5th International Workshop on Functional Nanostructured Materials (FuNaM-5)

September 24th – 26th, 2025, Krakow, Poland

Electrochemical capacitors for flexible energy storage applications

Chandini Kumar[1] Shahina Shareef[2], Amrita Jain[1*], Libu Manjakkal[2*]

[1]Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland.2
[2]School of Computing and Engineering & the built environment Edinburgh Napier University, Merchiston Campus, EH10 5DT, Edinburgh, UK
Presenting Author: ckumar@ippt.pan.pl,
Corresponding author e-mail: ajain@ippt.pan.pl , L.Manjakkal@napier.ac.uk

INTRODUCTION

The rise of transparent and flexible electronics has driven interest in wearable devices [1], soft robotics [2], and e-skin [3]. Transparent energy storage devices are key to these applications, requiring high optical clarity and stable electrochemical performance [4]. Electrochemical capacitors are promising due to their ion-electron interaction-based operation. However, achieving high ionic conductivity and mechanical flexibility in transparent electrolytes remains a challenge. This work focuses on designing flexible transparent electrochemical capacitors (TECs) using hydrogel-based gel electrolytes and ITO electrodes.

EXPERIMENTAL

TECs were fabricated using ITO-coated PET substrates (>90% transparency, 0.0001 $\Omega\cdot cm^{-1}$ sheet resistance) and NaCl/PVA, KCl/PVA, and LiCl/PVA gel polymer electrolytes (1:1 ratio). The gel electrolytes served as both ionic conductors and separators. Electrochemical properties were studied via CV and GCD, and optical transparency was evaluated using UV-Vis spectroscopy.

RESULTS AND DISCUSSION

LiCl/PVA and KCl/PVA gel electrolytes exhibited excellent optical transmittance (~98–100%) across the visible range, while NaCl/PVA showed slightly lower values (~95–99%). Among the samples, KCl/PVA demonstrated the highest ionic conductivity (98.8 mS/cm). Electrochemical impedance spectroscopy revealed solution resistance values of 12.17, 25.8, and 15.72 $\Omega\cdot cm^2$ for NaCl, KCl, and LiCl-based gels, respectively. Cyclic voltammetry indicated diffusion-controlled charge storage in LiCl-based devices (slope = 0.44), and its optical bandgap was determined to be 5.37 eV.

CONCLUSIONS

Among the tested systems, the TEC employing the LiCl/PVA gel electrolyte demonstrated superior electrochemical and optical performance. It achieved a specific capacitance of 6.61 mF cm^{-2} at a current density of 10 μA cm^{-2} and a total charge contribution of 4.59 mC cm^{-2}, attributed predominantly to diffusion-controlled processes. The electrolyte exhibited 99% transparency at 550 nm and a direct optical bandgap of 5.34 eV, making it highly suitable for transparent energy storage applications.

[More details will be presented at the conference.]

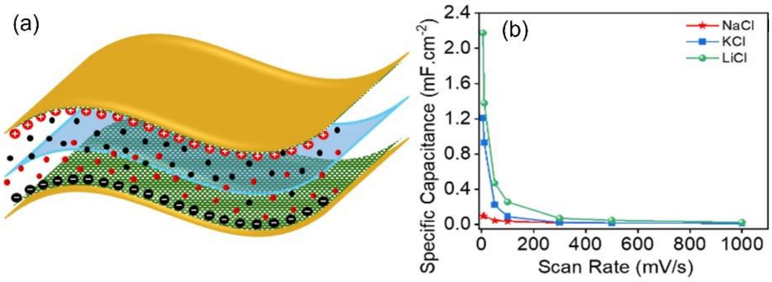

Fig. 1. (a) Schematic illustration of the TEC (b) Variation of specific capacitance with scan rate

Acknowledgements

CK received financial supported by NCBR, Poland; Project number: V4-Japan/2/17/AtomDeC/2022

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