1. Synthesis and Characterization of Aligned Pearl-Like Nanotube Arrays

A dense Al$_2$O$_3$ buffer layer is first deposited on a Si substrate by the ion-beam-assisted deposition technique, and then the iron layer is coated on the top surface of the buffer layer. The synthesis process was performed in a quartz tube furnace. Forming gas (Ar with 6% H$_2$) was used as the carrier gas, and pure ethanol served as the carbon source. In a typical synthesis, nanotube growth was carried out between 800 and 850 ºC. Arrays with thickness up to hundreds of micrometer can be prepared by this approach.

*Figure S1.* SEM on the top surface of carbon nanotube arrays.
**Figure S2.** X-ray diffraction patterns of the nanotube arrays with different X-ray incidence directions. (a) X-ray strikes the top surface. (b) X-ray strikes the sideways of arrays.

**Figure S3.** Cross-sectional view of a pearl-like nanotube by high resolution TEM.
2. Conduction Dimensionality of the Pearl-Like Nanotube Fibers

In more detail, the relationship between conductivity and temperature in Mott’s hopping model can also be expressed as \( \sigma \propto \exp\left(-\frac{A}{T^{1/(d+1)}}\right) \), where \( A \) is a constant and \( d \) is the dimensionality. The plot of \( \ln \sigma \) vs. \( T^{-1/4} \) (for \( d=3 \)), \( T^{-1/3} \) (for \( d=2 \)) and \( T^{-1/2} \) (for \( d=1 \)) have linear fitting coefficients of 0.990, 0.978, and 0.951, respectively (Figure S4–S6). The result suggests that the electron transport is consistent with a 3D hopping mechanism.

Figure S4. The plot of \( \ln \sigma \) vs. \( T^{-1/2} \) based on the Mott’s variable range hopping model as \( \sigma \propto \exp\left(-\frac{A}{T^{1/(d+1)}}\right) \), where \( \sigma \) is the electrical conductivity, \( A \) is a constant, \( T \) is the temperature, and \( d \) is the dimensionality. For this plot, \( d=1 \), i.e. one-dimension hopping mechanism.

Figure S5. The plot of \( \ln \sigma \) vs. \( T^{-1/3} \) based on the Mott’s variable range hopping model as \( \sigma \propto \exp\left(-\frac{A}{T^{1/(d+1)}}\right) \), where \( \sigma \) is the electrical conductivity, \( A \) is a constant, \( T \) is the temperature, and \( d \) is the dimensionality. For this plot, \( d=2 \), i.e. two-dimension hopping mechanism.
Figure S6. The plot of lnσ vs. T^{-1/4} based on the Mott’s variable range hopping model as σ ∝ \exp (-A/T^{(d+1)/4})], where σ is the electrical conductivity, A is a constant, T is the temperature, and d is the dimensionality. For this plot, d=3, i.e. three-dimension hopping mechanism.

Full list of references:

