Glycerol-silicone foams - Tunable 3-phase elastomeric porous materials

The time- and cost-efficient production of silicone foams is one of the main challenges of a silicone industry seeking to make these products more competitive compared to traditional foams. Current methods are either too expensive, environmentally harmful or do not provide sufficient control over the foaming process, and therefore intensive research efforts have been launched to tackle this problem. Herein, we present a simple, cheap and environmentally friendly method for preparing a 3-phase silicone-based porous material, the production of which involves a commercial silicone composition, glycerol (waste from bio-diesel production), and an inorganic base. The developed system allows for the precise tuning of foam density and its mechanical properties, thereby creating a robust platform for preparing well-defined porous silicone products.
Broadly, for wounds to heal, a moist, clean and warm environment is required. A moist wound bed easily promotes growth factors and many cell types including epithelial cells to migrate, facilitating wound edge contraction. Thus, appropriate dressings play a significant role to create and maintain such environment. [1] Silicone adhesives are silicone elastomers which are not fully crosslinked but remain close to the gelation threshold (i.e. with a low crosslinking degree). [2, 3] Within the field of advanced wound care, silicone adhesives are currently the preferred, state-of-the-art adhesive system due to its gentle skin adhesion properties. However, due to their hydrophobic nature, current silicone adhesives for wound care face challenges when it comes to moisture handling. Here, we propose a novel, skin-friendly, industrially relevant glycerol-silicone hybrid adhesive with improved moisture handling due to the incorporation of emulsified glycerol (Figure 1). Various parameters will be taken into account in order to develop a relevant adhesive, in particular glycerol content,
glycerol domain size and adhesive thickness to allow for a controlled moisture absorption.

**Advanced Wound Care Adhesives with New Functional Properties**

Wound healing is a dynamic process characterized by three overlapping cellular phases: inflammation, new tissue formation, and remodeling. Chronic wounds, which are often manifested in elderly and diabetic patients, result from anomalies in the cellular and molecular wound repair mechanism. Such wounds can lead to significant disability, amputation and increased mortality. The understanding of the normal wound healing mechanism and the consideration of the complexity of the wound environment, given by, e.g., hypoxia or bacterial infections, are crucial factors in order to develop an effective therapeutic approach.

Systemic drug delivery systems, such as oral and intravenous delivery, are the most common routes for drug administration. Nevertheless, these routes are characterized by several significant drawbacks. For instance, systemic delivery requires an appropriate blood perfusion of the target tissue, often insufficient in chronic wounds, and carries with it a high risk for systemic toxicity, which can limit dosing and duration of the medical treatment. Therefore, localized drug delivery is a promising approach to improve bioavailability and maintenance of a therapeutic drug concentration, while minimizing systemic drug toxicity.

Here, we propose a novel, skin-friendly, industrially relevant silicone/glycerol hybrid adhesive with new functional properties, including: improved moisture handling due to the incorporation of emulsified glycerol and dispersion of active compounds by glycerol-embedding. This particular matrix paves the way for an innovative drug delivery system. Various parameters will be taken into account in order to develop a relevant adhesive, in particular glycerol content, glycerol domain size and adhesive thickness.
Deeper Insight into the Dielectric Breakdown of Elastomers

Dielectric elastomers find more and more uses but nevertheless the fundamentals behind the electrical breakdown of these thin and elastic films are still not fully understood and elucidated. Dielectric breakdown strength measurement is one of the most common methods to evaluate stability of polymers in an electric field. This breakdown test has been extensively used over many years and is still gaining on importance, due to an increasing demand on novel polymeric materials applied in high electric fields, such as: dielectric or transport layers, modern devices or flexible electronics[1]. There are only few theoretical models that assess the physical processes occurring during a breakdown phenomenon, for example: the hole-induced breakdown model, the electron-trapping breakdown model, the resonant-tunneling-induced breakdown model and the filamentary model [2]. All these theories consider movements of electrons from electrodes to polymer film samples. Other theory is the so-called electro-mechanical model [3]. It implies, that polymer films are not always smooth, and when an electric field is applied, the force gets bigger at the thinnest spot of the film. For that reason the film sample starts to deform and when electric strength is reached at the thinnest spot, breakdown occurs [3]. This is also referred to as electro-mechanical instability (EMI) and has been extensively studied by modelling [4]–[6]. In this work a high-speed camera is used in order to capture macroscopic processes taking place during the dielectric breakdown to verify if the time-scale and behavior of the electrical breakdown can elucidate the underlying behavior.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Vaicekauskaite, J., Mazurek, P., Yu, L., Skov, A. L.
Number of pages: 1
Publication date: 2018
Peer-reviewed: Yes
Event: Abstract from MRS Spring meeting 2018, Phoenix, United States.
Electronic versions:
2._MRS_SPRING2018._Justina_Vaicekauskiate.pdf
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2018

Designing reliable silicone elastomers for high temperature applications

Silicone elastomers find application in fields ranging, for instance, from soft robotics and electronic skin, to the automotive and the aerospace industries. In addition, the high dissociation energy and the low energy barrier to rotation of the siloxane bond make silicone elastomers suitable for high temperature applications.[1,2] Reliability and durability are strict requirements for silicone elastomers employed in high temperature applications, and significant effort has been invested by the industrial and the scientific communities into improving their thermal stability. Exploiting traditional methods, such as adding heat-resistant fillers or chemical modifications, still suffer from remarkable shortcomings. Therefore, developing cheap and easy solutions to improve thermal stability of silicone elastomer is a major challenge. This study focuses on determining the role of network structure on the thermal degradation of silicone elastomers.[3] Elastomers with different stoichiometric ratios were synthesized to vary the relative fractions of elastic, dangling, and sol structures. Thermogravimetric analysis was used to investigate the thermal degradation behaviour of the silicone elastomers synthesized with different cross-linking densities and to analyse their thermal degradation products. Here, we demonstrate how to optimize the stoichiometric ratio used to prepare silicone elastomers in order to enhance their thermal stability by simple means.

General information
State: Published
Organisations: The Danish Polymer Centre, Department of Chemical and Biochemical Engineering
Contributors: Ogliani, E., Yu, L., Mazurek, P., Skov, A. L.
Number of pages: 1
Publication date: 2018
Peer-reviewed: Yes
Electronic versions:
Elisa_Ogliani_Abstract_PolyMac.pdf
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2018
Designing reliable silicone elastomers for high-temperature applications
Reliability and durability are strict requirements for silicone elastomers employed in high-temperature applications, if long-time device performance is desired. Improving the thermal stability of silicone elastomers is a major challenge, addressed by both the scientific and the industrial community. Nevertheless, traditional methods such as adding heat-resistant fillers or chemical modifications still suffer from considerable shortcomings. Here, it is demonstrated that the thermal degradation behavior of silicone elastomers is affected strongly by network reactant stoichiometry. Comparative thermal degradation studies were performed on silicone elastomers synthesized with different stoichiometric ratios—and thereby different fractions of elastic, dangling, and sol structures. With the reported findings, we demonstrate how to optimize the stoichiometric ratio used to prepare silicone elastomers, in order to enhance their thermal stability by simple means in high-temperature applications.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Ogliani, E., Yu, L., Mazurek, P., Skov, A. L.
Pages: 175-180
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Polymer Degradation and Stability
Volume: 157
ISSN (Print): 0141-3910
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.59 SJR 1.041 SNIP 1.44
Web of Science (2017): Impact factor 3.193
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.57 SJR 1.056 SNIP 1.577
Web of Science (2016): Impact factor 3.386
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.48 SJR 1.209 SNIP 1.62
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.37 SJR 1.282 SNIP 1.89
Web of Science (2014): Impact factor 3.163
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 3.35 SJR 1.336 SNIP 2.102
Web of Science (2013): Impact factor 2.633
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 3.25 SJR 1.411 SNIP 2.086
Web of Science (2012): Impact factor 2.77
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 3.17 SJR 1.346 SNIP 2.075
Web of Science (2011): Impact factor 2.769
Glycerol-silicone elastomers as active matrices with controllable release profiles

Drug release regimes must be controlled for optimal therapeutic effect. While it is relatively straightforward to create first order release matrices, it can be challenging to avoid an initial burst. Matrices with zero-order profiles are perceived to be beneficial in many cases, but are even more difficult to formulate. We describe the straightforward synthesis of elastomeric composites prepared from silicone in which the active is dispersed in glycerol. The release of glycerol-soluble actives from films of these materials was shown to be tunable with respect to the order of release (zero- or first-order) simply by changing glycerol content. Importantly, release from the elastomers showed no burst effect. The discrete glycerol domains embedded within a silicone matrix act as reservoirs for active substances. Upon contact with aqueous media the active substances are released from matrices exhibiting zero-order, near zero-order or first-order release kinetics. Various parameters that could influence the release process include glycerol content, glycerol domain size or membrane thickness are thoroughly investigated, elucidating guidelines for creating matrices capable of delivering active substances at desired rates. Additionally, the composites proved to absorb significant amounts of liquid water (up to 1850 % of sample mass), a feature that can be tuned by manipulation of the composite structure.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Mazurek, P., Brook, M. A., Skov, A. L.
Number of pages: 8
Pages: 11559-11566
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Langmuir
Volume: 34
Issue number: 38
Glycerol-silicone elastomers as active membranes for wound dressings and beyond

A green and cheap silicone-based elastomer has been developed.1,2 Through the simple mixing-in of biodiesel-originating glycerol into commercially available polydimethylsiloxane (PDMS) pre-polymer, a glycerol-in-silicone emulsion was produced. This counterintuitively stable mixture became a basis for obtaining elastomeric composites with uniformly distributed glycerol droplets. Various compositions, containing from 0 to 140 parts of glycerol per 100 parts of PDMS rubber by weight, were prepared and investigated in terms of mechanical properties as well as optical and scanning electron microscopy. The materials were proven additionally to exhibit a strong affinity to water, which was investigated by simple water absorption tests. Incorporating glycerol into PDMS decreased the Young’s modulus of the composites yet the ultimate strain of the elastomer was not compromised, even in the presence of very high loadings. The conducted experiments highlight the great potential of this new type of elastomer and reveal some possible applications especially in biomedical industry where controlled and tunable drug delivery is one of the requirements. This hybrid material was also adopted to produce glycerol-silicone elastomeric foams with adjustable densities, morphologies and mechanical properties creating a new platform for drug delivery devices.

Glycerol-silicone elastomers – current status and perspectives

Glycerol and silicone pre-polymer are two virtually immiscible liquids. However when sufficiently high shear forces are applied to a mixture of both then the glycerol phase breaks down to micro-size droplets evenly distributed within the silicone pre-polymer phase thus a glycerol-in-silicone emulsion is produced. Upon cross-linking of the silicone pre-polymer free-standing silicones with incorporated glycerol droplets are obtained as shown in Figure 1.1,2 Interestingly, mechanical properties of these composites are not compromised as the glycerol loading increases. Glycerol-silicone elastomers became a platform for creating multiple functional smart materials, e.g. drug delivery wound care membranes, silicone foams, water absorbing silicones and magnetochromic films. Here some of the most interesting examples of glycerol-silicone elastomers applications will be presented and briefly explained elucidating the great potential of this counterintuitive composition.
Insight into the Dielectric Breakdown of Elastomers

Nowadays, dielectric elastomers are used in many different fields, such as: dielectric or transport layers, modern devices or flexible electronics [1]. To test dielectric elastomer stability in electric field, dielectric breakdown measurements are used. These measurements have been used over many years and still gaining on importance, however, fundamentals behind the electrical breakdown of thin and elastic films are still not fully understood and elucidated.

There are only few theoretical models that assess the physical processes occurring during a breakdown phenomenon, for example: the hole-induced breakdown model, the electron-trapping breakdown model, the resonant-tunneling-induced breakdown model and the filamentary model [2]. In all these theories, electrons movements from electrode to polymer film samples are considered. Other theory is the, so-called, electro-mechanical model, which implies that polymer films are not always smooth, and when an electric field is applied, the force gets bigger at the thinnest spot of the film, which causes the deformation of a film. Subsequently, when electric strength is reached at the thinnest spot - breakdown occurs [3]. This is also referred to electro-mechanical instability (EMI) and has been extensively studied by modelling [4]–[7].

In this work, microscopic processes taking place during the dielectric breakdown were captured using high-speed camera, to verify if the time-scale and behavior of the electrical breakdown can elucidate the underlying behavior.

Silicone elastomers and their preparation and use

The present invention relates to an elastomeric composition comprising a silicone rubber, glycerol, at least one crosslinking agent, and optionally one or more excipients, wherein said glycerol is present as discrete droplets in the silicone rubber, obtainable through the application of high shear forces.

Thermal degradation mechanisms of silicone elastomer

Polydimethylsiloxane (PDMS) is the most extensively used polymer among silicones. It finds application in an unlimited number of fields, including use in high temperature environments. PDMS meets these demanding requirements, due to its excellent thermal stability. The thermal degradation of linear PDMS occurs by a molecular mechanism or a radical mechanism depending on the temperature and the heating rate.[1,2] Nevertheless, the thermal degradation of cross-linked
PDMS networks has not been thoroughly investigated yet. In this work, the thermal degradation mechanisms and thermal degradation products of silicone elastomers are studied. Thermogravimetric analysis (TGA) performed in inert atmosphere was carried out on PDMS networks synthesized with different stoichiometric ratios (r). Extraction of the samples was exploited to remove unreacted chains, with the aim of determining to which extent the degradation is influenced by the sol fraction and the amount of dangling chains present in the network (Figure 1). Furthermore, long-term isothermal TGA measurements were performed to recover the degradation products of the thermally treated elastomers. Soluble degradation products were analysed by size exclusion chromatography (SEC), while TGA coupled with FTIR was used to detect the released volatile degradation products.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Ogliani, E., Yu, L., Mazurek, P., Skov, A. L.
Number of pages: 1
Publication date: 2018
Peer-reviewed: Yes
Event: Abstract from 9th European Silicon Days, Saarbrucken, Germany.
Electronic versions:
Ogliani_Elisa_Abstract_9th_European_Silicon_Days.pdf. Embargo ended: 12/09/2018
Research output: Research - peer-review » Conference abstract for conference – Annual report year: 2018

**A simple method for reducing inevitable dielectric loss in high-permittivity dielectric elastomers**
Commercial viability of dielectric elastomers (DEs) is currently limited by a few obstacles, including high driving voltages (in the kV range). Driving voltage can be lowered by either decreasing the Young's modulus or increasing the dielectric permittivity of silicone elastomers, or a combination thereof. A decrease in the Young's modulus, however, is often accompanied by a loss in mechanical stability, whereas increases in dielectric permittivity are usually followed by a large increase in dielectric loss followed by a decrease in breakdown strength and thereby the lifetime of the DE. A new soft elastomer matrix, with high dielectric permittivity and a low Young's modulus, aligned with no loss of mechanical stability, was prepared through the use of commercially available chloropropyl-functional silicone oil mixed into a tough commercial liquid silicone rubber silicone elastomer. The addition of chloropropyl-functional silicone oil in concentrations up to 30 phr was found to improve the properties of the silicone elastomer significantly, as dielectric permittivity increased to 4.4, dielectric breakdown increased up to 25% and dielectric losses were reduced. The chloropropyl-functional silicone oil also decreased the dielectric losses of an elastomer containing dielectric permittivity-enhancing TiO2 fillers. Commercially available chloropropyl-functional silicone oil thus constitutes a facile method for improved silicone DEs, with very low dielectric losses.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Madsen, F. B., Yu, L., Mazurek, P. S., Skov, A. L.
Publication date: 2016
Peer-reviewed: Yes

**Publication information**
Journal: Smart Materials and Structures
Volume: 25
Issue number: 7
Article number: 075018
ISSN (Print): 0964-1726
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.38 SJR 1.152 SNIP 1.474
Web of Science (2017): Impact factor 2.963
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.1 SJR 1.038 SNIP 1.599
Web of Science (2016): Impact factor 2.909
Web of Science (2016): Indexed yes
A recently reported novel class of elastomers was tested with respect to its dielectric properties. The new elastomer material is based on a commercially available poly(dimethylsiloxane) composition, which has been modified by embedding glycerol droplets into its matrix. The approach has two major advantages that make the material useful in a dielectric actuator. First, the glycerol droplets efficiently enhance the dielectric constant, which can reach astonishingly high values in...
the composite. Second, the liquid filler also acts as a softener that effectively decreases the elastic modulus of the composite. In combination with very low cost and easy preparation, the two property enhancements lead to an extremely attractive dielectric elastomer material. Experimental permittivity data are compared to various theoretical models that predict relative permittivity changes as a function of filler loading, and the applicability of the models is discussed. VC 2016 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 2016, 133, 44153.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, University of Potsdam
Contributors: Mazurek, P. S., Yu, L., Gerhard, R., Wirges, W., Skov, A. L.
Number of pages: 8
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Journal of Applied Polymer Science
Volume: 133
Issue number: 43
Article number: 44153
ISSN (Print): 0021-8995
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.87 SJR 0.543 SNIP 0.742
Web of Science (2017): Impact factor 1.901
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.73 SJR 0.588 SNIP 0.792
Web of Science (2016): Impact factor 1.86
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.74 SJR 0.587 SNIP 0.846
Web of Science (2015): Impact factor 1.866
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.76 SJR 0.664 SNIP 0.972
Web of Science (2014): Impact factor 1.768
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.71 SJR 0.629 SNIP 1.085
Web of Science (2013): Impact factor 1.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.57 SJR 0.657 SNIP 1.075
Web of Science (2012): Impact factor 1.395
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.45 SJR 0.604 SNIP 0.969
Web of Science (2011): Impact factor 1.289
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Glycerol as high-permittivity liquid filler in dielectric silicone elastomers

A recently reported novel class of elastomers was tested with respect to its dielectric properties. The new elastomer material is based on a commercially available polydimethylsiloxane (PDMS) composition, which has been modified by embedding glycerol droplets into its matrix. The approach has two major advantages that make the material useful in a dielectric actuator. First, the glycerol droplets efficiently enhance the dielectric constant which can reach very high values in the composite. Second, the liquid filler also acts as a softener that effectively decreases the elastic modulus of the composite. In combination with very low cost and easy preparation, the two property enhancements lead to a very attractive dielectric elastomer material. Experimental permittivity data are compared to various theoretical models that predict relative-permittivity changes as a function of filler loading, and the applicability of the models is discussed.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, University of Potsdam
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Event: Poster session presented at 6th International Conference on Electromechanically Active Polymer (EAP) Transducers & Artificial Muscles, Helsingør, Denmark.
Electronic versions: eaposter_Piotr_Mazurek.pdf
Research output: Research - peer-review › Poster – Annual report year: 2017
Green silicone elastomer obtained from a counterintuitively stable mixture of glycerol and PDMS
A green and cheap silicone-based elastomer has been developed. Through the simple mixing-in of biodiesel-originating glycerol into commercially available polydimethylsiloxane (PDMS) pre-polymer, a glycerol-in-PDMS emulsion was produced. This counterintuitively stable mixture became a basis for obtaining elastomeric composites with uniformly distributed glycerol droplets. Various compositions, containing from 0 to 140 parts of glycerol per 100 parts of PDMS by weight, were prepared and investigated in terms of ATR-FTIR, broadband dielectric spectroscopy, mechanical properties as well as optical and scanning electron microscopy. The materials were proven additionally to exhibit a strong affinity to water, which was investigated by simple water absorption tests. Incorporating glycerol into PDMS decreased the Young's modulus of the composites yet the ultimate strain of the elastomer was not compromised, even in the presence of very high loadings. The conducted experiments highlight the great potential of this new type of elastomer and reveal some possible applications.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Mazurek, P., Hvilsted, S., Skov, A. L.
Pages: 1-7
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Polymer
Volume: 87
ISSN (Print): 0032-3861
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.59 SJR 1.097 SNIP 1.163
Web of Science (2017): Impact factor 3.483
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.77 SJR 1.207 SNIP 1.253
Web of Science (2016): Impact factor 3.684
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.72 SJR 1.144 SNIP 1.277
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.85 SJR 1.326 SNIP 1.613
Web of Science (2014): Impact factor 3.562
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 4.07 SJR 1.414 SNIP 1.649
Web of Science (2013): Impact factor 3.766
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 3.74 SJR 1.589 SNIP 1.777
Web of Science (2012): Impact factor 3.379
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 4.04 SJR 1.623 SNIP 1.797
Web of Science (2011): Impact factor 3.438
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Novel high dielectric constant hybrid elastomers based on glycerol-insilicone emulsions

Novel hybrid elastomers were prepared by speedmixing of two virtually immiscible liquids – glycerol and polydimethylsiloxane (PDMS) prepolymer. Upon crosslinking of the PDMS phase of the resulting glycerol-in-silicone emulsion freestanding films were obtained. In this way glycerol became uniformly distributed within PDMS in shape of discrete droplets thus acting as a high dielectric constant filler efficiently enhancing the dielectric constant of the composites. Low- and high-voltage dielectric spectroscopy measurements were conducted in order to verify applicability of the composites as dielectric elastomer actuators. Conductivities of samples based on various PDMS compositions with different loadings of embedded glycerol were thoroughly investigated providing useful information about the dielectric behavior.
Mechanically invisible encapsulations

Research into dielectric elastomers has intensified within the last two decades, due to the realisation that these materials undergo significant deformations when subjected to high electric fields. High efficiency, lightweight, low-cost and simple working principles are the main advantages of this technology. A major part of the research on dielectric transducers is dedicated to the development of elastomeric membranes that create a basis for each potential application. It has been recognised that higher energy density and more durable materials need to be created in order to enable the commercialisation of such devices. Therefore, this project was dedicated to exploring the possibility of using polar liquids as high dielectric constant fillers for dielectric PDMS-based elastomers. Incorporating polar liquids in the form of discrete droplets into nonpolar membrane was expected to produce a two-fold improvement with respect to a reference material. Firstly, dielectric constant enhancement and, secondly, a Young’s modulus decrease were anticipated. In the first approach a flow-focusing microfluidic technique was employed, in order to encapsulate polar liquids within a soft elastomeric shell. The produced core-shell microspheres served as a carrier for liquids, enabling the uniform dispersion of the filler droplets within PDMS prepolymer. The dielectric constant of the prepared water-PDMS composite was proven to be enhanced by 30% following the incorporation of 4.5 wt.% of water. Due to the favourable structure of the capsules, mechanical properties remained unaffected. Importantly, the approach substantiated the high potential of liquid-PDMS composites for dielectric transducers. In the second part of the study a new method for producing liquid-PDMS composites was developed and thoroughly investigated. Applying very high shear forces to mixtures of PDMS preelastomers and polar liquids facilitated the preparation of stable and uniform emulsions. Upon crosslinking the PDMS (which formed the continuous phase of the emulsions), stable hybridelastomers were obtained. The method allowed for incorporating up to 50% by volume of various liquids, which resulted in significant improvements to the dielectric constant of the composites. An incorporation of 120 wt.% of glycerol increased the dielectric constant of a commercial PDMS composition by 380%. Additionally a three-fold decrease in the elastic modulus was observed. Although the dielectric properties of the composites were very promising, the materials exhibited leakage current at high electric fields. Therefore, further study on improving high-voltage performance was conducted, exhibiting the high potential of the material. The second approach brought a breakthrough in the research on liquid-PDMS composites. The developed technique proved to be very versatile, thereby allowing for the preparation of multiplehybrid materials with very distinct properties – an attractive proposition from the point of view of multiple scientific fields.

Preparing mono-dispersed liquid core PDMS microcapsules from thiol–ene–epoxy-tailored flow-focusing microfluidic devices

An applied dual-cure system based on thiol–ene and thiol–epoxy “click chemistry” reactions was proved to be an extremely effective and easy to use tool for preparing microfluidic chips, thereby allowing for precise control over material properties and providing the possibility of covalently bonding chip wafers. Different thiol–ene–epoxy-based polymer compositions were tested with the help of DSC and ATR FTIR, in order to investigate their physical and chemical properties. Water contact angles were determined, thus verifying the high efficiency and selectivity of the chemical surface modification of compositions in relation to high hydrophilicity and hydrophobicity. An obtained microfluidic device was subsequently used in order to produce PDMS microcapsules of very narrow size distribution and which contained various common liquids, such as water and ethanol, as well as an ionic liquid 2-hydroxyethylammonium formate.
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, Department of Micro- and Nanotechnology
Contributors: Mazurek, P. S., Daugaard, A. E., Skolimowski, M., Hvilsted, S., Skov, A. L.
Pages: 15379-15386
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: RSC Advances
Volume: 2015
Issue number: 5
ISSN (Print): 2046-2069
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.01 SJR 0.863 SNIP 0.736
Web of Science (2017): Impact factor 2.936
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.06 SJR 0.889 SNIP 0.757
Web of Science (2016): Impact factor 3.108
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.42 SJR 0.947 SNIP 0.834
Web of Science (2015): Impact factor 3.289
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.87 SJR 1.113 SNIP 0.962
Web of Science (2014): Impact factor 3.84
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 3.74 SJR 1.119 SNIP 0.904
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): CiteScore 2.4 SJR 0.872 SNIP 0.619
Web of Science (2012): Impact factor 2.562
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
Web of Science (2011): Impact factor
Original language: English
Electronic versions:
RSC_OA_c4ra16255b.pdf
DOIs:
10.1039/C4RA16255B

Bibliographical note
This article is published Open Access as part of the RSC's Gold for Gold initiative, licensed under a Creative Commons Attribution 3.0 Unported Licence.
Research output: Research - peer-review › Journal article – Annual report year: 2015

Novel encapsulation technique for incorporation of high permittivity fillers into silicone elastomers
The research on soft elastomers with high dielectric permittivity for the use as dielectric electroactive polymers (DEAP) has grown substantially within the last decade. The approaches to enhance the dielectric permittivity can be categorized into three main classes: 1) Mixing or blending in high permittivity fillers, 2) Grafting of high permittivity molecules onto the polymer backbone in the elastomer, and 3) Encapsulation of high permittivity fillers. The approach investigated here is a
new type of encapsulation which does not interfere with the mechanical properties to the same content as for the traditionally applied thermoplastic encapsulation. The properties of the elastomers are investigated as function of the filler content and type. The dielectric permittivity, dielectric loss, conductivity, storage modulus as well as viscous loss are compared to elastomers with the same amounts of high permittivity fillers blended into the elastomer, and it is found that the encapsulation provides a technique to enhance some of these properties.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, Center for Energy Resources Engineering
Contributors: Mazurek, P. S., Hvilsted, S., Skov, A. L.
Number of pages: 9
Publication date: 2014

**Host publication information**
Title of host publication: Proceedings of SPIE : Electroactive Polymer Actuators and Devices (EAPAD) XVI
Volume: 9056
Publisher: SPIE - International Society for Optical Engineering
ISBN (Print): 9780819499820
Keywords: DEAP, PDMS, Encapsulation, Filler, Relative permittivity, Microfluidic device
Electronic versions:
Novel_encapsulation_technique_for_incorporation_of_high_permittivity_fillers_into_silicone_elastomers_Article_EAPAD_XVI_Piotr_Mazurek.pdf
DOIs: 10.1117/12.2044778

Research output: Research - peer-review > Article in proceedings – Annual report year: 2014

**Reinforced poly(propylene oxide)- a very soft and extensible dielectric electroactive polymer**
Poly(propylene oxide) (PPO), a novel soft elastomeric material, and its composites were investigated as a new dielectric electroactive polymer (EAP). The PPO networks were obtained from thiol-ene chemistry by photochemical crosslinking of 1,4-diallyl PPO with a tetra-functional thiol. The elastomer was reinforced with hexamethylenedisilazane treated fumed silica to improve the mechanical properties of PPO. The mechanical properties of PPO and composites thereof were investigated by shear rheology and stress–strain measurements. It was found that incorporation of silica particles improved the stability of the otherwise mechanically weak pure PPO network. Dielectric spectroscopy revealed high relative dielectric permittivity of PPO at 103 Hz of 5.6. The relative permittivity was decreased slightly upon addition of fillers, but remained higher than the commonly used acrylic EAP material VHB4910. The electromechanical actuation performance of both PPO and its composites showed properties as good as VHB4910 and a lower viscous loss.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Danish Polymer Centre, Center for Energy Resources Engineering, University of Pisa
Contributors: Goswami, K., Galantini, F., Mazurek, P. S., Daugaard, A. E., Gallone, G., Skov, A. L.
Publication date: 2013
Peer-reviewed: Yes

**Publication information**
Journal: Smart Materials and Structures
Volume: 22
ISSN (Print): 0964-1726
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.38 SJR 1.152 SNIP 1.474
Web of Science (2017): Impact factor 2.963
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.1 SJR 1.038 SNIP 1.599
Projects:

**Advanced wound care adhesives with new functional properties**
Chiaula, V., PhD Student, Department of Chemical and Biochemical Engineering
Skov, A. L., Main Supervisor, Department of Chemical and Biochemical Engineering
Mazurek, P. S., Supervisor, Department of Chemical and Biochemical Engineering
Nielsen, A. C., Supervisor
Tornøe, J., Supervisor, Department of Microbiology
Tornøe, J., Supervisor, Department of Microbiology
Industrial PhD
01/08/2017 → 31/07/2020
Award relations: Advanced wound care adhesives with new functional properties
Project: PhD

Mechanically invisible encapsulations
Mazurek, P. S., PhD Student, Department of Chemical and Biochemical Engineering
Skov, A. L., Main Supervisor, Department of Chemical and Biochemical Engineering
Hvilsted, S., Supervisor, Department of Chemical and Biochemical Engineering
Szabo, P., Examiner, Department of Chemical and Biochemical Engineering
Benslimane, M. Y., Examiner
Köllnberger, A., Examiner
Benslimane, M. Y., Examiner
Köllnberger, A., Examiner
Institut stipendie (DTU) Samf.
15/12/2012 → 14/03/2016
Award relations: Mechanically invisible encapsulations
Project: PhD

Activities:

Novel high dielectric constant hybrid elastomers based on glycerol-in-silicone emulsions
Period: 3 Jul 2016 → 7 Jul 2016
Piotr Stanislaw Mazurek (Lecturer)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Related event
International Conference on Dielectrics 2016
03/07/2016 → 07/07/2016
Montpellier, France
Activity: Talks and presentations › Conference presentations

Glycerol as high-permittivity liquid filler in dielectric silicone elastomers
Piotr Stanislaw Mazurek (Speaker)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Description
Best poster award
Documents:
eaposter_Piotr Mazurek

Related event
6th International Conference on Electromechanically Active Polymer (EAP) Transducers & Artificial Muscles: 6th international conference
14/06/2016 → 15/06/2016
Helsingør, Denmark
Activity: Talks and presentations › Conference presentations

Training School on Dielectric Elastomer Transducers 2015
Period: 8 Sep 2015 → 10 Sep 2015
Piotr Stanislaw Mazurek (Participant)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Description
Training School on Dielectric Elastomer Transducers 2015

Related event
Training School on Dielectric Elastomer Transducers 2015
08/09/2015 → 10/09/2015
Neuchatel, Switzerland
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

International Conference on Electromechanically Active Polymer (EAP) Transducers & Artificial Muscles
Period: 9 Jun 2015 → 10 Jun 2015
Piotr Stanislaw Mazurek (Participant)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Related event
5th International Conference on Electromechanically Active Polymer (EAP) Transducers & Artificial Muscles
09/06/2015 → 10/06/2015
Tallinn, Estonia
Activity: Attending an event › Participating in or organising a conference

Nordic Polymer Days 2015
Period: 1 Jun 2015 → 3 Jun 2015
Piotr Stanislaw Mazurek (Participant)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Description
Preparing mono-dispersed liquid core PDMS microcapsules from thiol–ene–epoxy-tailored flow-focusing microfluidic devices
Documents:
Abstract NPD_Piotr Mazurek

Related event
Nordic Polymer Days 2015
08/06/2015 → 10/06/2015
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising a conference

ESNAM Training School on Ionic Artificial Muscles
Piotr Stanislaw Mazurek (Participant)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Related event
ESNAM Training School on Ionic Artificial Muscles
29/10/2013 → 31/10/2013
Cartagena, Spain
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.
4th Laboratory Course on Dielectric Spectroscopy
Period: 20 May 2013 → 24 May 2013
Piotr Stanislaw Mazurek (Participant)
Department of Chemical and Biochemical Engineering
The Danish Polymer Centre

Related event

4th Laboratory Course on Dielectric Spectroscopy
20/05/2013 → 24/05/2013
San Sebastian, Spain
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.