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Nanocomposite based humidity sensors for structure health monitoring of lightweight structures

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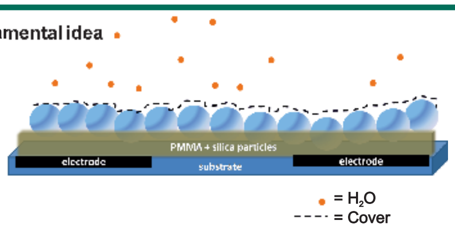
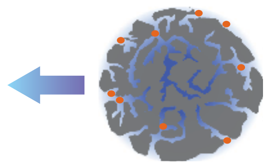
1. Introduction

Rising efforts concerning limitation of fossil energy consumption and reduction of CO2 emission encourage an increasing use of lightweight structures, e.g. in automotive, ship and aircraft engineering as well as in modern architecture. Beside unbeatable advantages compared to classical materials, there are also critical properties, like mostly unpredictable failure reaction in case of damage. Water, penetrating the lightweight material via (micro-) cracks, can lead to delamination and finally to a collapse of the whole mechanical structure. Consequently, the integration of humidity sensors into compound materials is able to promote the reliability via condition monitoring. Here, we present the fabrication technology and, furthermore, the characterisation of nanocomposite based humidity sensors.

2. Fundamental idea

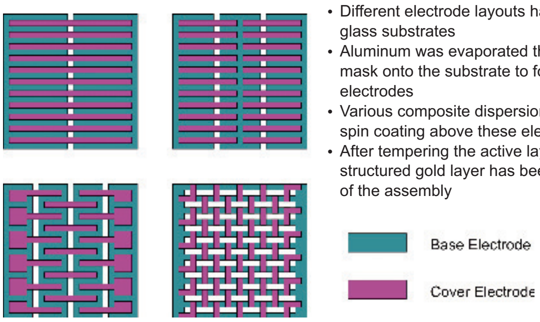


- Nanoporous silica particle are embedded in PMMA
- The electrodes are at the glass substrate and on top of the silica particles
- The silica particles, which increase the active surface, and their pores lead to an improved water adsorption



- Here, a single silica particle with adsorbed water molecules inside the pores is shown

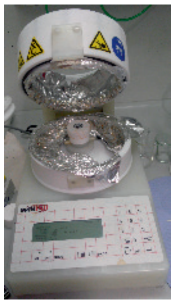
3. Preliminary test



- Different electrode layouts have been produced on glass substrates
- Aluminum was evaporated through a structured mask onto the substrate to form 100 nm thick base electrodes
- Various composite dispersions has been applied by spin coating above these electrodes
- After tempering the active layer, a 20 nm thick structured gold layer has been evaporated on top of the assembly

4. Preparation

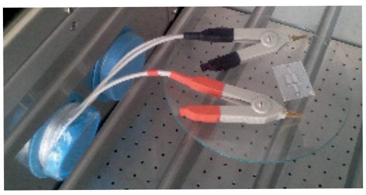
- Different composites with various volumetric contents of silica particles in PMMA have been produced for measurements and comparison



- The different composites with silica particles and PMMA were prepared on glass substrates by spin coating

5. Measurement

- Water molecules within the ambient air diffuse into the pores of the silica particles and lead to a variation of the dielectric constant of the composite material corresponding to the air's water vapor content
- This variation of the dielectric constant results in a capacitance change

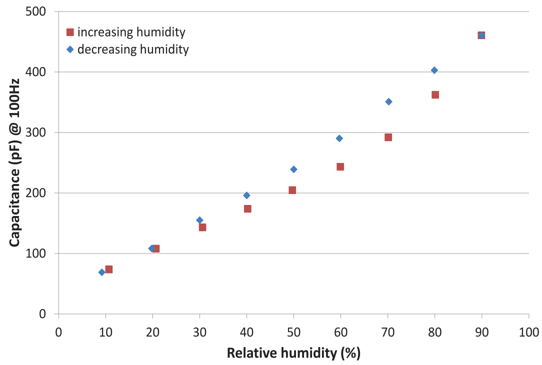


- A test pattern placed in a Feutron climate chamber 3343/16 connected to a HAMEG HM8118 programmable LCR bridge is shown in this picture
- Both devices were controlled by a LabVIEW programme running on a desktop computer

- The most promising layout (top-right) and dispersion (60% silica / 40% PMMA) have been utilised
- Test patterns with varying spin-coating and PVD parameters were prepared
- These have been determined with respect to absolute and relative change of capacitance

6. Characterisation

- These graphs show the immense capacitance change during at relative humidity change from 10 to 90% from around 70 to 460 pF, which is a relative capacitance increase of more than 500%
- At higher humidity levels, more time to adsorb the water molecules is required



6. Conclusion

Measurements in a climate chamber have shown an immense capacitance change of the sensor. These considerable findings will be transferred to printed sensors on flexible substrates in future researches including an integrated signal conditioning circuitry. In addition, the integration of these sensors into smart hybrid laminates as a semi-finished product for lightweight structures is also scheduled.

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This work was performed within the Federal Cluster of Excellence EXC 1075 "MERGE Technologies for Multifunctional Lightweight Structures" and supported by the German Research Foundation (DFG). Financial support is gratefully acknowledged.

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