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Nafion/PVDF membranes with enhanced through-plane conductivity

Ariel Odess

MSc Seminar

Advisor: Prof. Slava Freger
Department of Chemical Engineering, Technion-Israel Institute for Technology

Fuel cell (FC) is the most attractive alternative for the inefficient and pollute combustion systems. In commonly used FCs, polymer electrolyte membrane (PEM) serve as a selective barrier between the cathode and anode compartments, conducting ions but blocking passage of electrons and fuel. High conductivity together with chemical, thermal and mechanical stability are desired for reliable and durable FC operation. Nafion, perfluoro-sulfonic acid material, is the benchmark PEM, owing to its highly stable Teflon-like backbone and superior conductivity, originating from the sufonic groups forming conductive ionic microphase in the hydrated state. Structural studies show the conductive microphase in Nafion assumes rod- or ribbon-like morphology and produce well-connected network of elongated conductive channels.

A possibility to enhance Nafion conductivity by aligning the channels in a specific direction has been widely explored. In-plane membrane stretching was shown to produce a significant enhancement of in-plane conductivity, well correlated with SAXS analysis, showing channel alignment in anisotropic manner. A similar conductivity enhancement was achieved in nanofibers produced by electric field-driven stretching using electrospinning, which could be fused to produce nanofiber mats with enhanced in-plane conductivity. These studies demonstrated the large potential of channel and fiber alignment for improving membrane in-plane conductivity, yet through-plane conductivity, most desired for FC operations, remains a challenge. The alignment in Nafion was also not long-lasting and hydrated membranes eventually relaxed to isotropic state.

The present study addressed these challenges by combining electrospun Nafion and PVDF nanofibers for confining and stabilizing channel arrangement in a composite Nafion-PVDF structure. In addition, we applied unique mechanical folding and compression to achieve desired trough-plane orientation. The alignment in the new membrane as well as an in-plane aligned reference Nafion-PVDF membrane and pure Nafion membranes was verified with X-ray diffraction as well as by SEM and TEM. The influence of the orientation on conductivity was confirmed by measuring in-plane and through-plane conductivity in all membranes using impedance spectroscopy