Supplementary Information

TiO₂ nanotubes-coated hierarchical SiC nanowires as novel electrode material with enhanced electrochemical performances for

supercapacitors

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To ascertain the mechanism by which the SiC NWs/TiO₂ NTs electrode stores energy, the individual contributions of SiC NWs and TiO₂ NTs to energy storage were first verified. As illustrated in Fig. S1a, the CV curves of SiC NWs presents a symmetrical rectangular feature, and no obvious redox peaks are observed. This result indicates that SiC NWs primarily accumulate energy via the electric double-layer capacitance (EDLC) process.¹ Double-layer capacitance is a typical physical adsorption process, where charges are stored in the EDLC formed between electrode material surface and electrolyte interface without undergoing chemical reactions. This energy storage method has the characteristics of rapid charging and discharging and is suitable for applications requiring high power density. Further, Fig. S1b shows the GCD curves of SiC NWs electrode material within the current density increases. The curve is approximately triangular, consistent with the CV analysis results, further confirming its double-layer capacitance characteristics. It is worth noting that the initial potential slightly decreases, indicating that the electrode exhibits good electrochemical reversibility during energy storage. That is, the charging and discharging processes can be carried out efficiently and stably, which is crucial for long-term use in practical applications. Capacitance retention rate refers to the proportion of the initial capacitance ability that the electrode material can maintain after multiple charging and discharging cycles, and serves as one of the crucial indicators for evaluating performance and lifespan of electrode material. Fig. S1c shows the cycling results of SiC NWs after 500 cycles, and the capacitance retention rate reaches 90.38%. This result indicates that the studied electrode material exhibits excellent stability in longterm cycling use.

To assess the electrochemical properties of fabricated TiO_2 NTs electrode, tests were conducted. As depicted in **Fig. S1d**, within the voltage range of 0 to 0.55 V, CV curves are obtained at varying scan rates exhibited distinct redox peaks. The existence of these redox peaks suggests that the TiO_2 NTs electrode possess significant pseudocapacitive characteristics. Pseudocapacitance is an energy storage mechanism that lies between traditional capacitors and batteries, combining the advantages of both: it has a relatively high energy density and a relatively fast charge and discharge speed. This characteristic makes the TiO_2 NTs electrode perform well in energy storage applications. Additionally, the GCD curves in **Fig. S1e** shows a symmetrical distorted triangle, further supporting the existence of the pseudocapacitive energy storage mechanism.² This symmetrical distorted shape reflects the rapid redox reactions that occur during the charging and discharging of the electrode material, thereby achieving efficient energy storage and release. **Fig. S1f** presents the cycling stability results. At a current density of 5 A/g, after 500 cycles, the TiO₂ retained approximately 66% of its initial capacitance, which needs further improvement. Overall, these experimental results not only reveal the respective energy storage mechanisms of SiC NWs and TiO₂ NTs, but also provide important theoretical basis and technical support for the development of high-performance composite electrode materials.



Fig. S1 Electrochemical performance of SiC NWs (a) CV curves at different scan rates; (b) GCD curves at different current densities; (c) 500 cycles; electrochemical performance of TiO₂ NTs (d) CV curves at different scan rates; (e) GCD curves at different current densities; (f) 500 cycles

In order to comprehensively evaluate the structural stability of SiC NWs/TiO₂ NTs-H electrode material after stability tests, the scanning images before and after

cycling were compared, and the SEM images of the material before and after cycling were focused on. Through this method, the changes in the surface morphology and microstructure of the material can be intuitively observed, thereby judging its stability and durability in long-term use. As shown in Fig. S2, by observing with a scanning electron microscope (SEM), it was found that the SiC NWs/TiO₂ NTs-H electrode material still maintained a coral-like morphology overall after 3000 cycles. Only in a few areas of the nickel foam substrate, the coral-like structure was partially transformed into nanoparticles. It is speculated that this phenomenon may be related to the electrode preparation process: the active material was coated on the surface of the nickel foam after 30 minutes of grinding and then pressed into thin sheets under a pressure of 10 MPa as the working electrode. Based on the above analysis, it can be concluded that the SiC NWs/TiO₂ NTs-H electrode material exhibits good long-term cycling stability and structural integrity. Although structural changes were observed in some areas, overall, the material still maintained its unique coral-like morphology after 3000 cycles, demonstrating excellent electrochemical performance and potential application prospects. This research result lays a solid foundation for the further development of high-performance electrode materials.

XRD is a commonly used material characterization technique that can provide detailed information about the crystal structure of materials. However, in order to obtain reliable XRD data, a certain amount of samples is usually required to ensure sufficient signal intensity and resolution. In this case, due to the inevitable loss of active materials during the cycling process, the final remaining material amount could not reach the minimum requirement for effective XRD analysis. Therefore, although we hoped to conduct detailed structural analysis of the active materials after cycling, due to the insufficient sample quantity, this goal could not be achieved. However, it has been shown that rutile TiO_2 is a non-intrinsic pseudocapacitive storage material. When the Faraday charge transfer process occurs on or near the active material surface, surface redox pseudocapacitance is induced; while intercalation pseudocapacitance involves a large volume change, but the active materials do not undergo phase transformation.³

Therefore, it can be inferred that the diffraction peaks of TiO_2 and SiC were well retained after cycling, but their intensities have decreased, indicating that the samples had good phase structure stability during the long-term cycling process. Generally, the reduction of peak intensity after general cycling is caused by the interference of the solid electrolyte interface (SEI) layer formed on the active material surface.⁴



Fig. S2 SEM images of the SiC NWs/TiO₂ NTs-H₃ electrodes (a)300nm (b)100nm (after 3000 cycles)

In order to determine the valence band and conduction band positions of the prepared TiO₂ NTs and SiC NWs semiconductor samples, electrochemical tests were conducted on them. The Mott-Schottky test was carried out using a CHI660e electrochemical workstation with a three-electrode system. The Ag/AgCl electrode and the platinum electrode were used as the reference electrode and the counter electrode respectively. The working electrode was prepared by uniformly coating the electrode material on the fluorine-doped tin oxide (FTO) glass substrate, and the electrolyte was 0.5 M Na₂SO₄ solution. The measurements were conducted at frequencies of 500, 1000 and 1500 Hz (amplitude of 5 mV). The potential of the reference electrode with respect to Ag/AgCl was converted to the reference NHE potential ($E^{\theta}_{Ag/AgCl} = 0.197eV$) through formula (1) ^{5,6}.

$$E_{NHE} = E_{Ag/AgCl} + 0.059 \times PH + E_{Ag/AgCl}^{\theta} \setminus * \text{MERGEFORMAT}$$

(1)

$E_{VB} = E_{CB} + E_{g}$ * MERGEFORMAT (2)

From the obtained Mott-Schottky plots (**Fig. S3a, b**), the Fermi level potentials of TiO₂ NTs and SiC NWs can be analyzed and determined. Based on these test results, the flat band potentials of these two materials can be accurately measured. Specifically, the flat band potentials of TiO₂ NTs and SiC NWs are -0.91 eV and -1.15 eV (vs Ag/AgCl), respectively. After conversion according to Formula 1, the flat band potentials of TiO₂ NTs and SiC NWs relative to the standard hydrogen electrode (NHE) are -0.30 eV and -0.54 eV, respectively. In the research of semiconductor materials, the flat band potential relative to NHE can be approximately regarded as the position of the conduction band (CB). Based on the absorption spectra and electrochemical test results, the valence band positions (VB) of TiO₂ NTs and SiC NW were calculated by Formula 2 as 2.90 eV and 1.86 eV respectively. Thus, it can be inferred that there is a difference in the positions of the energy band structures of these two samples, as shown in **Fig. S3c**.



Fig. S3 Mott-Schottky plot of (a) TiO₂ NTs; (b) SiC NWs; (c) band structure of TiO₂ NTs and SiC NWs

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