Porous materials for electrical gas sensors and actuators without moveable part

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Sensors and actuators that do not require additional converters must be able to be read out and set electrically. This enables optimal connection to the readout, adjustment and control electronics. Gas sensors sand actuators can be used directly in microfluidic chips as elementary building blocks. Microfluidics is concerned with the behavior of liquids and gases in very small spaces. This talk briefly summarizes the work of our group over the last decade, showing how highly porous materials can be used as both electrical sensors and electrical actuators without the need for moving parts. This is because both applications ultimately require flow through electrically conductive material, for which highly porous materials are ideally suited. Highly porous structures from the aeromaterial family proved to be ideally suited for both gas sensors and actuators. Aerographite was first described in 2012. The material is based on a template consisting of interpenetrating microscale tetrapoal ZnO crystals. The template, which can be shaped to the desired geometry at the macroscale, is fabricated by gently pressing the tetrapodal powder and then sintering it. The tetrapodal shape as basic blocks guarantees a high free volume between the blocks. In further steps, a desired nanomaterial, e.g. graphene, in the case of Aerographite graphite, but as well carbon nanotubes, layered materials like h-BN, etc., are first wrapped around the surface as a deposited thin film (wet chemical or CVD) and the underlying ZnO tetrapods are detached either by wet chemical or hydrogen gas etching. The resulting structure consists of an interconnected microscopic tubular network of macroscopic extent with wall thickness on the order of thin films, i.e., a few nanometers. These open structures are ideal for gas sensors. Surface effects dominate and enable high sensitivity and selectivity, both with and without the underlying zinc oxide template. Actuation can be accomplished by resistive heating of the aeromaterial. The usual resistive heating is associated with either slow heating or low volume effects. In this case, neither applies. The actuator responds in milliseconds, moves volumes up to four times its volumetric expansion, and is capable of carrying high loads, at least 10,000 times its own weight. This is due to the negligible mass of the aermaterial, which results in negligible heat capacity of the material. The 3d structure with the high open porosity provides homogeneous heating of the gas trapped in the material between the tubes and leads to rapid volume expansion or presure increase. In addition, the talk will provide application examples that go beyond microfluidics.