Influence of hydrophilicity on hydrogen gas sensing properties of TiO_2 nanowires

Saman Azhari[1], Mohd Nizar Hamidon[2], Hirofumi Tanaka[1]
[1] Department of Human Intelligence Systems, Kyushu Institute of Technology, 808-0196, Japan
[2] Institute of Advanced Technology, University Putra Malaysia, UPM, Serdang, Malaysia
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 nanowires for room temperature H_2 gas sensing application.
[Methodology] TiO_2 nanowires were synthesized via alkali hydrothermal treatment, reported by Kasuga et al. using a Teflon lined stainless steel autoclave at 140 °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% ethyl alcohol (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 top of silver Interdigitated Electrodes (IDE). IDE was screen printed on an alumina substrate and fired at 150 °C for 1 hour. The sample was then heated up to 500 °C for 30 minutes.
[Results & Discussion] The FESEM and TEM results display the presence of high aspect ratio tubular and wire like morphologies with unsmooth surface as a result of alkali hydrothermal treatment of TiO_2 nanoparticles. This is ideal for gas sensing applications, since such structures have higher surface area. 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 shows the presence of tubular morphologies similar to nanotubes and nanowires. The I-V characteristics of the sample exhibit an increase in resistance with increase in temperature from 0 to 100 °C and decrease in resistance at above 100 °C. This observation suggest the influence of surface adsorbed water molecules on the electrical behavior of TiO_2 nanostructure. The H_2 sensing properties of synthesized nanowires display a p-type behavior. This observation confirms the possibility to utilize TiO_2 nanostructures for room temperature H_2 sensing applications and its dependency to the presence of humidity.

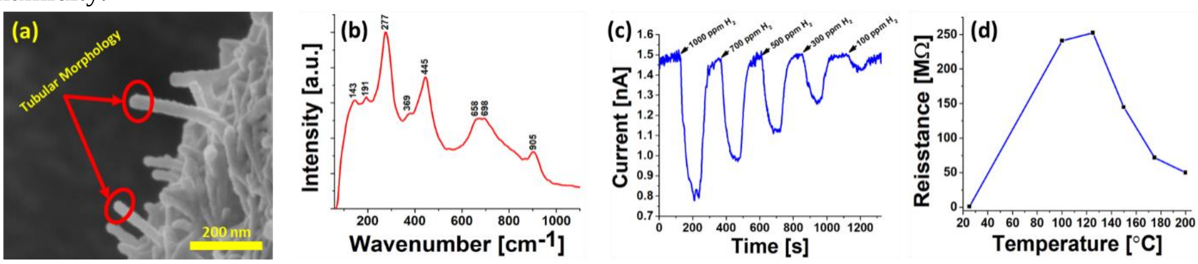

Figure 1. (a) FESEM image of TiO_2 nanowire; (b) Raman spectra of TiO_2 nanowires; (c) H_2 gas sensing characteristics of TiO_2 nanowires; (d) I-V characterization resistance vs temperature

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