Electrical conductivity mechanisms of nanocrystalline TiO_2 powders prepared in acidic environment

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For the preparation of the samples in acidic environment, 3.32 mL TBO were digested in 100 mL of 0.5 M aqueous solution of sulphuric acid (SA) for 30 min under vigorous stirring at room temperature. Then, the solution was poured into a 100 mL Teflon-lined autoclave occupied 80% of its volume. Two different solution heat treatments were used, the first at 180 ^{o}C for 10h and the second at 180 ^{o}C for 24h. Moreover, TiO_2 nanocrystalline powder, TiO_2-W, was prepared in neutral environment. After natural cooling to room temperature, the powder products were washed with distilled water to neutral conditions, and then dried at 70 ^{o}C for 24 h. The powders obtained were abbreviated as sample TiO_2-SA 10h and TiO_2-SA 24h, respectively. From XRD spectra (Fig.1), the phase of the TiO_2-SA samples was found only anatase while for TiO_2-W a mixture of anatase and brookite phase was identified.
The temperature dependence of the conductivity for all samples, plotted as ln(σ) versus 10^3/T, in vacuum, is given in Fig.2.Several conductivity mechanisms are shown, acting at different temperature regions for each sample. Looking for the suitable conduction mechanism, in the temperature range 199-130K for TiO_2 –SA 24h, 277-187K for TiO_2 –SA 10h and 247-193K for the TiO_2 –W samples, the best fit of electrical conductivity data was attained for the $\ln(\sigma T^{1/2})$ versus $T^{-1/4}$ plot, indicating that it obeys to the Mott's variable range hopping (VRH). In Fig.4, the temperature dependence of $\ln(\sigma T^{3/2})$ versus 10^3/T suggests the SPH non-adiabatic conduction mechanism in the temperature regime 292-214K for TiO_2 –SA 24h, 343-277K for TiO_2 –SA 10h and 322-247K for the TiO_2-W, respectively. At high temperatures , the best fit was achieved for the $\ln(\sigma T^{1/2})$ versus 10^3 /T plot related to grain boundary model (GB) for polycrystalline semiconductors (Fig.5) , indicating that grains are partially depleted of charge carriers.

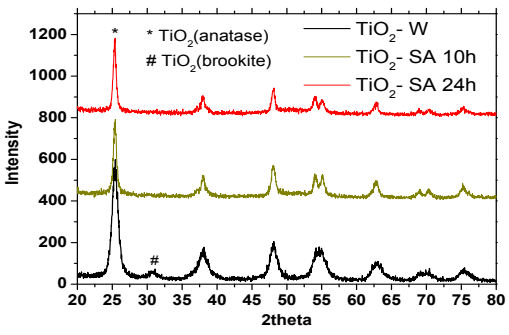

Fig. 1. XRD pattern

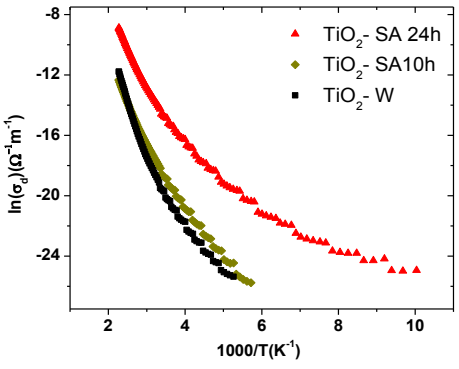

Fig. 2. Temperature dependence of the electrical conductivity plotted as ln(σ) versus 10^3/T in vacuum

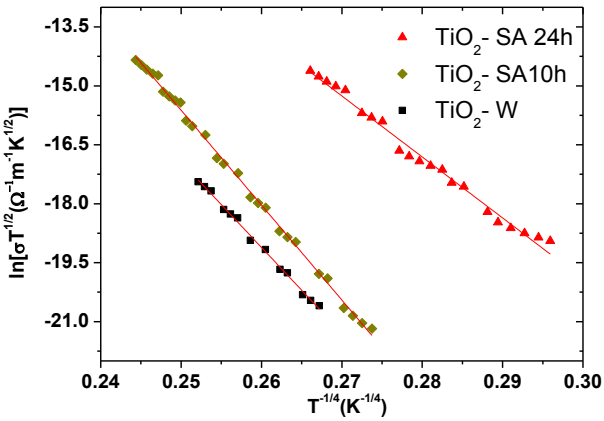

Fig. 3. Temperature dependence of $\ln(\sigma T^{1/2})$ versus $T^{-1/4}$, in vacuum

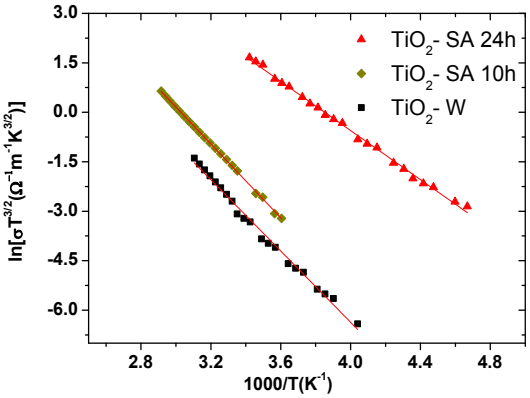

Fig. 4. Temperature dependence of $\ln(\sigma T^{3/2})$ versus $10^3/T$, in vacuum

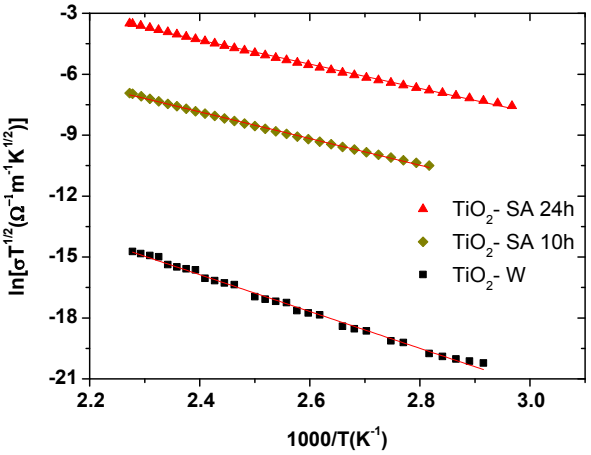

Fig.5. Temperature dependence of the electrical conductivity plotted as $\ln(\sigma T^{1/2})$ versus $10^3/T$ in vacuum

References

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