**High-rate lithium ion energy storage to facilitate increased penetration of photovoltaic systems in electricity grids**

Alison Lennon1, Yu Jiang1, Charles Hall1, Derwin Lau1, Ning Song1, Patrick Burr2, Clare P. Grey3, and Kent J. Griffith3,4

1School of Photovoltaic and Renewable Energy Engineering, UNSW Sydney, NSW 2052, Australia.

2School of Mechanical and Manufacturing Engineering, UNSW Sydney, NSW 2052, Australia.

3Department of Chemistry, University of Cambridge, Cambridge CB2 1EW, UK

4Department of Materials Science and Engineering, Northwestern University, Evanston, IL 60208, USA.

**Supporting Information**



Figure S1. Ramp rate compliance of a PV array for different energy storage technologies. Compliance (%) of an energy storage system (ESS) of volume, *VESS*, to limit the ramp rate of the generated power to ≤ 10% per min from a 7.2 MW PV array (*PN* = 7.2 MW) for a period of 46 summer days (using 1 s irradiance data) in Sydney, Australia (adapted from Jiang et al.1). Note the compliance (%) was calculated as the percentage of power ramps over the total time (including day and night) where the power ramping was limited to within the 10% min-1 target.

Table S1. Theoretical gravimetric and volumetric capacity of different anode materials.

|  |  |  |  |
| --- | --- | --- | --- |
| Anode Material | Densitya(g cm–3) | *n*b | Theoretical Capacity |
| Gravimetric (mAh g–1) | Volumetric (mAh cm–3) |
| Graphite (C6) | 2.27 | 1 | 372 | 843 |
| Li4Ti5O12 | 3.42 | 3 | 175 | 611 |
| TiO2 (Rutile) | 4.13 | 1 | 335 | 1384 |
| TiO2 (Brookite) | 3.99 | 1 | 335 | 1337 |
| TiO2 (Anatase) | 3.79 | 1 | 335 | 1270 |
| TiO2 (Bronze) | 3.64 | 1 | 335 | 1219 |
| TiNb2O7  | 4.29 | 3/5 | 233/388b | 998/1663 b |
| Ti2Nb10O29 | 4.43 | 12/22 | 216/396 b  | 957/1755b |
| TiNb24O62 | 4.54 | 25/49 | 205/402b | 930/1824b |

aSingle crystal densities are listed for each material. Practical electrode densities are a function of particle size/morphology and electrode preparation.

bWhere two values are given, the value on the left is calculated for the one electron reduction of Ti4+/Ti3+ and Nb5+/Nb4+; the value on the right corresponds to the one electron reduction of Ti4+ to Ti3+ and the two electron reduction of Nb5+ to Nb3+ as is increasingly common in the literature.

**References**

1. Jiang, Y., Fletcher, J., Burr, P., Hall, C., Zheng, B., Wang, D.-W., Ouyang, Z. and Lennon, A.: Suitability of representative electrochemical energy storage technologies for ramp-rate control of photovoltaic power. *J. Power Sources*  **384**, 396-407 (2018).