High Performance Electrocatalyst for Vanadium Redox Flow Battery

A. Di Blasi, C. Busacca, O. Di Blasi, G. Giacoppo, N. Briguglio, V. Antonucci

CNR-Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano" (ITAE),

Salita S. Lucia sopra Contesse, 5 - 98126 Messina, Italy

Abstract

Vanadium Redox Flow Batteries (VRFBs) represent a valid and promising energy storage system to support the growing of renewable energy sources. Several limits are mandatory to overcome in order to push towards a concrete introduction of the technology into the market. The developing of cost-effective materials having a high electrocatalytic activity play a fundamental role to enhance the charge-discharge current density during the cycles. The aim is reducing the potential losses improving the power density for a reduction of stack cost for kW [1-6]. A composite material based on nickel manganite and carbon nanofibers ($NiMn_2O_4$/CNF) is synthesized by electrospinning method and characterized in a single cell configuration to evaluate the electrochemical parameters at very high current density values. An energy efficiency (EE) of about 68% with corresponding deep of discharge (DoD) of about 55% at 500 mA/cm^2 was recorded. A significant power density at very high current density was achieved, 550 mW/cm^2 at 500 mA/cm^2. The obtained performance means an enhancement of about 5 times higher, with respect to the state of the art. This can be ascribed to the surface morphology and ternary spinel structure properties of the synthesized $NiMn_2O_4$/CNF [7-9], structural defects and the presence of hydroxyl (OH), carboxyl (COOH) and nitrogen functional groups. The remarkable performance represents a strong contribution towards the material optimization contributing to the massive introduction of the technology into the market.

Reference

[1] Y. Gao, H. Wang, Q. Ma, A. Wu, W. Zhang, C. Zhang, Z. Chen, X. Zeng, X. Wu, Y. Wu, Carbon sheet-decorated graphite felt electrode with high catalytic activity for vanadium redox flow batteries, Carbon. 148 (2019) 9–15. doi:10.1016/j.carbon.2019.03.035.

[2] M. Ulaganathan, V. Aravindan, Q. Yan, S. Madhavi, M. Skyllas-kazacos, T.M. Lim, Recent Advancements in All-Vanadium Redox Flow Batteries, Adv. Mater. Interfaces 3, (2016) 1–22. doi:10.1002/admi.201500309

[3] A. Parasuraman, T. Mariana, C. Menictas, M. Skyllas-kazacos, Review of material research and development for vanadium redox flow battery applications, Electrochim. Acta. 101 (2013) 27–40. doi:10.1016/j.electacta.2012.09.067.

[4] X. Zhang, Q. Wu, Y. Lv, Y. Li, X. Zhou, Binder-free carbon nano-network wrapped carbon felt with optimized heteroatom doping for vanadium redox flow batteries, J. Mater. Chem. A. 7 (2019) 25132–25141. doi:10.1039/c9ta08859h.

[5] Q. Wu, Y. Lv, L. Lin, X. Zhang, Y. Liu, X. Zhou, An improved thin-film electrode for vanadium redox flow batteries enabled by a dual layered structure, J. Power Sources. 410–411 (2019) 152–161. doi:10.1016/j.jpowsour.2018.11.020.

[6] M.A. Aziz, S. Shanmugam, Zirconium oxide nanotube–Nafion composite as high performance membrane for all vanadium redox flow battery, J. Power Sources. 337 (2017) 36–44. doi:10.1016/j.jpowsour.2016.10.113.

[7] A. Di Blasi, O. Di Blasi, N. Briguglio, A.S. Aricò, D. Sebastián, M.J. Lázaro, G. Monforte, V. Antonucci, Investigation of several graphite-based electrodes for vanadium redox flow cell, J. Power Sources. 227 (2013) 15–23. doi:10.1016/j.jpowsour.2012.10.098.

[8] M.A. Aziz, S.I. Hossain, S. Shanmugam, Hierarchical oxygen rich-carbon nanorods: Efficient and durable electrode for all-vanadium redox flow batteries, J. Power Sources. 445 (2020) 227329. doi:10.1016/j.jpowsour.2019.227329.

[9] K. Ketpang, B. Son, D. Lee, S. Shanmugam, Porous zirconium oxide nanotube modified Nafion composite membrane for polymer electrolyte membrane fuel cells operated under dry conditions, J. Memb. Sci. 488 (2015) 154–165. doi:10.1016/j.memsci.2015.03.096.

ACKNOWLEDGEMENTS

Authors from CNR-ITAE acknowledge the financial support from “Ministero dello Sviluppo Economico – Accordo di Programma MiSE-CNR per “la Ricerca di Sistema elettrico Nazionale”. (PTR 2019-2021).