On the stability and transition of rotating flows as applied to Chemical Vapour Deposition

Robert Miller (University of Leicester)

Visiting: Dr. Zahir Hussain (Manchester Metropolitan University), Prof. Jitesh Gajjar (University of Manchester)

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Chemical Vapour Deposition (CVD) is a microfabrication process used to grow atomically thin films such silicon wafers or – more recently – graphene. Much work has gone into modelling CVD flows, though due to the low Reynolds numbers used, linear convective instabilities are typically not considered. This work aims to establish analytically whether convective instabilities could be present within the operating parameters of a CVD reactor, and how these might affect the film growth and overall product quality.

The visit began with an informal discussion with Dr. Zahir Hussain and Dr. Frank Bierbrauer over lunch, before heading to a 30-minute seminar held by myself. The presentation consisted of the specifics of CVD and how one would model the effects of the reactor conditions as mechanisms that influence flow stability. Special attention was paid to the steep temperature gradients present in CVD reactors, the effects of which were considered through a temperature-dependent viscosity function and its influence on the appearance of primary instabilities over both a rotating disk and a flat plate. The many insightful questions and lively discussion following the presentation were particularly enjoyable.

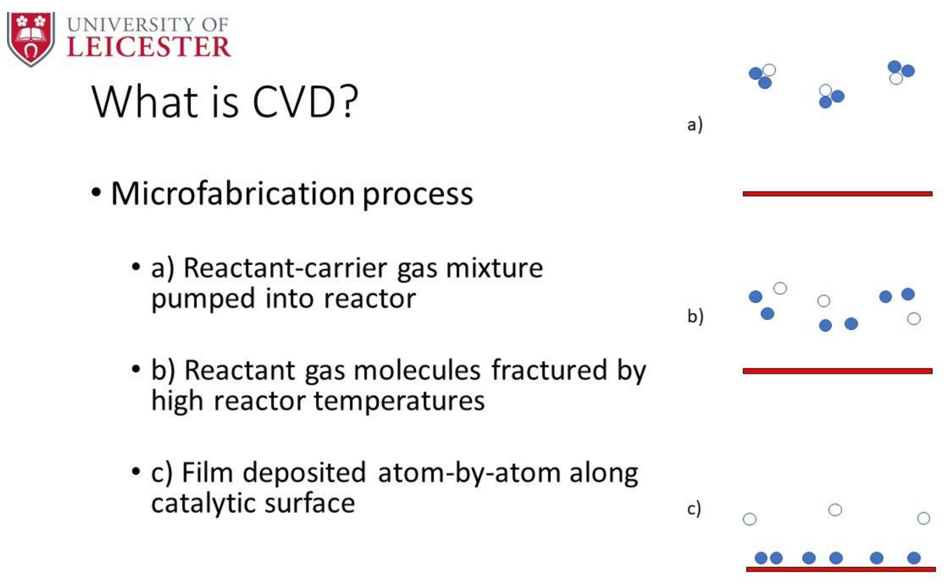

Figure 1 - A slide from the presentation, highlighting the specifics of the CVD process.

We then moved to the common room for coffee with two of Dr. Hussain's masters students, where we discussed the broader scope of instabilities in rotating frames, the possibility of extending their work to PhDs, and opportunities for them to get involved in UKFN activities such as the SRV programme.

The rest of the day was spent in the office. We began by discussing the extension of the disk-type reactor results to incorporate travelling modes of instability, which were speculated to be present due to the intense cleaning and smoothing process required of CVD susceptors i.e. the disk surface.

We also discussed at length the physical interpretation of the variation in boundary layer thickness due to the viscosity temperature-dependence for both the plate and the disk, as well as how this is consolidated with the effects of a forced flow component.

The next day, Dr. Hussain and I met with Prof. Jitesh Gajjar for lunch, where we discussed connections with experimentalists at University of Manchester, particularly regarding the need for rotational rigs built for observing instabilities, as well as the potential of utilising CVD for graphene growth. We then briefly met with Dr. Lida Nejad and discussed how to further develop the current fluid mechanical model to feature chemical kinetics, and the potential for future publications. Finally, we conducted an energy analysis of the stability mechanisms in the temperature-dependent model for both the plate and the disk, which was found to support the physical interpretations made the previous day.

We move forward from this visit with the intention of producing a paper on comparing an asymptotic analysis with numerical results for the stability of forced axial flow with temperature-dependent viscosity over a rotating disk. We will continue working towards future collaborations with Dr. Bierbauer, Dr. Nejad and Prof. Gajjar; employing their expertise in heat transfer, chemical kinetics and flow instabilities, respectively. We also intend to establish links (on behalf of the SIG: “Boundary Layers and Complex Rotating Flows”) with the Japanese research institute “AIST” and utilise the results from their heated, rotating graphene-growth apparatus.