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The sensitivity and the hysteresis of humidity sensors based on graphene oxides

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Currently, commercially-available thin-film humidity sensors for monitoring environments are made of polymers due to the cost-effectiveness. Recently, carbon-based nanomaterials as a humidity sensing layer have attracted much attention in developing gas sensors owing to their excellent electrical, mechanical, and chemical properties. Among them, derivatives of graphene, for example, graphene oxide (GO) have been shown to present high performances in some humidity sensing properties such ultrahigh sensitivity and ultrafast response time. However, these GO-based sensors present a hysteretic behaviour during water sorption and desorption which is not yet systematically studied so far.
We present the water sorption/desorption properties of humidity sensors made of GO and amine-modified GO (GO-NH2) as a humidity sensing material. Among the characteristics of humidity sensors, the sensitivity and the hysteresis of these sensors are investigated by varying pH of each solution. The pH of the solution is known to change surface charges of GO and GO-NH2 and thus the relationship between surface charges and sensing properties are studied. It is found that the sensitivity of GO sensors is increased at high pH which induces high surface charges on GO due to the ionization of carboxylic acid group from COOH to COO-. However, the increased surface charge induced a higher degree of the sorption/desorption hysteresis. Therefore, a trade-off relationship between the sensitivity and the hysteresis is found in GO-based humidity sensors. On the other hand, the increase of pH of GO-NH2 humidity sensors has a negligible effect on their sensitivity. This is because the carboxylic acid group is changed from COOH to COO- while amine group is changed from NH3+ to NH2. The net surface charge is thought to remain similar at varied pH. The mechanism of the increased sensitivity and the hysteresis is discussed on the basis of molecular compositions and their interactions with water by using Fourier transform infrared (FT-IR) spectroscopy. The present study emphasizes the importance of sorption/desorption hysteresis in the development of humidity sensors using GO and/or its derivatives.