Enhancing the electro-mechanical properties of polydimethylsiloxane elastomers through blending with poly(dimethylsiloxane-co-methylphenylsiloxane) copolymers

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Enhancing the electro-mechanical properties of polydimethylsiloxane elastomers through blending with poly(dimethylsiloxane-co-methylphenylsiloxane) copolymers

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Abstract

Dielectric elastomers (DE) hold great promise as materials for novel, advanced electromechanical applications such as actuators, generators and sensors. Choosing the right polymer for the blending approach is of utmost importance to improve the electro-mechanical properties of DEs. In this study, our laboratories shows that sub-percentage additions of various aromatic substances can increase electrical breakdown strength significantly via voltage stabilisation, due to an electron trapping effect. In this work, improved electro-mechanical properties of silicon-based dielectric elastomers were achieved by means of adding so-called "voltage-stabilisers" prepared from phenyl-functional copolymers prepared using anionic ring-opening polymerisation of octamethylcyclotetrasiloxane (OD4) and either tetramethyldicyclosiloxane (T4) or octaphenylcyclooctasiloxane (OD4). The concentration of the voltage stabiliser was varied both by changing the molar ratio between methyl and phenyl groups in the copolymer and also by varying the amount of copolymer mixed into a polydimethylsiloxane (PDMS) based elastomer. The phenyl-functional copolymers were generally found to disperse homogeneously in the PDMS matrix and this resulted in networks with improved mechanical and electrical properties.

Keywords: electro-mechanical properties, silicone dielectric elastomer, voltage stabiliser, phenyl functionalised copolymer, blend

1. Introduction

Fig.1 Unpolarised dipoles randomly aligned in the elastomer matrix.

Fig.2 Re-orientation of polarised dipoles in the elastomer matrix.

Fig.3 The enhancement of electrical breakdown strength due to electron-trapping: (a) a silicone elastomer with an aromatic group pre-functionalised with an electron donor group, leading to the disorientation of the cloud of dipoles around the elastomer, and a phenyl group (b) The formation of cationic radicals resulting from the disturbance of the cloud of dipoles about the aromatic group.

2. Experimental

Fig.4 Anionic Ring-Opening Polymerisation of octamethylsiloxanes in the presence of N,N-dimethylformamide as a polymerisation promoter.

Fig.5 Cross-linked elastomer consisting of phenyl-PDMS copolymer in PDMS matrix and structures of the added phenyl-PDMS copolymers.

3. Results

Fig.6A. Normalised 1H NMR spectra in the range 0.1 - 3 ppm for D4 (yellow), T4 (purple), PDMS 5120 (black), 126DMS_2PMS (blue) and PDT_525 (red).

Fig.6B. FTIR spectra of PD, PDT_5050 and PDT_7525 showing through-space correlations between aromatic protons and methyl protons.

4. Conclusions

The developed elastomers were inherently extensible with enhanced tensile and tear strengths, due to phenyl-rich microphases acting as reinforcing domains. Furthermore, addition of phenyl-functional copolymers resulted in elastomers with increased relative permittivity and electrical breakdown strength compared to control elastomers while retaining a low dielectric loss. This demonstrates their efficiency as voltage stabilisers.

Table 1 Overall properties of the elastomers

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Composition</th>
<th>Theoretical phenyl concentration (mol %)</th>
<th>Gel fraction (%)</th>
<th>Cure (Cure Rate)</th>
<th>Viscous loss measured at 2% strain and 0.01 Hz</th>
<th>Mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDMS 5120</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>PDT_525</td>
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<tr>
<td>V31 + 5 phr PDMS 5120</td>
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<td>0.47</td>
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<td>0.25</td>
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Acknowledments

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References