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\textsuperscript{st} step - synthesize PDMS-PEG prepolymer

2\textsuperscript{nd} step - Blending PDMS-PEG block copolymer with commercial PDMS elastomer

3\textsuperscript{rd} 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>H21</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></td>
<td>PDMS Hydride-terminated</td>
<td>6000,00</td>
<td>81</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H11</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>1050,00</td>
<td>14</td>
<td>23</td>
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<tr>
<td>H03</td>
<td>PEG-DE</td>
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<td>38</td>
<td>1,03</td>
<td>0,62</td>
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<tr>
<td>SIH</td>
<td>PEG-DE</td>
<td>250,00</td>
<td>4</td>
<td>57</td>
<td>1,02</td>
<td>0,45</td>
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<td>56</td>
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</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 (SIH617.0)
- 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

![Conductivity comparison graph](image-url)

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