New approaches in obtaining nano- and microstructured metal oxide materials with improved properties and functionality

Aigi Salundi, Martin Järvekülg, Martin Timusk, Tanel Tätte, Valter Reedo, Madis Paalo, Kristjan Saal and Ants Lõhmus
Institute of Physics, University of Tartu, Riia 142, 51014 Tartu, Estonia
aigi.salundi@ut.ee

Sol-gel has emerged as an alternative to conventional methods of preparing oxide materials. Sol-gel technology has many advantages. For example there is no need to use high temperatures during syntheses process. The rise of nanotechnology stimulated new trends in sol-gel which holds considerable potential with its simplicity and possibility of giving the precursor different shapes before gelation- oxide material that is generally hard to process is synthesized directly in desired shape. This work reports our recent progress in the elaboration of novel original sol-gel materials [1], [2], [3].

The preparation and characterization of sol-gel micropatterns, -rolls and, -tubes and functional composites is covered. Firstly, a novel method for preparation of aminofunctional SiO_2 films has been developed. The latter method allows varying the concentration of amino groups on the surface and wettability of the film. Prepared materials were successfully used as substrates in DNA microarray analyses and found to be suitable for practical applications including mutation screening. Simple pulling methods for preparing metal oxide fibers with diameters 200 nm- 50 nm have been developed. Also, sharp oxide tips can be obtained by pinching the pulled sol jets. Tip radius of the transparent and electrically conductive SnO_2 tip depends on fiber drawing speed, ambient humidity and viscosity of the precursor. Tip radii down to 15-25 nm were achieved. The sharp structures were tested as probes in STM and tunneling current induced photon imaging, both showed very good lateral resolution. Similar high-viscosity sol is also suitable for micro molding with polymeric stamps; surface structures of ~ 1 micron lateral dimension could be thereby readily obtained. Sol-gel method is also suitable for preparing electrodes from CNT-doped high refractive index transparent metal oxides like TiO_2 or SnO_2. After baking at 340°C in air, dense oxide ceramics containing aligned nanotubes were obtained as fibers and films. Prepared materials were conductive (up to 500 S/m). By that we have shown that CNT-doping can boost the electrical properties of the material without sacrificing transparency. Another composite material that we have elaborated is glass dispersed liquid crystal (GDLC), transparency of which can be controlled by electric field [4]. Microdroplets of liquid crystal in modified SiO_2 matrix are obtained by phase separation, prepared GDLC devices show superior performance compared to these reported in papers by other groups. Our finest transparency difference which we have achived is 74 %. Also, we have recently introduced a strategy for obtaining novel microscopic tubular oxide structures by film rolling. This non-template synthesis includes the steps of gelling the surface of a metal-alkoxide precursor, spontaneous cracking of obtained gel film, subsequent dissolving of the non-gelled layer of precursor and self-rolling of the gel film segments. It is important to point out that the gel film rolling is based on general and spontaneous phenomena. Formation of a gel film can be observed in all situations where a sol layer with a suitably low flowing rate is exposed to humidity. This method can potentially yield tubular structures of tunable size from all sol-gel materials. Advantages of novel obtained microtubular structure of oxide material include large specific surface area and outstanding resistance to high temperatures and harsh chemical environment for using them in catalytic processes. For the first time cracking prosess of metal alkoxide sol-gel films have been modeled [3].

References

[1] Hussainov, M., Tätte, T., Paalo, M., Gurauskis, J., Mändar, H., Lõhmus, A., Structure and Rheological Behavior of Alkoxide-Based Precursors for Drawing of Metal Oxide Micro- and Nanofibres. Advanced Materials Research, 214 (2011), 354 - 358.

[2] Saal, K., Tätte, T., Järvekülg, M., Reedo, V., Lõhmus, A., Kink, I., Micro- and nanoscale structures by sol-gel processing, International Journal of Materials and Product Technology, 40(1/2) (2011), 2 - 14.

[3] Jõgi, J., Järvekülg, M., Kalda, J., Salundi, A., Reedo, V., Lõhmus, A., Simulation of cracking of metal alkoxide gel film formed on viscous precursor layer using a spring-block model, EPL - A Letters Journal Exploring the Frontiers of Physics, 95(6) (2011), 64005-p1 - 64005-p6.

[4] Timusk, M., Järvekülg, M., Lõhmus, R., Kink, I., Saal, K., Sol–gel matrix dispersed liquid crystal composite: Influence of methyltriethoxysilane precursor and solvent concentration, Materials Science and Engineering B, 172(1) (2010), 1 - 5.

Figures

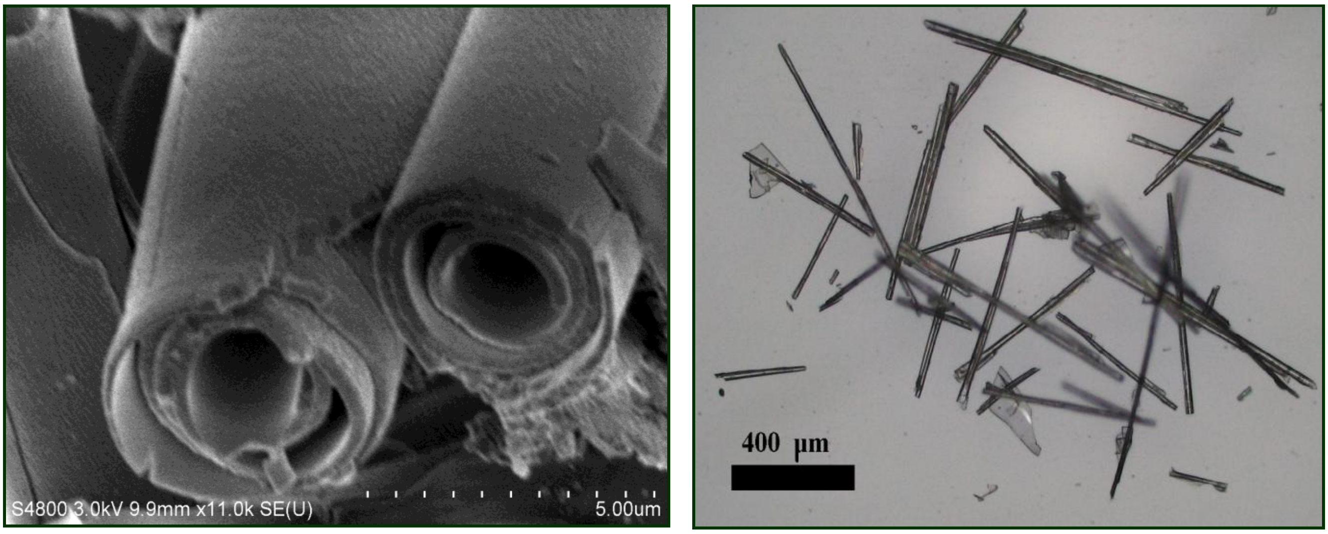

Fig.1. Tubular oxide structures, which combines sol-gel method and self-formation.

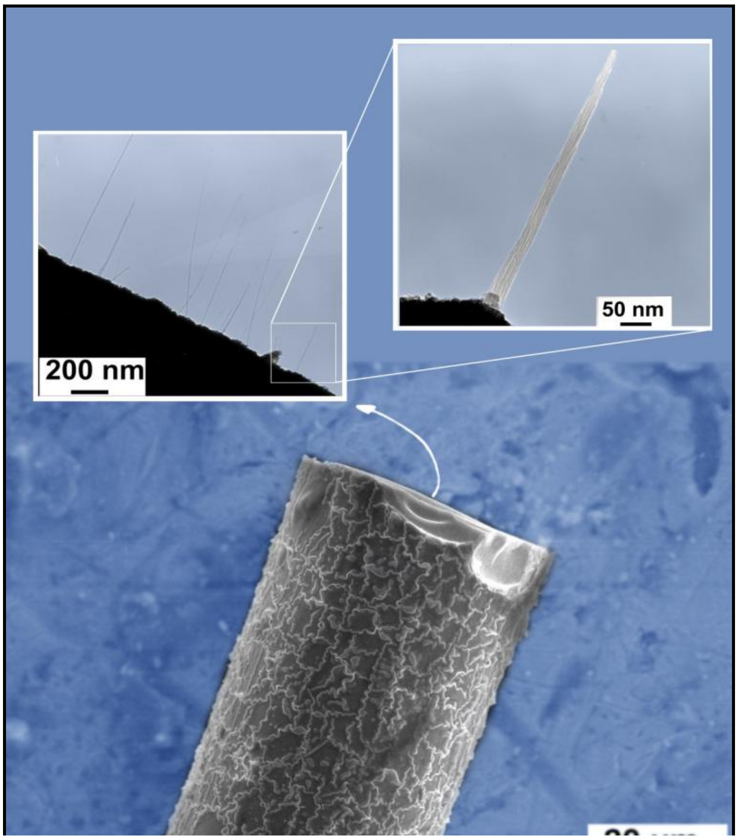

Fig.2. CNT doped metal oxide electrodes