MOCVD Synthesis of Wafer-Scale WSe_2 at the 2D Crystal Consortium: Observations on Growth Dynamics and Exploratory Doping Studies

Andrew R. Graves[1], Yiru Zhu[1], Chen Chen[1], Rohini Sanikop[1], Muhtasim Ul Karim Sadaf[2], Subir Ghosh[2], Saptarshi Das[1,2,3,4], and Joan M. Redwing[1,3,4]

[1]*2D Crystal Consortium Materials Innovation Platform, Materials Research Institute,*
The Pennsylvania State University, University Park, PA USA
[2]*Dep. of Engineering Science and Mechanics,*
The Pennsylvania State University, University Park, PA USA
[3]*Dept. of Materials Science and Engineering,*
The Pennsylvania State University, University Park, PA USA
[4]*Dep. of Electrical Engineering and Computer Science,*
The Pennsylvania State University, University Park, PA USA

Among the most exciting applications of transition metal dichalcogenides (TMDs) is their integration into next-generation scaled electronics where conventional silicon-based approaches face fundamental limitations. In addition to their superior electrostatics at atomic thickness, their 2D nature enables novel, high-density device architectures. Of the TMDs, tungsten diselenide (WSe_2) has emerged as a particularly promising candidate for complementary metal–oxide–semiconductor (CMOS) technologies due to its intrinsic p-type conductivity.

However, to harness this potential for practical electronics, synthesis approaches must deliver high crystalline quality, uniformity over large areas, and compatibility with existing semiconductor manufacturing infrastructure. Metal–organic chemical vapor deposition (MOCVD) satisfies these criteria, offering scalable growth of uniform 2D films on industry-relevant substrates. Furthermore, by tuning growth conditions to promote epitaxial alignment with the substrate, MOCVD enables the formation of high-quality, wafer-scale, nominally single-crystalline films that can be transferred to device platforms with minimal degradation. This is the approach used in the 2D Crystal Consortium at the Pennsylvania State University for the synthesis of WSe_2.

In this talk, we present studies on the growth of WSe_2 films, focusing on how key synthesis parameters influence the film crystalline and chemical quality. We also report newly observed phenomena that emerge during the dynamic growth process. To track film evolution in real time, we employ in situ spectroscopic ellipsometry (SE), building on previous work modeling TMD surface coverage. Post-growth characterization—including in-plane X-ray diffraction (XRD), atomic force microscopy (AFM), Raman spectroscopy, photoluminescence (PL), and X-ray photoelectron spectroscopy (XPS)—offers a comprehensive view of crystalline quality, epitaxial alignment, nucleation density, domain coverage, and phase composition. Together, these tools provide deeper insight into growth mechanisms and highlight the advantages of real-time optical monitoring.

To round out the discussion, we will also touch on recent efforts to achieve controlled p-type doping of WSe_2 films, a critical step toward enabling CMOS-compatible device functionality. These studies explore exposure to dopant gases such as nitric oxide (NO), which offer promising pathways for tuning carrier concentration without compromising film integrity. Taken together, this work provides an integrated view of scalable WSe_2 synthesis, in situ monitoring, and post-growth modification strategies—all essential components in advancing 2D semiconductors from the lab to practical electronic applications.