Growth kinetics of ZnO nanorods prepared by chemical bath deposition

Nikola Bašinová, Ondřej Černohorský, and Jan Grym

Institute of Photonics and Electronics of the Czech Academy of Sciences, Chaberska 57, Prague, Czech Republic

Zinc oxide nanorods have been extensively studied in the last two decades for their outstanding properties and prospective applications in photonics and electronics. There is a large number of deposition techniques to prepare arrays of ZnO nanorods. Chemical bath deposition (CBD) on a seeded substrate is a frequently used method, which is easily accessible and non-expensive, with many adjustable parameters. In the growth solution, both homogeneous and heterogeneous nucleation take place, which is followed by precipitation and growth of zinc oxide crystals. To obtain well-ordered nanorods with desired physical properties, it is necessary to control the growth conditions. The growth conditions strongly affect the growth mechanism. A key parameter, which significantly alters the growth rates, is the precursor concentration in the growth solution. It is therefore essential to analyse the time evolution of zinc ion concentration and to evaluate the kinetic parameters.

The precursor solution for CBD consists of zinc nitrate and hexamethylenetetramine (HMTA) equimolar solution. Zinc nitrate acts as a source of zinc ions and HMTA supplies hydroxyl ions, both needed to produce ZnO. The OH^- ions are in excess to Zn^{2+} ions; therefore, it is important to analyse the decrease of the Zn^{2+} concentration with time. The consumption of zinc ions corresponds to the formation of ZnO crystals grown directly on the seeded substrate, as well as in the solution. An effective tool for this purpose is a quantitative chemical analysis - titration. It is an accessible and reliable analytical method that provides information about unknown concentration of an identified substance in an analyte solution. The chelatometric titration was used to determine the zinc concentration in the growth solution. The time and temperature dependence of the zinc concentration was investigated. The obtained data together with the SEM image analysis of the grown nanorods are discussed in terms of reversible first-order reaction model and serve for the calculation of the reaction kinetic parameters, from which the growth mechanism can be identified.

This work was supported by the Czech Science Foundation project 17-00355S.

[1] Ashfold, M.N.R., R.P. Doherty, N.G. Ndifor-Angwafor, D.J. Riley and Y. Sun, The kinetics of the hydrothermal growth of ZnO nanostructures. Thin Solid Films, 2007. 515(24): p. 8679-8683.

[2] Černohorský, O., J. Grym, H. Faitová, N. Bašinová, Š. Kučerová, R. Yatskiv and J. Veselý, Modeling of Solution Growth of ZnO Hexagonal Nanorod Arrays in Batch Reactors. Crystal Growth & Design, 2020.

[3] Cheng, J.J., S.M. Nicaise, K.K. Berggren and S. Gradecak, Dimensional Tailoring of Hydrothermally Grown Zinc Oxide Nanowire Arrays. Nano Lett, 2016. 16(1): p. 753-9.

[4] Morin, S.A., M.J. Bierman, J. Tong and S. Jin, Mechanism and Kinetics of spontaneous Nanotube Growth Driven by Screw Dislocations. Science, 2010. 328(5977): p. 476-480.