Materials World Network - 2-Dimensional Ion Conducting Bismuth Vanadates for Electrochemical Devices

Funded by the German research foundation (DFG, grant MO 1060/16-1)

Deutsche Forschungsgemeinschaft

Joint project with New Mexico Institute of Mining and Technology (NMT), Prof. Paul Fuierer, Materials and Metallurgical Engineering Department

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

Summary

Bismuth vanadate compounds are of high interest due to their high ionic conductivity, especially at moderate temperatures between 300 °C and 500 °C. Therefore, a large potential exists to apply them in the field of fuel cells, oxygen separation membranes, and gas sensing. This project was a collaborative project between the Department for Functional Materials (Prof. Ralf Moos) and the New Mexico Institute of Mining and Technology (Prof. Paul Fuierer), in the framework of the Materials World Network. Project aims were the detailed investigation of material stability and properties as well as to explore their suitability for electrochemical devices.

Two main goals existed should be achieved. Firstly, for a fundamental understanding of the anisotropic material properties (ionic conductivity, dielectric constant, thermal expansion and conductivity, thermopower), a quantitative defect chemical should be developed. Secondly, the application of bismuth vanadate in electrochemical devices was evaluated. While the NMT counterpart focused on the preparation of textured bulk ceramics [1-2], the group at the Department of Functional Materials investigated the formation of bismuth vanadate films using a novel spray coating technique called Aerosol Deposition (AD) [3-4], and the resulting electrical properties of the films. Using aerosol deposition, the formation of ceramic layers occurs at room temperature without any necessary heating steps and directly from a suitable ceramic raw-powder.

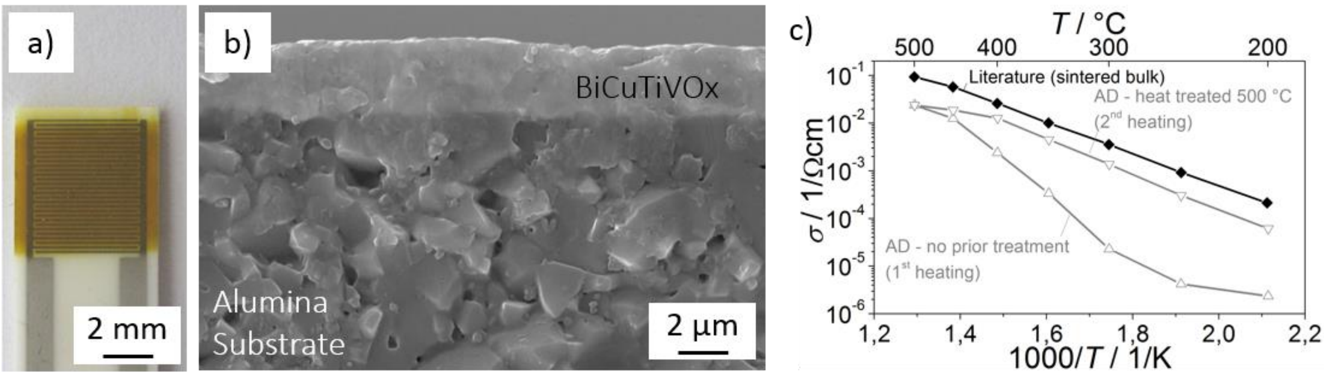

Figure: Dense doped Bismuth Vanadate films (BiCuTiVOx) formed by aerosol deposition: a) semi opaque film on platinum electrode structure, b) cross-sectional SEM image and c) conductivity

Dense thick films of doped bismuth vanadate were produced for the first time using AD (see figure). The aftertreatment was investigated in detail and already moderate annealing at 500 °C yield an oxygen ionic conductivity close to the bulk value.

The release of non-uniform lattice strain was identified as the main reason for the increase of conductivity during annealing. AD films showed improved strength, adhesion and ionic conductivity compared to conventional screen-printed films. Furthermore, dense composite films of a Bi_2O_3:V_2O_5 mixture were deposited by aerosol co-deposition, a derivation form conventional aerosol deposition where two or more different powders were processed together.

To demonstrate the suitability of aerosol deposited bismuth vanadate films for the usage in electrochemical devices, a planar NO_2 sensor was prepared. The sensor utilizes the pulse polarization technique and it was achieved to measure small concentrations down to 3 ppm of NO_2 without any cross-sensitivity to NO.

Project related publications (selection)

[1] P. Fuierer, M. Maier, J. Exner, R. Moos: Anisotropy and thermal stability of hot-forged BICUTIVOX oxygen ion conducting ceramics, *Journal of the European Ceramic Society*, **34**, 943–951 (2014), doi: 0.1016/j.jeurceramsoc.2013.10.016

[2] P. Fuierer, K. Ring, J. Exner, R. Moos: BICU(TI)VOX as a Low/Intermediate Temperature SOFC Electrolyte: Another Look, *Ceramics for Energy Conversion, Storage, and Distribution Systems*, John Wiley & Sons, Inc., Hoboken, NJ, USA (2016), 29–40, ISBN 9781119234531, doi: 10.1002/9781119234531.ch3

[3] J. Exner, P. Fuierer, R. Moos: Aerosol deposition of (Cu,Ti) substituted bismuth vanadate films, *Thin Solid Films*, **573**, 185–190 (2014), doi: 10.1016/j.tsf.2014.11.037

[4] J. Exner, P. Fuierer, R. Moos: Aerosol Codeposition of Ceramics: Mixtures of Bi_2O_3-TiO_2 and Bi_2O_3-V_2O_5, *J. Am. Ceram. Soc.*, **98**, 717–723 (2014), doi: 10.1111/jace.13364

Contact

Prof. Dr.-Ing. Ralf Moos
Ralf.Moos@Uni-Bayreuth.de
Phone: +49 921 55 7401
Fax: +49 921 55 7405
www.funktionsmaterialien.de