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Boundary stabilization of cross-diffusion systems in moving domains

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(joint work with Jean Cauvin-Vila and Amaury Hayat)

This work is motivated by a collaboration with the French Photovoltaic Institute. The aim of the project is to propose a model in order to simulate and optimally control the fabrication process of thin film solar cells. The production of the thin film inside of which occur the photovoltaic phenomena accounting for the efficiency of the whole solar cell is done via a Physical Vapor Deposition (PVD) process. More precisely, a substrate wafer is introduced in a hot chamber where the different chemical species composing the film are injected under a gaseous form. Molecules deposit on the substrate surface, so that a thin film layer grows by epitaxy. In addition, the different components diffuse inside the bulk of the film, so that the local volumic fractions of each chemical species evolve through time. The efficiency of the final solar cell crucially depends on the final chemical composition of the film, which is freezed once the wafer is taken out of the chamber. A major challenge consists in optimizing the fluxes of the different atoms injected inside the chamber during the process for the final local volumic fractions in the layer to be as close as possible to target profiles. Two different phenomena have to be taken into account in order to correctly model the evolution of the composition of the thin film: 1) the cross-diffusion phenomena between the various components occuring inside the bulk; 2) the evolution of the surface. As a consequence, the underlying model reads as a cross-diffusion system defined on a moving boundary domain. The complete optimal control problem of the fluxes injected in the hot chamber is currently out-of-reach in terms of mathematical analysis. The aim of this talk is to theoretically investigate a simpler problem, which is the boundary stabilization of the model used to simulate the PVD process. We show first exponential stabilization and then finite-time stabilization in arbitrary small time of the linearized system around uniform equilibria, provided the underlying cross-diffusion system has an entropic structure with a symmetric mobility matrix. This stabilization is achieved with respect to both the volumic fractions of the different chemical species composing the thin film and the thickness of the latter. The feedback control is derived using the backstepping technique, adapted to the context of a time-dependent domain. In particular, the norm of the backward backstepping transform is carefully estimated with respect to time.

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