Characterization of the effect of humidity on nanoparticle based strain gauges using small angle x-ray scattering coupled with electromechanical measurements

Lucas Digianantonio,[1] Mélanie Gauvin,[1] Thomas Alnasser,[1] David Babonneau,[2] Alessandro Coati,[3] Benoit Viallet,[1] Jérémie Grisolia,[1] Guillaume Viau[1] and Laurence Ressier[1]

1 LPCNO, INSA-CNRS-UPS, 135 avenue de Rangueil, 31077 Toulouse, France
2 Institut P', CNRS - Université de Poitiers, 11 Boulevard Marie et Pierre Curie, 86962 Futuroscope Chasseneuil, France
3 Synchrotron Soleil, L'Orme des Merisiers Saint-Aubin, 91192 Gif-sur-Yvette, France
laurence.ressier@insa-toulouse.fr

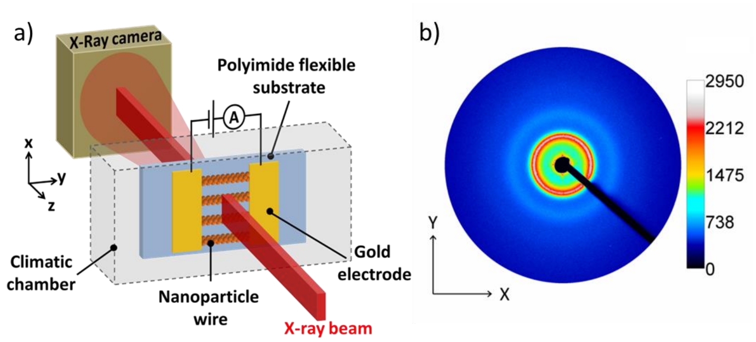
Abstract

In the last past years, our group has developed resistive nanoparticle based strain gauges made of an assembly of colloidal gold nanoparticles deposited on a flexible polyimide substrate by convective self-assembly [1,2,3]. The nanoparticles are coated with organic ligands, thereby the current flow in the nanoparticle assembly is driven by the tunnel conduction between neighboring nanoparticles through the ligand barriers. This leads to an exponential increase of the electrical resistance of these gauges when a strain is applied to the substrate, conferring them a very high sensitivity (30 times the sensitivity of a conventional metallic strain gauge). Moreover, these nanosensors present a very low electrical consumption because of their high resistance at rest (adjustable between 10kΩ and 100MΩ) and an ease of integration due to the small size of their active area (<0.1mm²). Despite all these advantages, nanoparticle based strain gauges present one main issue: their sensitivity to humidity: when the humidity varies from 10 to 60%, the electrical resistance at rest of the gauges increases of 40% and their sensitivity of 35%.
We have thus investigated the impact of humidity on the strain gauges using small angle x-ray scattering (SAXS) measurements, conducted at the Soleil synchrotron on the SIXS beamline [4]. The samples were placed in a climatic chamber and the SAXS measurements were coupled with electrical ones (Figure 1), to correlate the evolution of the inter-particle distance at the nanoscale with the increase of the electrical resistance observed at the macroscopic scale. As the humidity increases, these experiments revealed an increase of the inter-particle distance which is in good agreement with the increase of the electrical resistance, this coupled with a reorganization of the nanoparticles. Eventually in order to protect the strain gauges from the effect of the humidity we have developed an encapsulation solution based on the deposition of Al_2O_3 by atomic layer deposition.

References

[1] C. Farcau, N.M. Sangeetha, H. Moreira, B. Viallet, J. Grisolia, D. Ciuculescu-Pradines & L. Ressier, ACS Nano, **5** (2011) 7137
[2] N.M. Sangeetha, N. Decorde, B. Viallet, G. Viau & L. Ressier, J. Phys. Chem. C, **117** (2013) 1935-1940
[3] H. Moreira, J. Grisolia, N. M. Sangeetha, N. Decorde, C. Farcau, B. Viallet, K. Chen, G. Viau and L. Ressier, Nanotechnology, **24** (2013) 095701
[4] N. Decorde, N. M. Sangeetha, B. Viallet, G. Viau, J. Grisolia, A. Coati, A. Vlad, Y. Garreau & L. Ressier, Nanoscale, **6** (2014) 15107

Figure 1



a) Schematics of the experimental setup used to characterize the effect of humidity on the nanoparticle based strain gauges with small angle x-ray scattering, b) Typical SAXS scattering pattern of an unstrained gauge at a humidity of 30%