Importance of hydrophilicity on hydrogen gas sensing properties of TiO_2 nanotubes

Saman Azhari[1,3], Mohd Nizar Hamidon[2], Hirofumi Tanaka[1,3]
[1] Department of Human Intelligence Systems, Kyushu Institute of Technology, 808-0196, Japan
[2] Institute of Advanced Technology, University Putra Malaysia, UPM, Serdang, Malaysia
[3] Reserach Center for Neuromorphic AI Hardware, Kyushu Institute of Technology, Kitakyushu 808-0196, Japan.
E-mail: saman@brain.kyutech.ac.jp

[Introduction] Hydrogen gas is an abundant, clean and portable gas with potential to resolve energy crisis, however it is highly explosive even in low concentration (4-75 vol%) with low ignition energy (0.02 mJ) and large flame propagation velocity [1]. The current metal oxides based gas sensors require high operating temperature which could result in critical and irreparable situations [2]. Therefore, the ability to precisely detect and monitor H_2 at low operating temperature has an utmost importance [1]. Recently, there have been extensive research work on synthesis and formation of TiO_2 nanostructures via alkali hydrothermal treatment of nanoparticles [3]–[5]. These nanostructures have shown properties that differ from their nanoparticles counterpart [6]. Herein, we report the possibility to utilize hydrophilic properties of TiO_2 nanotubes for H_2 gas sensing application at room temperature.

[Methodology] TiO_2 nanotubes were synthesized via alkali hydrothermal treatment, reported by Kasuga et al. [7], [8] using a Teflon lined stainless steel autoclave at 125 °C for 30 hours. The product was washed with distilled water and 0.1 M HCl (Aldrich) till pH 7 was achieved. The product was dispersed in 99 wt% ethanol (Aldrich). The dispersion was, then, mixed with the pre-prepared binder that is a binary mixture of α-terpineol (Aldrich) and ethyl cellulose (Aldrich) with ratio of 95 wt% to 5 wt%, respectively. After full evaporation of solvent, the paste was screen printed on the top of silver interdigitated electrodes (IDE). The IDE was screen printed on an alumina substrate and annealed at 150 °C for 1 hour. The sample was, then, heated up to 500 °C for 30 minutes.

[Results & Discussion] The TEM result display the presence of high aspect ratio hollow tubular morphologies because of alkali hydrothermal treatment of TiO_2 nanoparticles. This is ideal for gas sensing applications since such structures have higher surface area and porosity. The XRD peaks implies the presence of $Na_2Ti_3O_7$ which is an open layered structure. This means that the synthesized material is readily prone to hydration. The Raman data confirms the presence of tubular morphologies known as nanotubes. The *I-V* characteristics of the sample exhibit an increase in resistance as increase in temperature from 0 to 100 °C and decrease in resistance at above 125 °C. This observation suggests the influence of surface adsorbed water molecules on the electrical behavior of TiO_2 nanostructure. The H_2 sensing properties of synthesized nanotubes display p-type behavior. This observation confirms the possibility to utilize TiO_2 nanostructures for H_2 sensing applications at room temperature, and its dependency to the presence of humidity.

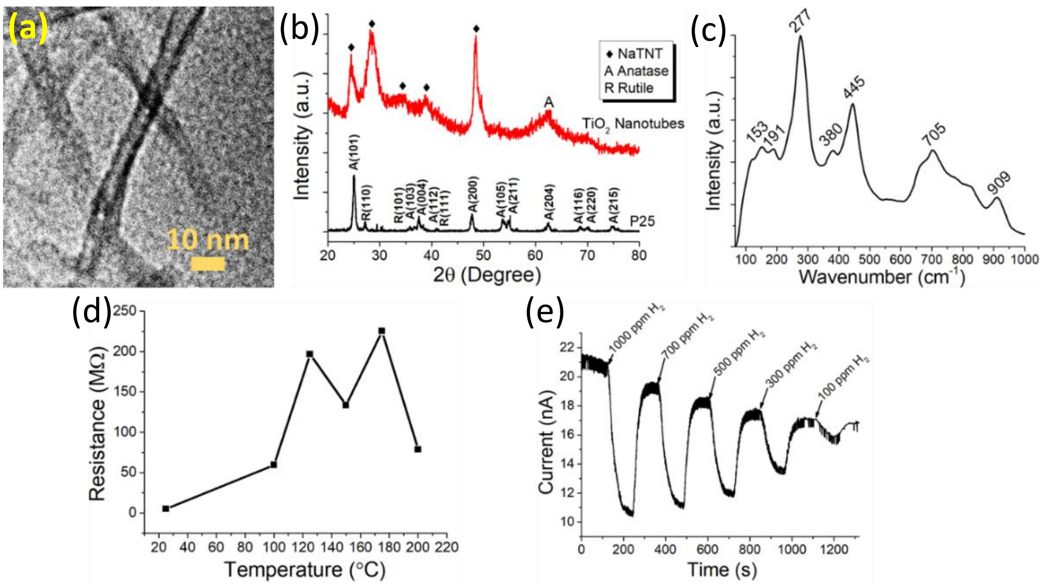

Figure 1. (a) TEM image of TiO_2 nanotube; (b) XRD of TiO_2 nanotubes; (c) Raman spectra of TiO_2 nanotubes; (d) I-V characterization resistance vs temperature; (e) H_2 gas sensing characteristics of TiO_2 nanotubes

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