

## Supporting Information

### **Novel Electrode Geometry for High Performance CF/Fe<sub>2</sub>O<sub>3</sub> based Planar Solid State Micro-electrochemical Capacitor**

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#### **S1: Electric field near sharp edge:**

The electric field near the surface of a conductor<sup>1</sup>

$$\text{Vector}(E) = \frac{\sigma}{\varepsilon} \text{cap}(n) = \frac{\Delta Q}{\Delta S \varepsilon} \text{cap}(n)$$

where  $\Delta S$  is an elementary area consists of  $\Delta Q$  amount of charge,  $\text{cap}(n)$  is unit vector normal to the surface,  $\sigma$  is surface charge, the constant  $\varepsilon$  is called the permittivity of free space.

$\Delta S$  goes as  $r^2$  and at surface of a conductor  $Q$  as  $r$ ,<sup>1</sup> therefore  $E$  goes as  $1/r$  which makes the electric field near the sharp edge, where the radius of curvature is small, very high.

#### **Now two edges are parallel, contain opposite charges**

Which eventually increase the electric field nearly twice. Near the curve portion, the electric field lines are diverging in/out over a very small region of the curve or equivalently has a high voltage difference but as we are maintaining the voltage difference ( $V$ ) which prevents voltage

difference to grow,  $V = \frac{Q}{C}$ , by equation<sup>1</sup> capacitance ( $C$ ) has to grow.

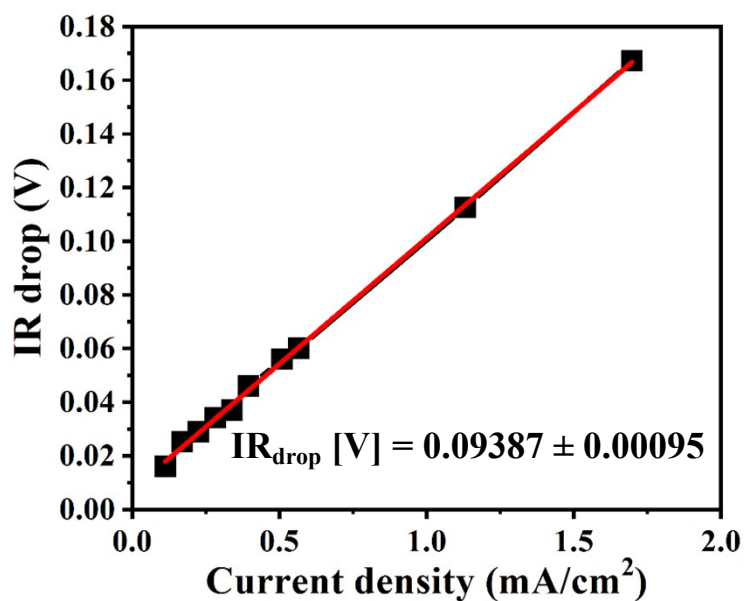


Figure S2: Voltage drop or IR drop vs applied current density for the sharp-edged micro-electrochemical capacitor.

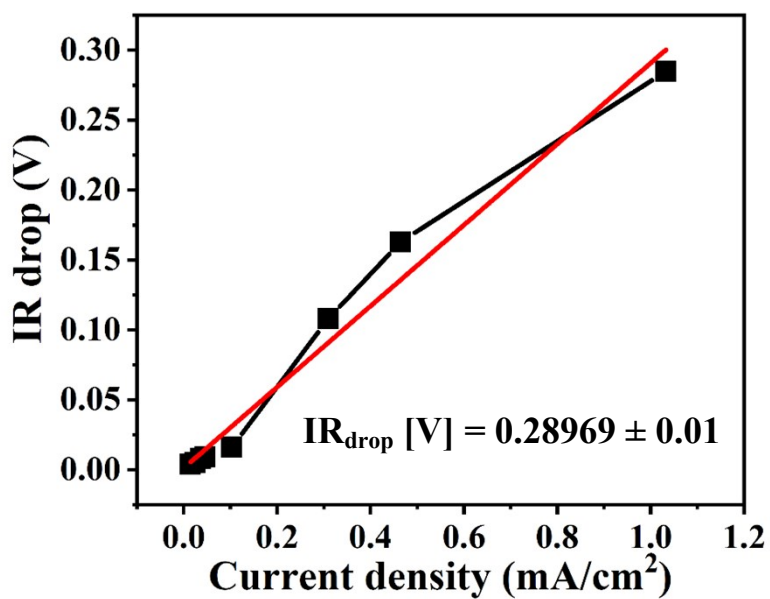


Figure S3: Voltage drop or IR drop vs applied current density for the interdigitated micro-electrochemical capacitor.

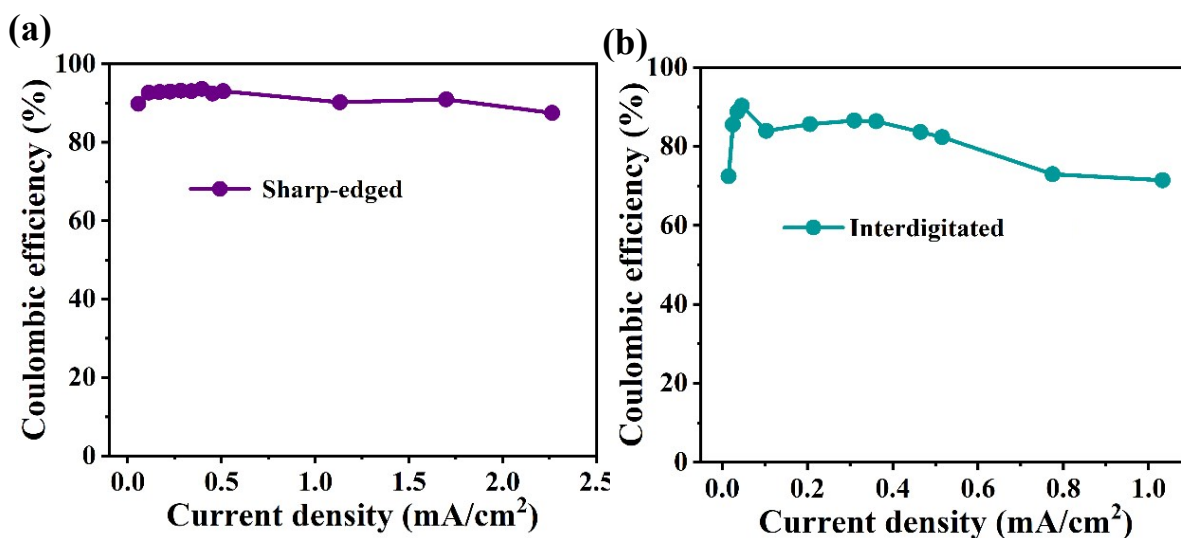


Figure S4: (a) Coulomb efficiency of the sharp-edged micro-electrochemical capacitor plotted against current density ranging from 0.0566 to 2.264 mA/cm<sup>2</sup>. (b) Coulomb efficiency of the Interdigitated micro-electrochemical capacitor plotted against current density ranging from 0.015 to 1.033 mA/cm<sup>2</sup>

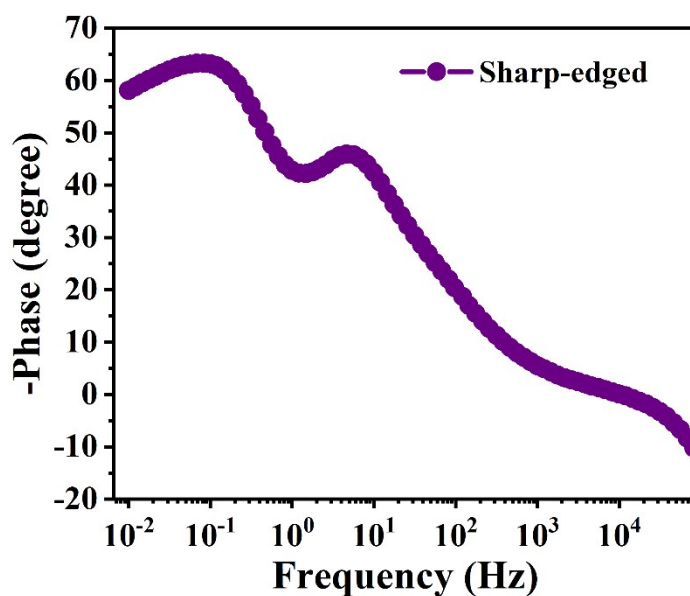


Figure S5: Bode plot of the sharp-edged micro-electrochemical capacitor.

## S6: Synergistic response of the electrode material

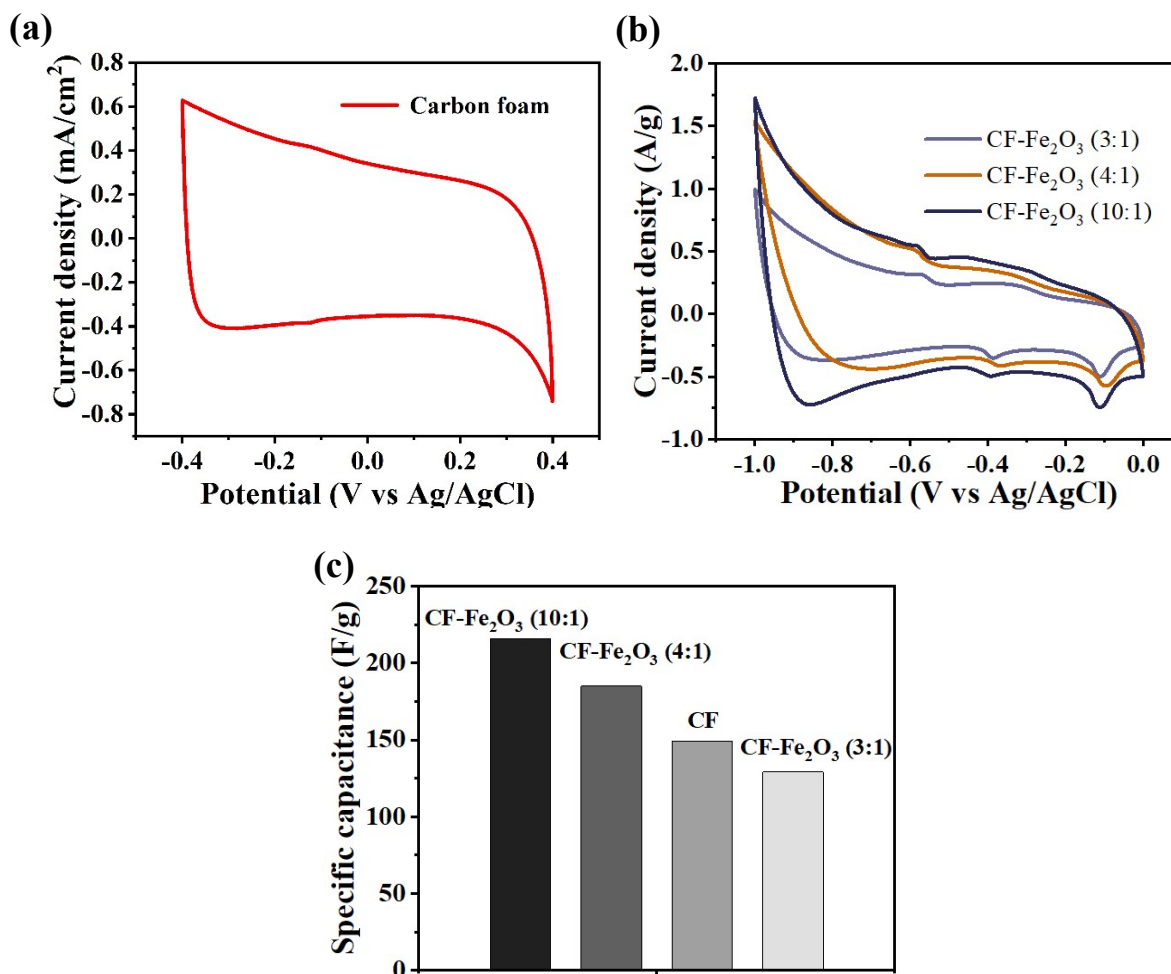


Figure S6: a) CV curves of pristine carbon foam recorded in three-electrode setup at 5 mV/s scan rate in 6 M KOH aqueous electrolyte. b) CV curves of CF-Fe<sub>2</sub>O<sub>3</sub> composites recorded in three-electrode setup at 5 mV/s scan rate in 6M KOH aqueous electrolyte. c) Comparison of specific capacitance calculated from CV curve at 5 mV/s scan rate.

The synergistic response of CF-Fe<sub>2</sub>O<sub>3</sub> composite was measured in electrochemical measurement using the three-electrode setup of the pristine carbon foam as well as CF-Fe<sub>2</sub>O<sub>3</sub> composite materials. After coating on the current collector of nickel foam, the electrochemical behavior of pristine carbon foam electrode were recorded in 6 M KOH electrolyte. Carbon foam coated nickel foam used as a working electrode, Pt as a counter electrode, Ag/AgCl as

reference electrode. CV was recorded at a scan rate of 5 mV/s within a potential window of 0.4 to -0.4V. Figure S6a shows CV curve of nearly rectangular shape indicating an ideal double layer capacitive behaviour of carbon foam. The electrochemical performance of the CF-Fe<sub>2</sub>O<sub>3</sub> composites were also evaluated using the same process. FigureS6b shows CV curves of the CF-Fe<sub>2</sub>O<sub>3</sub> composites electrode at a 5 mV/s scan rate within a potential window of 0 to -1V (verses Ag/AgCl reference electrode). The samples labelled as CF-Fe<sub>2</sub>O<sub>3</sub> (10:1), CF-Fe<sub>2</sub>O<sub>3</sub> (4:1), CF-Fe<sub>2</sub>O<sub>3</sub> (3:1) had raw materials weight ratios of 10:1, 4:1 and 3:1, respectively at the time of material synthesis. CV curves of CF-Fe<sub>2</sub>O<sub>3</sub> exhibit redox peaks indicating involvement of faradaic redox reaction. The specific capacitance (C, F/g) were calculated from the CV

curves using the equation 
$$C = \frac{\int I(t)dV}{mv\Delta V}$$
,  $m$  is the mass of the active material in the working electrode (g),  $v$  is the scan rate (V/s),  $\Delta V$  is the potential range (V),  $I$  is the discharge current (A). The calculated specific capacitances are shown in the figure S6c, where the capacitance of CF-Fe<sub>2</sub>O<sub>3</sub> (10:1) was significantly increased from other composites as well as from porous carbon foam. At the same scan rate CF-Fe<sub>2</sub>O<sub>3</sub> (10:1) shows a much higher capacitance of 216 F/g than porous carbon foam (149 F/g). The higher electrochemical performance of CF-Fe<sub>2</sub>O<sub>3</sub> (10:1) composite attributed to the synergistic effects of CF and Fe<sub>2</sub>O<sub>3</sub> materials. Again, it is worth noting that optimum decoration of Fe<sub>2</sub>O<sub>3</sub> helps in increasing electrochemical performance of the composite. Increasing amount of Fe<sub>2</sub>O<sub>3</sub> in the 3D network leads to increase in specific capacitance by adding more pseudocapacitive charge centres. While, more crowding the networks with nanoparticles leads to a decrease in the performance as filling of pores causes hindrance in the pathway of ions, less utilization of surface area and congregation of nanoparticles limits the participation of some of the nanoparticles in the electrochemical reaction. Optimum ratio during preparation helps to achieving highest response because of

easier conducting pathway, good interfacial contact between the nanoparticles and carbon sheet, shorter diffusion path for electrolyte ion and electrons.

References:

1 D. J. Griffiths, Introduction to Electrodynamics, Cambridge University Press, 1981.