Piezoresistive effect in epoxy-graphite composites

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Study of the piezoresistive response in thick-films made of epoxy-graphite

Important parameters: - particle size effect

- matrix effect on stability

→ Study of the creep of the sample

Experimental:

•Bi-component composite:

- Epoxy matrix: Epotek 377, Martens Plus → critical property: **glass transition temperature T_g**
- Filler: graphite with ellipsoidal shape and particle size of 4 and 15 µm (95% of the particles have a major axis smaller than 4 µm resp. 15 µm), named KS4 and KS15

•Samples:

- Resistive thick-film Wheatstone bridge deposited on alumina substrate by screen-printing process → calculation of the gauge factor (GF) longitudinal (GF_L) and transverse (GF_T)
- Fabrication of longitudinal and transverse beams

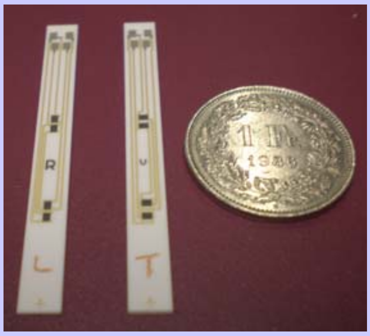

Fig 1. Beams for longitudinal (left) and transverse (right) gauge factor

Particle size effect

Higher resistivity → higher GF

Tunneling effect: smaller *spherical* particles present more junctions leading in theory to a smaller GF

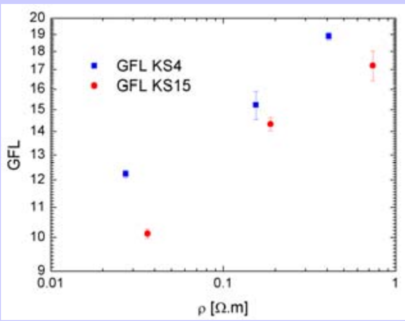

Fig 2. Effect on particle size on the GF_L vs. resistivity (matrix Epotek 377)

$GF_{L\ 4\ \mu m} > GF_{L15\ \mu m}$

can be explained by the morphological aspect (ellipsoidal) and the different aspect ratio being higher for the biggest particles [1]. For the same volumic concentration GF should be smaller

[1] Ambrosetti G. On the insulator-conductor transition in polymer nanocomposites, Thesis n°4612 EPFL, 2010

Matrix effect

Influence of T_g: Epotek 377: low T_g (~90°C)

Martens Plus: high T_g (~200°C)

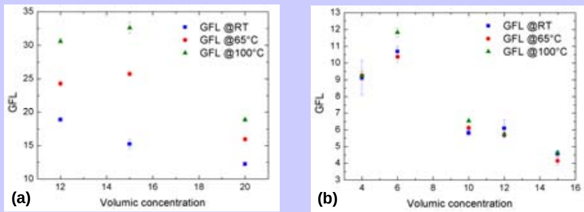

Fig 3. GF_L at RT, 65°C and 100°C vs. Graphite (KS4) volumic concentration for Epotek 377 (a) and Martens Plus (b)

At T~ T_g, dilatation of epoxy in z direction: matrix stiffness drops → high strains in the composite leading to higher GF_L values [2]

High T_g epoxy, effects shifted = improved stability

[2] Grimaldi et al. Gauge factor enhancement driven by heterogeneity in thick-film resistor, *Journal of Applied Physics*, 2001, vol 90

Creep:

For 1 cycle (unloaded/loaded/unloaded); for each epoxy, the same beam (longitudinal) is used at 25°C, 50°C and 80°C

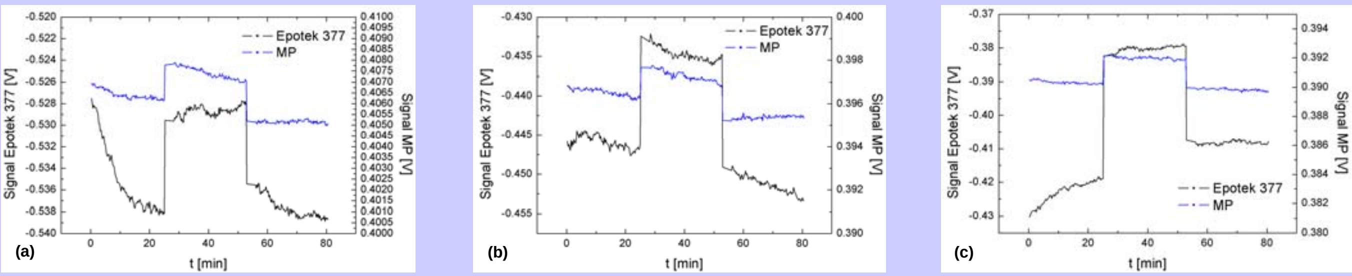

Fig 4. Signal vs. time for 12% vol of graphite in Epotek 377 and Martens Plus at 25°C (a), 50°C (b) and 80°C (c)

- Epotek 377: when T increases close to T_g (see graphs (b) and (c)), increase of the matrix dilatation: higher GF_L values and relaxation effects of the matrix→ strong instabilities in the signal (drifts)
- Martens Plus: not perfect but presents better stability regarding the creep (T_g)

Conclusion

Particle size has more effect than in resistivity measurements

Importance of T_g in thermomechanical stability and creep study → Promising results **for low-cost mechanical sensors**

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