

Dielectric behaviour of polyimide films containing TiO₂ nanotubes

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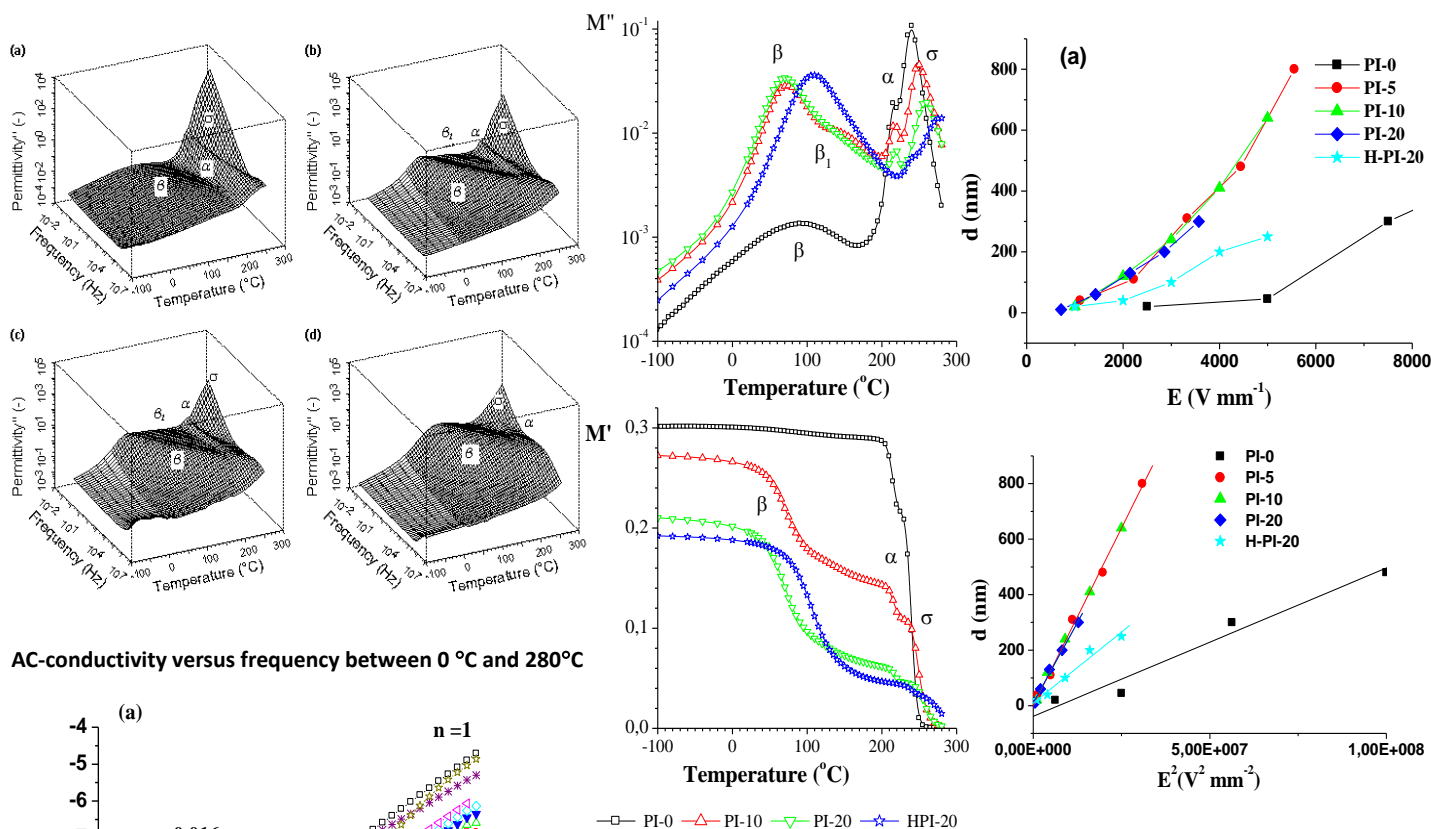
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ABSTRACT: Within the herein study polyimide composite dielectrics containing TNTs of 10-12nm diameter and several hundreds of nanometers in length were prepared and characterized. TNTs content influence upon composite's properties was investigated. The good compatibility between the filler and the polyimide matrix is demonstrated via AFM and SEM. The dielectric properties, dielectric constant, ϵ , and dissipation/loss factor, $\tan \delta$, were investigated via broadband dielectric spectroscopy. Dielectric behavior was studied while varying frequency between 10²Hz and 10⁷Hz and temperature from -100°C up to 300°C. At low temperatures a secondary relaxation β while introduction of TNTs decreased the activation energy and facilitated the appearance of an additional β_1 process. At higher temperature an α relaxation was visible. The increase of TNTs content raised the values of dielectric constant and dissipation factor while the maximum of σ relaxation peak shifted to higher temperatures.

Dependence of dielectric loss vs. frequency and temperature Temperature dependences of M' and M'' at 1 Hz Nano-displacement vs. E and E²



Thermal properties and dielectric constant of the samples

| Sample | T ₅ ^a (°C) | T ₁₀ ^b (°C) | T _{max1} ^c (°C) | T _{max2} ^d (°C) | Char yield at 750°C (%) | Dielectric constant | | | |
|---------|-------------------------------------|--------------------------------------|--|--|-------------------------------|---------------------|----------|------|------|
| | | | | | | Temperature (°C) | | | |
| | | | | | | at 0.1 Hz | at 1 kHz | | |
| PI-0 | 515 | 540 | 580 | 660 | 40.8 | 3.35 | 3.50 | 3.31 | 3.42 |
| PI-10 | 500 | 560 | 570 | - | 42.8 | 3.74 | 6.33 | 3.67 | 4.09 |
| PI-20 | 460 | 535 | 565 | - | 42.0 | 5.01 | 13.6 | 4.40 | 5.78 |
| H-PI-20 | 470 | 540 | 576 | - | 39.1 | 5.37 | 12.02 | 3.98 | 5.49 |

CONCLUSIONS

New polyimide composite films were prepared starting from a poly(amic acid) and TNTs. The films having the thickness in the range of tens of micrometers were tough and flexible. AFM and SEM analysis revealed good compatibility between polyimide matrix and TNTs. The films had high thermal stability, but the introduction of the inorganic filler slightly decreased the initial decomposition temperature. The dielectric constant of the films was in the range of 3.40-5.34, at 100°C and 1 kHz while the dielectric loss, in the same conditions, was in the range of 0.015-0.110. By increasing the TNTs content, an increase of the dielectric constant values was observed. The introduction of TNTs into the polyimide matrix improved the nanoactuation characteristics. The films exhibited electrostrictive properties with the strains proportional to the square of electric field.



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