Improving dielectric permittivity by incorporating PDMS-PEG multi block copolymer into PDMS network

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Improving dielectric permittivity by incorporating PDMS-PEG multi block copolymer into PDMS network

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Outline

• INTRODUCTION:
  – Dielectric electroactive polymer (DEAP).
  – Poly(dimethylsiloxane) (PDMS) versus Poly(ethylene glycol) (PEG)
  – Morphology of block copolymer and phase continuity
  – Experimental setup and characterization methods

• RESULTS
  – Properties of PDMS-PEG multi block copolymer
  – Binary polymer blends of PDMS-PEG block copolymer and commercial PDMS elastomer

• CONCLUSION
Principal of DEAP material
PDMS versus PEG

PDMS

- Hydrophobic
- Low surface energy
- Low conductivity
- Wide temperature range
- High stability
- Low modulus
- Low permittivity

PEG

- Hydrophilic
- High surface energy
- Low toxicity
- High mobility in solution
- High permittivity
- High Conductivity
Morphology in block copolymer (AB) \(^1, \, 2\)

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Phases in polymer blend

Sequence(s) of project

1<sup>st</sup> step - synthesize PDMS-PEG prepolymer

2<sup>nd</sup> step - Blending PDMS-PEG block copolymer with commercial PDMS elastomer

3<sup>rd</sup> step - crosslinking with methylhydrosiloxane-dimethylsiloxane copolymer (HMS-501)
## Experimental setup

<table>
<thead>
<tr>
<th>PDMS Hydride-terminated</th>
<th>Reactant</th>
<th>Average number of molecular weight $M_n$ [g/mol]</th>
<th>No. of repeating units - reactant- ($N$)</th>
<th>No. of repeating units - block copolymer- ($X$)</th>
<th>Stoichiometry ratio $(r)$</th>
<th>Volume fraction of PDMS $(f_A)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PEG-DE</td>
<td>250,00</td>
<td>4</td>
<td>6</td>
<td>1,21</td>
<td>0,94</td>
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<tr>
<td>H21</td>
<td>PDMS Hydride-terminated</td>
<td>6000,00</td>
<td>81</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEG-DE</td>
<td>250,00</td>
<td>4</td>
<td>24</td>
<td>1,04</td>
<td>0,75</td>
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<td>H11</td>
<td>PDMS Hydride-terminated</td>
<td>1050,00</td>
<td>14</td>
<td>23</td>
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</tr>
<tr>
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<td>38</td>
<td>1,03</td>
<td>0,62</td>
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<td>H03</td>
<td>PDMS Hydride-terminated</td>
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<tr>
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<td>57</td>
<td>1,02</td>
<td>0,45</td>
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<tr>
<td>SIH</td>
<td>PDMS Hydride-terminated</td>
<td>208,00</td>
<td>3</td>
<td>56</td>
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</tr>
</tbody>
</table>
Characterization

1. Chemical reaction
   • NMR (Si-H ~ 4.70ppm)

2. Mechanical properties
   • LVE properties.
   • Parallel plate (25 mm)

3. Electrical properties
   • Dielectric properties
   • 20 mm electrode

4. Contact angle
   • Sessile method
   • Static contact angle

1. Bruker 300 MHz NMR
2. Rheometer (ARES-G2)
3. Novocontrol GmbH
4. Dataphysics OCA20
Result: Block copolymer (H21, H11, H03, SIH)
Contact angle for all block copolymer

Comparison of contact angle between pure PDMS (Wacker) and PDMS-PEG block copolymers

- MJK 4/13 A & B
- PDMS-PEG (SIH6117.0)
- PDMS-PEG (H03)
- PDMS-PEG (H11)
- PDMS-PEG (H21)
Comparison of **Permittivity** among H21, H11, H03 and SIH
Comparison of Conductivity among H21, H11, H03 and SIH

![Graph showing the comparison of conductivity among different materials](image)

- **Conductivity, \( \sigma \) (S/cm)**
- **Frequency (Hz)**

Materials:
- PDMS-PEG H21
- PDMS-PEG H11
- PDMS-PEG H03
- PDMS-PEG SIH
Comparison of modulus among H21, H11, H03 and SIH
Result: Binary polymer blend of PDMS-PEG block copolymer and commercial PDMS elastomer
Comparison of permittivity for PDMS-PEG (H03) with commercial PDMS elastomer
Comparison of **conductivity** for PDMS-PEG (H03) with commercial PDMS elastomer
Comparison of **modulus** for PDMS-PEG (H03) with commercial PDMS elastomer
Conclusion

- PDMS-PEG is a conductive block copolymer (10^{-8} S/cm) with amphiphilic behaviour.
- Incorporating PDMS-PEG (H03) with commercial PDMS elastomer:
  - Improve storage permittivity up to 60% with low loss permittivity.
  - Maintain LVE properties compared to the commercial.
  - Has amphiphilic behaviour (contrast with PDMS elastomer).
Thank you

DPP Group