Electronic Supplementary Information

Enhanced capacitive properties of all-metal-oxide-nanoparticles-based asymmetric supercapacitors

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Fig. S1. FE-SEM images of TiO$_2$-free (a) Fe$_2$O$_3$ and (b) MnO$_2$ electrodes.
Fig. S2. TEM images and SAED patterns (inset) of the (a) Fe$_2$O$_3$, (b) TiO$_2$-Fe$_2$O$_3$, (c) MnO$_2$ and (d) TiO$_2$-MnO$_2$ NPs
Fig. S3. Cyclic voltammograms of (a) TiO$_2$-free-Fe$_2$O$_3$, (b) TiO$_2$-Fe$_2$O$_3$, (c) TiO$_2$-free-MnO$_2$ and (d) TiO$_2$-MnO$_2$ half-cell electrodes at various scan rates.

Fig. S4. BET N$_2$ adsorption-desorption isotherm plots of (a) MnO$_2$ and Fe$_2$O$_3$ and (b) TiO$_2$-MnO$_2$ and TiO$_2$-Fe$_2$O$_3$ NPs.
Fig. S5. FE-SEM images of (a, b) TiO$_2$-Fe$_2$O$_3$ and (c, d) TiO$_2$-MnO$_2$ half-cell electrodes in the TiO$_2$-Fe$_2$O$_3$/TiO$_2$-MnO$_2$ ASC. The images (a) and (c) were taken before the GCD cycle test, and the images (b) and (d) were taken after 2000 GCD cycles.
Table S1. Summary of the contribution of each capacitive element calculated by deconvolution analyses for the Fe$_2$O$_3$-NPs-based single electrodes with and without incorporation of TiO$_2$ NPs.

| Scan rate (mV s$^{-1}$) | TiO$_2$-free-Fe$_2$O$_3$ | TiO$_2$-Fe$_2$O$_3$ |
|-------------------------|--------------------------|---------------------|
|                         | Surface element (%)      | Insertion element (%)| Surface element (%) | Insertion element (%)|
| 30                      | 41.9                     | 58.1                | 22.0                 | 78.0                |
| 50                      | 46.7                     | 53.4                | 27.9                 | 72.1                |
| 100                     | 57.6                     | 42.4                | 40.7                 | 59.3                |

Table S2. Summary of the contribution of each capacitive element calculated by deconvolution analyses for the MnO$_2$-NPs-based single electrodes with and without incorporation of TiO$_2$ NPs.

| Scan rate (mV s$^{-1}$) | TiO$_2$-free-MnO$_2$ | TiO$_2$-MnO$_2$ |
|-------------------------|----------------------|----------------|
|                         | Surface element (%)  | Insertion element (%)| Surface element (%) | Insertion element (%)|
| 30                      | 31.1                 | 68.9            | 49.3                 | 50.7                |
| 50                      | 39.7                 | 60.3            | 55.0                 | 45.0                |
| 100                     | 59.4                 | 40.6            | 67.6                 | 32.4                |
| Scan rate (mV s\(^{-1}\)) | Specific capacitance (F g\(^{-1}\)) | TiO\(_2\)-Fe\(_2\)O\(_3\)/TiO\(_2\)-Fe\(_2\)O\(_3\) symmetric | TiO\(_2\)-MnO\(_2\)/TiO\(_2\)-MnO\(_2\) symmetric | TiO\(_2\)-Fe\(_2\)O\(_3\)/TiO\(_2\)-MnO\(_2\) asymmetric |
|--------------------------|------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 10                       |                                         | 46.9                                            | 73.7                                            | 72.7                                            |
| 30                       |                                         | 35.5                                            | 61.4                                            | 58.5                                            |
| 50                       |                                         | 29.9                                            | 54.9                                            | 52.8                                            |
| 100                      |                                         | 24.3                                            | 45.8                                            | 45.6                                            |

**Table S3.** The \(C_{sp}\) values obtained from CV analyses for the TiO\(_2\)-Fe\(_2\)O\(_3\)– and TiO\(_2\)-MnO\(_2\)–NPs–based symmetric and asymmetric devices at various scan rates.

| Specific current (A/g) | Specific capacitance (F/g) | TiO\(_2\)-Fe\(_2\)O\(_3\)/TiO\(_2\)-Fe\(_2\)O\(_3\) symmetric | TiO\(_2\)-MnO\(_2\)/TiO\(_2\)-MnO\(_2\) symmetric | TiO\(_2\)-Fe\(_2\)O\(_3\)/TiO\(_2\)-MnO\(_2\) asymmetric |
|------------------------|----------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 1                      | 12.8                       | 53.5                                            | 87.5                                            |
| 2                      | 10.3                       | 43.2                                            | 77.7                                            |
| 3                      | 3.5                        |                                                 |                                                 |
| 5                      |                            | 31.6                                            | 60.6                                            |

**Table S4.** The \(C_{sp}\) values obtained from GCD analyses for the TiO\(_2\)-Fe\(_2\)O\(_3\)– and TiO\(_2\)-MnO\(_2\)–NPs–based symmetric and asymmetric devices at various current densities.