New Proton Conductive Composite Materials with Co-continuous Phases Using Functionalized and Crosslinkable TFE/VDF Fluoropolymers

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Project Objective

Develop a new composite membrane material with hydrophilic inorganic particles as a major component and TFE/VDF polymers as a matrix to be used in a PEMFC in temperature range of -20 to 120°C and relative humidity range of 25-50%.
Three research groups will be involved in a loop of continuous synthesis and serial testing until the final product meets the target requirements.
Approach

• We will synthesize a poly[vinylidene fluoride]-based polymer with chain–end functional groups which is highly compatible with the inorganic surfaces.

• We will synthesize a number of highly hydrophilic proton conductive inorganic materials such as structured metal phosphates, mesoporous oxides, etc.

• We will develop an approach to incorporate high loads of hydrophilic inorganic particles into the polymer.
Anticipated Structure of Inorganic/Polymer Composite

- ~ ~ ~ : Teflon-segment
- G : Crosslinker (C-Si-C or C-Si-O-Si-C)
- Y : Polar functional group
- : Proton-conducting material
In our preliminary study, an inorganic/organic composite membrane containing 60% of 3-D structured H$_3$OZr$_2$(PO$_4$)$_3$ and 40% of functionalized poly[vinylidene fluoride] with Si-terminal groups and Si-OH functional groups was fabricated.

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<tr>
<th>T, °C</th>
<th>Water uptake, wt.%</th>
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<tbody>
<tr>
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<td>New composite material</td>
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<tr>
<td>23</td>
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<table>
<thead>
<tr>
<th>T, °C</th>
<th>Conductivity in Water, S/cm</th>
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<tbody>
<tr>
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<td>New composite material</td>
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<tr>
<td>120</td>
<td>0.07</td>
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<tr>
<td>140</td>
<td>0.1</td>
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In contrast to Nafion, the composite membrane’s conductivity continued to grow as temperature increased from 120 to 140°C. At 140°C, it reached the same value as conductivity of a Nafion membrane. The new membrane has a very low water uptake.
SEM images of the new 60% $\text{H}_3\text{OZr}_2(\text{PO}_4)_3$ / 40% PVDF(Si) membrane: (a) and (b) show the surface on the opposite sides of the membrane and (c) is the cross-sectional image.

Based on the surface images the distribution of inorganic particles (300-500 nm in size) inside the membrane is uniform.