Supporting information for ***Journal of Materials Chemistry A***

Hybrid supercapacitor based on the flower-like $Co(OH)_2$ and urchin-like VN electrode materials

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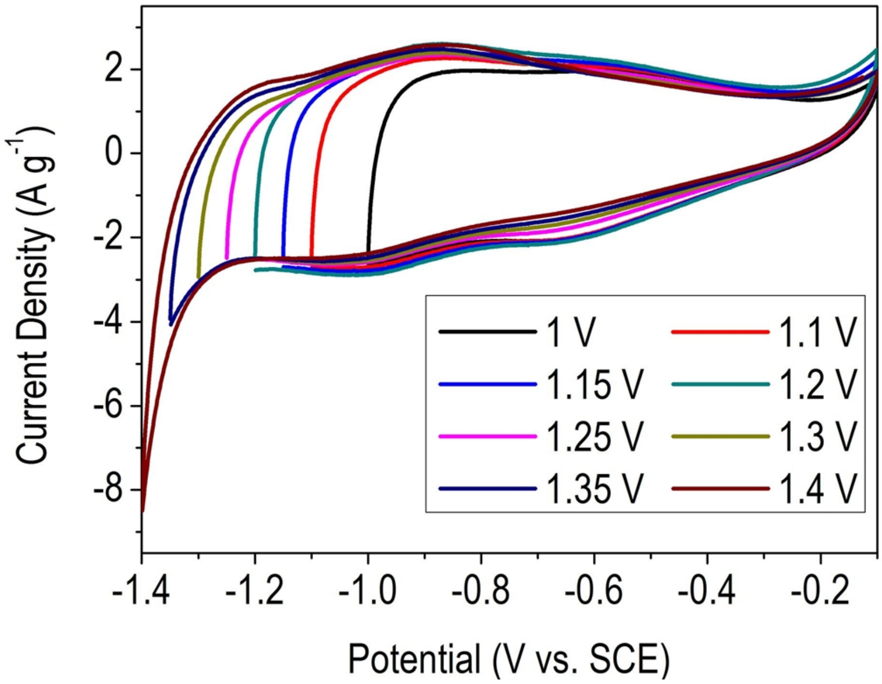

Figure S1 CV curves of VN at the scan rate of 20 mV s^{-1} under the different working potential range. Obviously, the cycling potential is lower than 1.2 V, the polarization current is observed, indicating the wide work potential range of urchin-like VN.

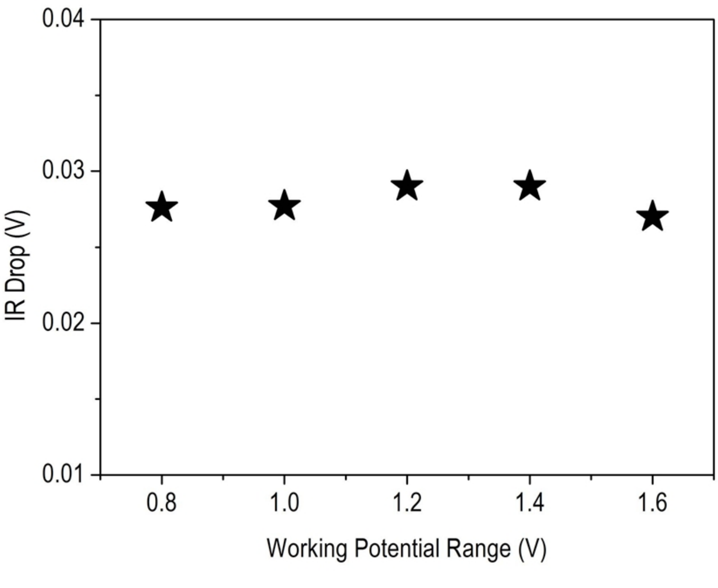

Figure S2 Voltage drop (IR drop) of hybrid supercapacitor from the charing/discharging curves at the current density of 1 A g^{-1}.

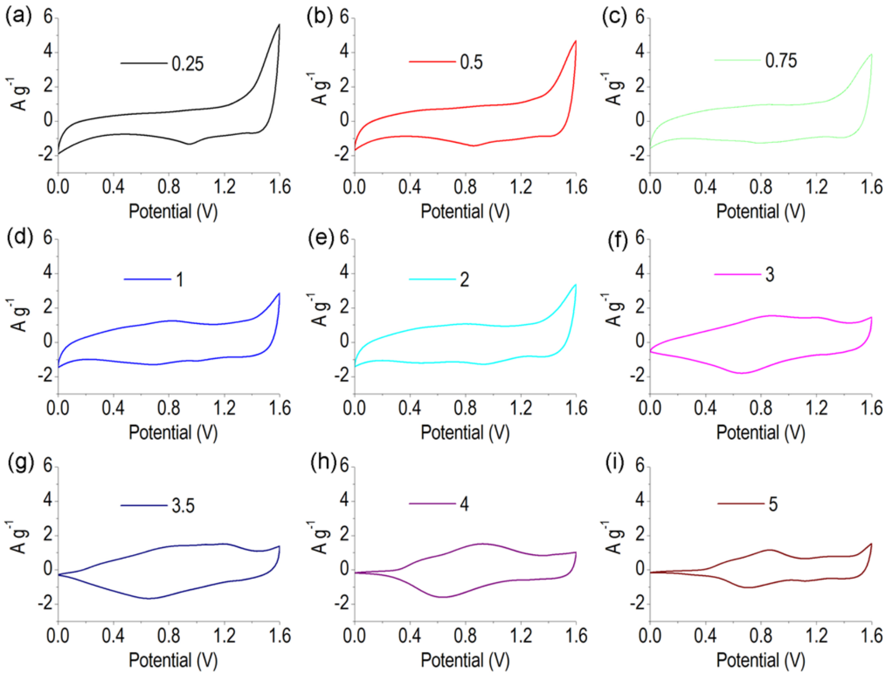

Figure S3 CV curves of hybrid supercpacitprs at the scan rate of 20 mV s^{-1} under the different VN/$Co(OH)_2$ mass ratios.

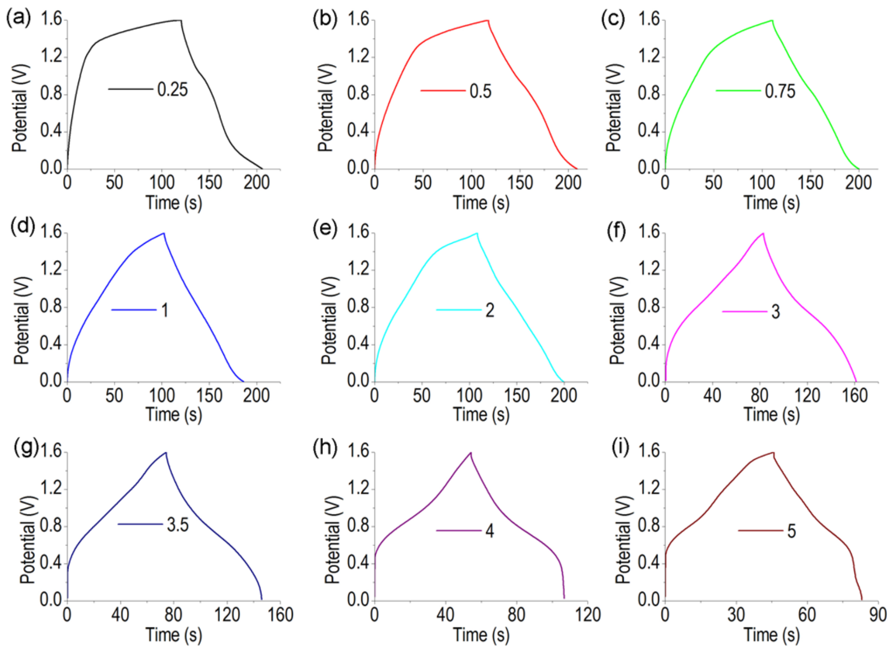

Figure S4 Galvanostatic charge/discharge curves of hybrid supercapacitors at the current density of 1 A g^{-1} under the different VN/$Co(OH)_2$ mass ratios.

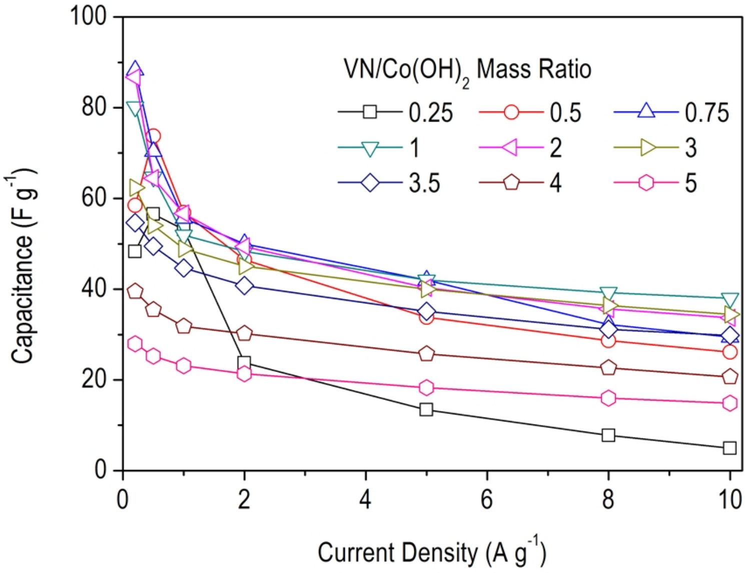

Figure S5 Comparison of specific capacitance of hybrid supercapacitor fabricated by different VN/$Co(OH)_2$ mass ratios at the different current densities.

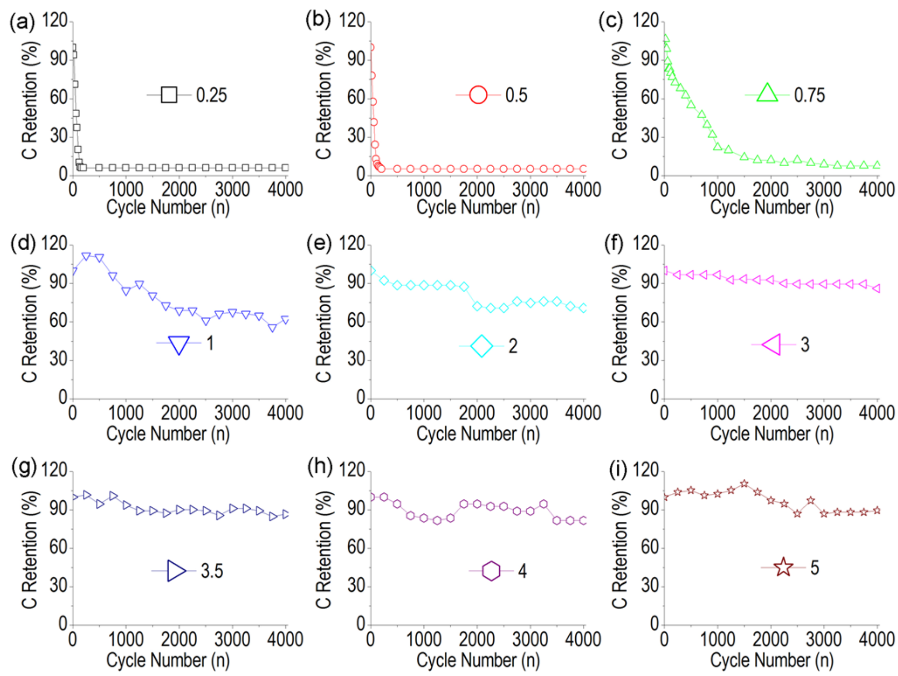

Figure S6 Cycle-life performance of hybrid supercapacitor fabricated by different VN/$Co(OH)_2$ mass ratios with a voltage of 1.6 V at the current densities of 1 A g^{-1} in 2 M KOH electrolyte.

It is important to understand the relation between the cell capacitances and positive/negative mass ratios. Here, we used the Wilson' mathematical model (***reference 39***) to predict cell parameters for a theoretical hybrid $Co(OH)_2$//VN systems and to correlate experimentally obtained parameters as well as to find the optimal positive/negative mass ratio. Wilson' mathematical model is very simple and effective way in where the potential of both electrodes swings during cycling. In our hybrid system, the potential of $Co(OH)_2$ and VN electrode swing during cycling, as shown in Figure 3b and Figure 6c. Thus, Wilson' mathematical model is effective in our hybrid system.

To a hybrid supercapacitor, this class of cell assembly can simplistically be treated as two (dissimilar capacitor) in series. Assuming two capacitors in series, the total capacitance, *Cc* (F), is given by

$$\frac{1}{Cc} = \frac{1}{Cp} + \frac{1}{Cn} \quad (1)$$

where the capacitance of the positive ($Co(OH)_2$) electrode is *Cp* (F) and that of the negative (VN) electrode is *Cn* (F).

$$Cc = c_c \times m_c \quad (2)$$

$$Cp = c_p \times m_p \quad (3)$$

$$Cn = c_n \times m_n \quad (4)$$

Where, c_p, c_n, and c_c is the specific capacitance of positive electrode material, negative electrode material, and hybrid supercapcitor, respectively, and m_p, m_n, and m_c is the total mass of active electrode in the positive electrode, negative electrode, and hybrid supercapacitor, respectively. Obviously

$$m_c = m_p + m_n \quad (5)$$

According to equation (1), (2), (3), and (4), we can obtain

$$\frac{1}{c_c \times m_c} = \frac{1}{c_p \times m_p} + \frac{1}{c_n \times m_n} \quad (6)$$

Performing this substitution and subsequent rearrangement allows us to obtain expressions that include the mass ratio, γ, where

$$\gamma = \frac{m_n}{m_p} \quad (7)$$

Here, (5) and (7) substitute into Eq. (6), where c_c expresses as

$$c_c = \frac{c_p c_n /(c_p + c_n / \gamma)}{1 + (1/r)} \quad (8)$$

Differentiating Eq. (8) with respect to mass ratio, γ, and equating to zero yields the electrode mass ratio that achieves the maximum value of c_c:

$$\gamma_{\max} = \sqrt{\frac{c_p}{c_n}} \tag{9}$$

Simulation results in Figure S5 and Figure 7 can be obtained from Eq. (8). As c_p and c_n value is 405 F g^{-1}, 89 F g^{-1} under the current density of 2 A g^{-1}, γ_{max} value in our hybrid supercapacitor is about 2.1, according to Eq.(9). As the optimal VN/$Co(OH)_2$ mass ratio is about 2.1, the maximum specific capacitance of hybrid capacitance can be obtained.

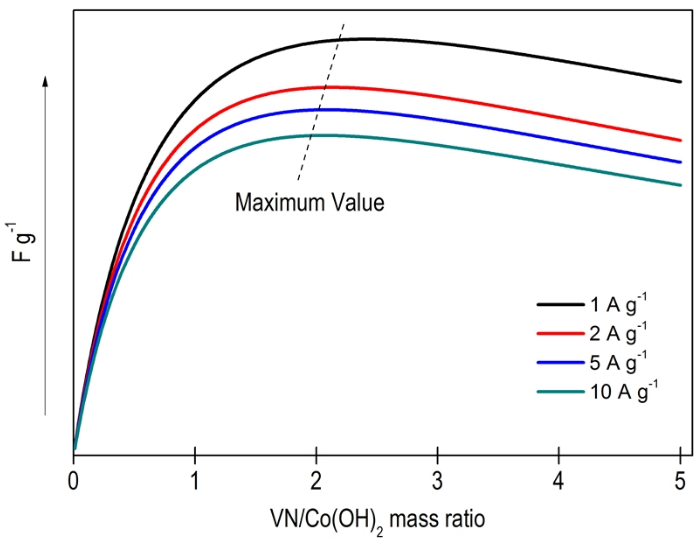

Figure S7 Plots depicts specific capacitance to VN/$Co(OH)_2$ mass ratio of hybrid supercapacitor simulated from Wilson' mathematical model under the different current densities.

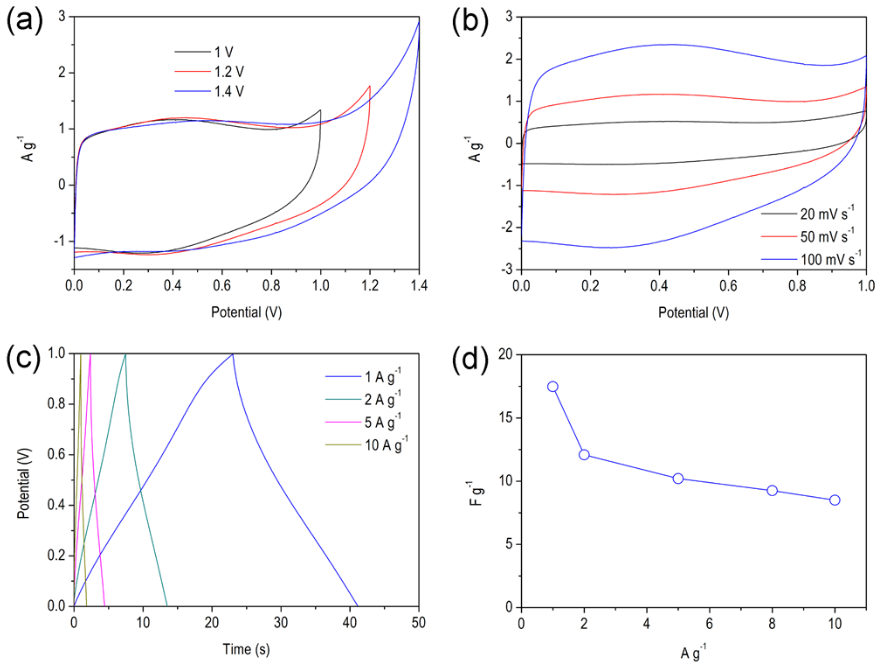

Figure S8 Electrochemical properties of VN//VN supercapacitor: (a) CV curves measured at different potential windows in 2 M KOH electrolyte at the scan rate of 50 mV s^{-1}. It is noted that the positive polarization occurring at the high potential window (>1 V), so the optimal operating working potential is 1 V. (b) CV curves at the different scan rates. (c) Galvanostatic charge/discharge curves at the different current densities. (d) Specific capacitance calculated from the different current densities.

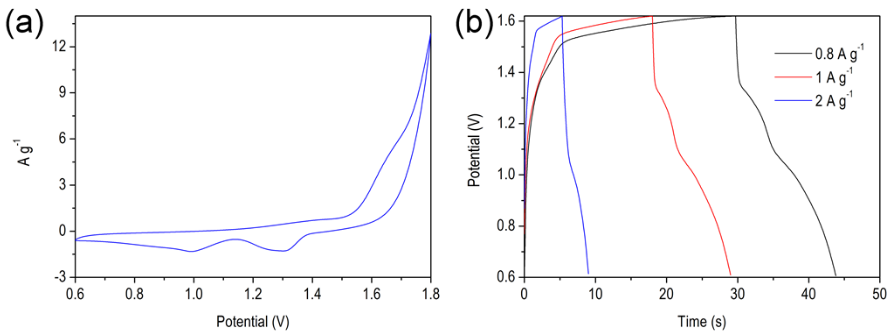

Figure S9 Electrochemical properties of $Co(OH)_2$//$Co(OH)_2$ supercapacitor: (a) CV curves of at the scan rate of 50 mV s^{-1}. (b) Galvanostatic charge/discharge curves at the different current densities.

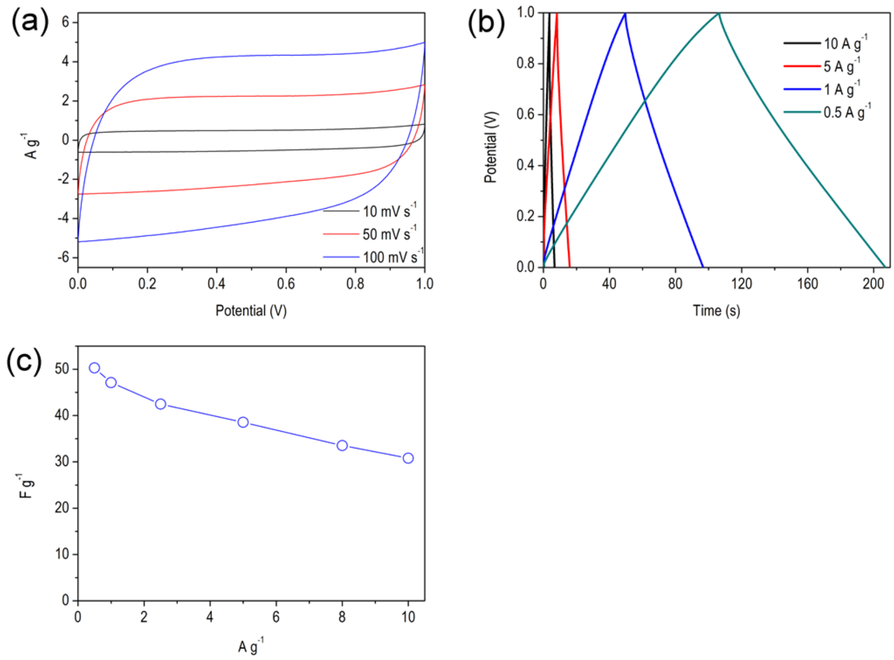

Figure S10 Electrochemical properties of AC//AC supercapacitor: (a) CV curves at the different scan rates. (b) Galvanostatic charge/discharge curves at the different current densities. (c) Specific capacitance calculated from the different current densities. AC was purchased from *Shihezi Tianfu Tech Co., Ltd, China* (TF-01, BET SSA: 2100 m^2 g^{-1}).