Tunneling Holes in Microparticles to Facilitate the Transport of Lithium Ions for High Volumetric Density Batteries

Jian Zhu, K. Y. Simon Ng, Da Deng*

Department of Chemical Engineering and Materials Science, Wayne State University, 5050 Anthony Wayne Dr., Detroit, Michigan, United States, 48202

*E-mail: da.deng@wayne.edu

Figure S1. The optical images show that (a) cloudy solid in orange color formed after 30 min of reaction and the solid is the precursor of Fe$_2$O$_3$, and (b) the Fe$_2$O$_3$ aggregates in typical red color
formed after a reaction time of 1 h. The clear transparent solvent in reactor after 1 h, which was different from the dark yellow of FeCl₃ solution before reaction, indicates conversion of dissolved Fe³⁺ ions in solution to precipitate Fe₂O₃. The color of solid product did not further change with longer reaction time, possibly, due to the formation of solid Fe₂O₃. (c) and (d) Additional SEM characterization of the sample in (a) and (b), respectively.

Figure S2. BET analysis by N₂ gas adsorption-desorption isotherm of α-Fe₂O₃ (a) solid beads and (b) beads with tunnel-like hole; pore size distribution of α-Fe₂O₃ (c) solid beads and (d) beads with tunnel-like hole;
Figure S3. Electrochemical performance of α-Fe$_2$O$_3$ micro chevron beads with tunnel-like holes and α-Fe$_2$O$_3$ solid microbeads in terms of specific capacity: (a) charge-discharge profiles for the 1$^{st}$, 2$^{nd}$, 10$^{th}$ and 80$^{th}$ cycles and (b) dQ/dV vs. V plot for the first two cycles of chevron microbeads; (c) charge-discharge profiles for the 1$^{st}$, 2$^{nd}$, 10$^{th}$ and 80$^{th}$ cycles and (d) dQ/dV vs. V plot for the first two cycles of solid microbeads for comparison. (e) cycling performance of α-
Fe$_2$O$_3$ chevron microbeads and the corresponding solid microbeads for 80 cycles. The conventional unit of mAh/g is used here.

**Figure S4.** $dQ/dV$ vs $V$ plot of 80$^{th}$ cycle for the microbeads with tunnels.