Reduced Order Modeling and Control of Thin Film Growth in an HPCVD Reactor

S.C. Beeler, G.M. Kepler, H.T. Tran, H.T. Banks

Abstract. This paper describes the development of a reduced order model-based feedback control methodology for regulation of the growth of thin films in a high-pressure chemical vapor deposition (HPCVD) reactor. Precise control of the film thickness and composition is highly desirable, making real-time control of the deposition process very important. The source vapor species transport is modeled by the standard gas dynamics partial differential equations, with the species decomposition reactions, reduced down to a small number of ordinary differential equations through the use of the proper orthogonal decomposition technique. This system is coupled with a reduced order model of the surface reactions involved in the source vapor decomposition and film growth on the substrate. Also modeled is the real-time observation technique used to obtain a partial measurement of the deposition process.

The utilization of reduced order models greatly simplifies the mathematical formulation of the physical process so that is can be solved quickly enough to be used for real-time model-based feedbak control. This control problem is fairly complicated, however, because the surface reactions render the model nonlinear. To deal with this we use a nonlinear feedback control method based on the state-dependent Riccati equation (SDRE). A second SDRE is contained in a state estimator which uses the nolinear partial observations of the growth process to obtain an estimated state on which to base the feedback control. These nonlinear control techniques are implemented on the HPCVD model and the results analyzed as to the effectiveness of the reduced order model and nonlinear control at tracking the desired film growth profile.