BaTiO$_3$–Polymer Composites

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Introduction

Barium titanate-polymer composites are of great interest as capacitor materials because they combine high permittivity and high dielectric strength and can be solution processed on large and flexible substrates at low temperatures. [1] This combination offers the possibility to manufacture high-performance dielectric materials.

In this work barium titanate nanoparticles in an organic poly(vinylidenefluoride-co-hexafluoropropylene) host are investigated. A phosphonic acid assisted surface modification inhibits agglomeration and improves the wetting behavior of the nanoparticles to yield a homogenous distribution of particles in the composites.

Experimental

We synthesized BaTiO$_3$ by a sol-gel [2] and a precursor method [3] to correlate the different grain sizes of the oxides with the finally resulting dielectric properties. The obtained samples were compared with a commercially available nanosized powder.

The calcinated precursor particles agglomerate during the heating step, which is unfavourable for the processing of thin composite films (figure 1). These powders were initially ball milled prior to the surface modification.

The several steps of the experimental procedure to gain ceramic–polymer composites are shown in figure 2.

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Composite thin films were produced by spin coating with various speeds between 1000 – 5000 rpm. The effect of rotation speed for film thickness is demonstrated in figure 6.

For the formation of highly uniform composite films without particle agglomeration, cavities or cracks it is necessary to use aged suspensions. The resulting films for the different barium titanate powders show increasing film thicknesses in the order commercial nano powder < precursor BaTiO$_3$ < sol-gel BaTiO$_3$ (figure 7).

For the dielectric measurement composite thin films are spin coated on aluminium coated glass substrates and dried afterwards. The resulting composite films are contacted with aluminium top electrodes using a shadow mask (figure 8).

Until now all observed samples reveal a large dielectric loss. After compensation of the losses by a linear model we found improved capacitances for the sol-gel and precursor barium titanate composites compared to the commercial nano powder (figure 10).

Acknowledgments

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References


Figure 1. Agglomerates after calcination of the BaTiO$_3$ precursor

Figure 2. Experimental procedure to gain ceramic–polymer composites

Figure 3. XRD patterns of the different BaTiO$_3$ powders

Figure 4. FT-IR spectra of BaTiO$_3$, surface modified BaTiO$_3$, and the pentafluorobenzyl phosphonic acid

Figure 5. DTA/TGA plot of surface modified BaTiO$_3$

Figure 6. Influence of spin coating speed for the composite film thickness

Figure 7. SEM cross section image of a composite thin film from a sol-gel BaTiO$_3$ precursor.

Figure 8. Construction of a capacitor

Figure 9. Dielectric measuring system

Figure 10. Capacitance of the different BaTiO$_3$ composites with similar film thickness

Dielectric properties of the different composites are summarized in table 2.

Table 2. Dielectric properties of the different BaTiO$_3$ composites

<table>
<thead>
<tr>
<th>BaTiO$_3$ concentration (wt%)</th>
<th>0.001</th>
<th>0.01</th>
<th>0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>1000</td>
<td>2500</td>
<td>5000</td>
</tr>
<tr>
<td>Relative permittivity</td>
<td>3.5 ± 0.2</td>
<td>3.5 ± 0.2</td>
<td>3.5 ± 0.2</td>
</tr>
</tbody>
</table>

Dielectric loss tanδ at 1 kHz measured at 1 kVd.