Plasma-Assisted Surface Modification on $TiNb_2O_7$ Anode for High-Rate Lithium-Ion Battery

T.-Y. Lin[1], C.-Y. Wu[1], M. Hori[2], J.-G. Duh[1]

[1] Department of Materials Science and Engineering, National Tsing Hua University, [2] Center for Low-temperature Plasma Sciences (cLPS), Nagoya University

e-mail (speaker): tzuying.lin@mx.nthu.edu.tw

This study explores the use of atmospheric pressure plasma jet (APPj) treatment to optimize the performance of TiNb2O7 (TNO) as an anode material for lithium-ion batteries. Renowned for its high theoretical capacity (~387 mAh/g) and outstanding safety features,[1] TNO shows great potential but faces practical limitations such as low electrical conductivity and unstable interfaces. Recognized for its versatility across various applications of APPj,[2] it is presented in this work as an effective method for simultaneously improving the properties of TNO, conductive carbon, and the PVDF binder.

The APPj treatment significantly improves electrochemical performance by introducing N-doping on conductive carbon, enhancing electrolyte wettability on the PVDF binder, and creating beneficial defects in the $TiNb_2O_7$ material. Notably, the APPj-treated sample (APP-10) demonstrates exceptional high-rate capability, achieving over 200% improvement at 10 C compared to the untreated sample (APP-0). This remarkable fast-charging performance highlights the synergistic effects of the modified components. Furthermore, protective layers such as Li_3N or LiN_xO_y formed during cycling enhance ionic conductivity and interface stability. This approach using N_2/Air plasma offers a scalable, roll-to-roll modification method without complex synthesis, paving the way for practical applications of plasma technology in energy storage materials and cost-effective lithium-ion battery manufacturing.

References

[1] Han, J. T., & Goodenough, J. B. (2011). 3-V full cell performance of anode framework $TiNb_2O_7$/spinel $LiNi_{0.5}Mn_{1.5}O_4$. *Chemistry of materials*, ***23***(15), 3404-3407.

[2] Ito, M., Oh, J. S., Ohta, T., Shiratani, M., & Hori, M. (2018). Current status and future prospects of agricultural applications using atmospheric-pressure plasma technologies. *Plasma Processes and Polymers*, ***15***(2), 1700073.

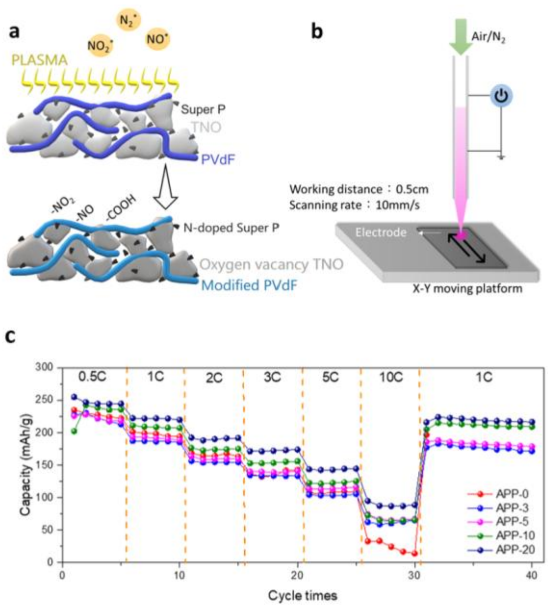

Figure 1 The scheme diagram of (a) surface surgery on $TiNb_2O_7$ electrode *via* N_2 /air atmospheric pressure plasma jet, and (b) the set-up of atmospheric pressure plasma jet device. (c) C-rate performance of of APP-0, APP-3, APP-5, APP-10 and APP-20.