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Increasing the Electrical Values of Polydimethylsiloxane by the Integration of Carbon Black and Carbon Nanotubes: A Comparison of the Effect of Different Nanoscale Fillers.

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1. Introduction

The requirements for adhesives and sealants for industrial applications are rising up continuously through the variety of properties which an adhesive joint should contain. At the one hand should the adhesive achieve strong connections between the adherends, should be resistant against environmental conditions, temperature, solvents, and should achieve durable joints without a complex pretreatment. At the other hand are special requirements like electrical conductivity of the adhesive demanded. The electrical conductivity of the adhesive is necessary to create joints for the prevention of explosions by discharging anti-static loads. Conventional adhesives are electrical isolating and not able to solve the anti-static leakage. There are also inquiries for flexible conductive paths, flexible electrode layers for elastic capacitor like dielectric elastomer actuators and much more.

A promising way to achieve the required electrical conductivity is the integration of carbon allotropes like carbon black (CB) or multi walled carbon nanotubes (MWCNTs) into the basic polymer which form an electrical conductive network inside the polymer. CB and MWCNTs are different regarding to their geometric values and therefore the behavior at

the modification and influencing of the PDMS will be different regarding to the kind particles. As basic polymers may be also usable epoxy, polyurethane, acrylic and thermoplastic based adhesive systems for the modification process.

2. Experimental

The basic polymer was the two-component PDMS Sylgard[®] 184 produced by Dow Corning. The cross-linking of the PDMS was done at a temperature of 80 °C and duration of 4 hours. The used CB was Ketjenblack[®] EC-300J produced by AkzoNobel and the MWCNTs were Baytubes[®] C 70 P produced by Bayer MaterialScience.

The deagglomeration and homogenisation was done for different mechanism of action to achieve a good dispersion with a minor reduction of the particle size. Used were the dual asymmetric centrifuge DAC 150 FV from Hauschild & Co. KG and the three roll calender calender 80E from EXAKT Advanced Technologies GmbH.

The characterisation of the specific resistivity of the cured PDMS was done with two different set-ups. At the range of higher values above 10⁵ Ohm m were used an electrometer 6517B in combination with the test fixture 8009, both produced from Keithley Instruments Inc. The electrical values underneath 10³ Ohm m were determined with a Keithley multimeter 2000 in combination with self-made fixture based on the four-wire-measurement. The rheological values were measured by a digital rheometer C-VOR from Malvern Instruments Ltd.

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3. Results and Discussion

The integration of the particles into the polymer was investigated for both particles separately. The baseline value of the viscosity prevented the usability of some devices because the inertia of the polymer caused e.g. that the ultrasonic field has only a working range of less than 1 cm around the tip and the surrounding polymer was not reached. The best way to homogenize the particles of CB into the PDMS was the dual asymmetric centrifuge. The CB does not build such strong agglomerates like CNTs and therefore only a homogenization was necessary. Whereas, the MWCNTs build strong agglomerated clusters and the deagglomeration and homogenization was done by a two-step process. At first were the agglomerates of the MWCNTs pre-mixed with the dual asymmetric centrifuge and then with the three roll calender deagglomerated and homogenized.

The investigations showed that CB and MWCNTs influence the rheological values of the dispersions as well as the electrical values of cured samples differently, shown in Fig. 1.

Fig. 1 Resistivity and viscosity regarding to the filler content of CB and MWCNTs.

Particles like MWCNTs exhibit a distinctive aspect ratio and build inside the polymer an interconnected network^{1,2)}. The occurrence of the network is provable with the rheological percolation threshold^{1,2)}. The rheological percolation threshold of the MWCNTs was detected at 1.0 wt% and the electrical percolation threshold at 0.5 wt%. Above these thresholds increased the complex viscosity and decreased the electrical resistivity significantly. At filler content of 3.0 wt% of MWCNTs reached the complex viscosity values up to

5.0×10^4 Pas and the specific resistivity values of 0.5 Ohm m. The basic polymer has a complex viscosity of 4.5 Pas and a specific resistivity of 4.7×10^{12} Ohm m. In contrast, CB achieved already a reduction of the specific resistivity at 0.1 wt% which is very low filler content. But the value of the specific resistivity reached a plateau at 6.9×10^4 Ohm m which is nearly constant up to a filler content of 3.0 wt%. The complex viscosity of the dispersion with CB showed a slighter influence on the complex viscosity and only a less increase were detected. The complex viscosity with a filler content of 3.0 wt% of CB reached values of 48 Pas. The comparative filler content of CB to achieve a comparable specific resistivity according to the 3.0 wt% of MWCNTs was determined at 21 wt%.

4. Conclusion and Outlook

The investigation showed that the kind of the particle cause a different behavior of the properties like viscosity and resistivity. The final demands of the application should be the decisive factor for choosing the kind of particles. Every solution offers advantages and drawbacks but customized solutions are realizable.

5. Fields of application

The electrical conducting PDMS was investigated as electrode material for full polymer dielectric polymer actuators to solve the problems with incompatible metal electrodes³⁾. Additionally the material may be used for elastic conductive paths, conductive sealings and joinings to obtain an electrical conducting bonding and especially to prevent explosions by antistatic loadings.

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