electrochemical performances of the Si/C/CNT@TiC electrode versus carbonization time

The electrochemical performance of the Si/C/CNT@TiC electrodes with different carbonization durations are evaluated in a two electrodes system cells, and compared in Figure S1. The three symmetric CV curves at a scan rate of 100mV s^{-1} indicated an excellent electrochemical reversibility by CNT@TiC core-shells. As the reaction time increases, the area enclosed by the quasi-rectangular shaped curves shows a gradually increasing trend. This result is in agreement with the GCD curves tested at the current density of 80 μA cm^{-2}. As the reduction time increase, the CNT@TiC core-shells exhibit increased capacitive performance. Furthermore, according to the EIS curves of the three electrodes, in the high frequency region, the longer the reaction time, the smaller the R_0 value and equivalent series resistance. This is due to the excellent interfacial contact between TiC and CNT obtained by sufficient reaction time. The EIS curves mean that as the time increases, fully reduced CNT@TiC core-shells offers more conductive electrodes and facilitates higher electronic/ionic transport efficiency.

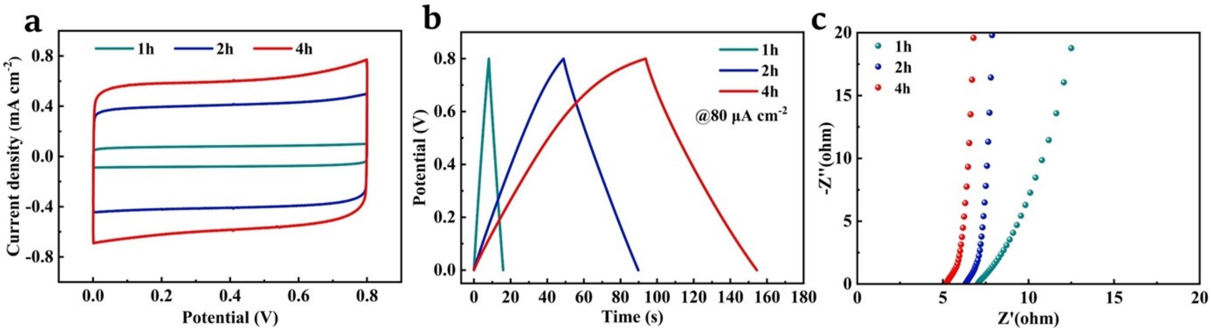

Figure S1. Electrochemical performances of the Si/C/CNT@TiC electrode with different carbonization time (1 h, 2 h, and 4 h). (a) CV curves at a scan rate of 100 mV s^{-1}; (b) GCD curves at the current density of 80 μA cm^{-2}; (c) EIS curves for the Si/C/CNT@TiC electrodes.

Note S2: CV curves for the Si/C/CNT@TiC electrode in a three-electrode system

The as-prepared individual Si/C/CNT@TiC MSC electrode was further characterized in a three-electrode system. The CV curves at the scan rate of 5-100 mV s^{-1} show quasi-rectangular shapes and a maximum specific capacitance of 18.77 mF cm^{-2} (9.39 F g^{-1}) at a scan rate of 5 mV s^{-1}.

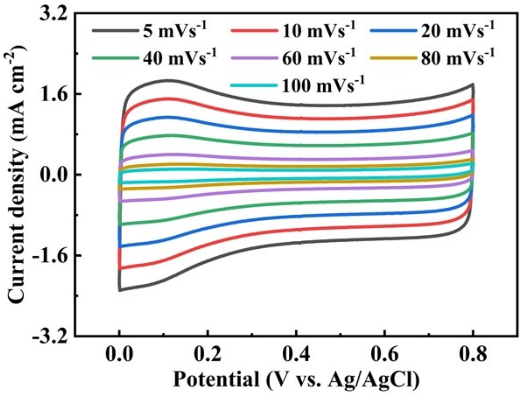

Figure S2. CV curves for individual Si/C/CNT@TiC electrode with the scan rate from 5 to 100 mV s^{-1} using a three-electrode system.

Note S3: Comparison of phase angle as a function of frequency for the three full devices.

For AC-line filtering applications, the phase angle should be around −90° at 120 Hz. Although, the phase angle at 120 Hz decreased from 78° for Si/C to 22° for Si/C/CNT@TiC full devices in Figure S3, there is great potential for all full device in AC-line filtering application.

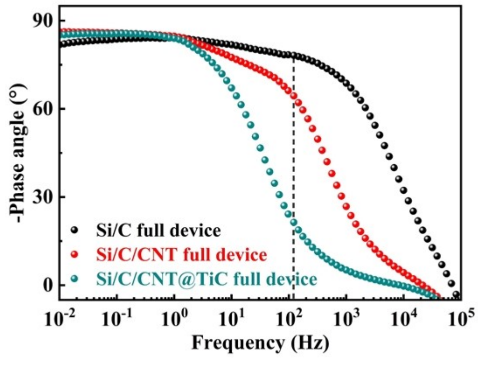

Figure S3. The plots of impedance phase angle versus frequency of the three 3D MSCs.

Note S3: Comparison of the series-parallel characteristics of the MSC devices for applications in a low-pass filtering circuit.

According to the equation: $S = 1/(4R_LCf - 1)$, S (fluctuation coefficient of the output) depends on the capacitance of the device in the same circuit. Therefore, the Si/C/CNT@TiC full device with the highest specific capacitance shows the best AC-line filtering performance, as seen in Figure S4.

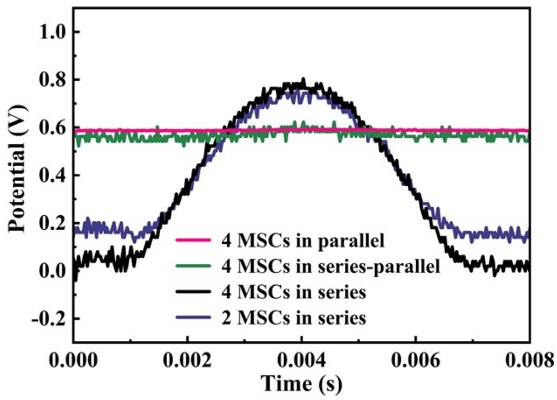

Figure S4. The series-parallel characteristics of the MSC devices for the applications in a low-pass filtering circuit.