Public Abstract
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For the advancement of basic science, it is critical to understand, predict, and control the fundamental thin film growth processes and mechanisms. Secondly, in commercial applications, it is important to be able to control the growth of thin films, so one can design, adjust, and tune the desired physical properties.

When an atom is missing from its atomic location, it is considered to be a vacancy defect. If there is a large number of missing atoms conglomerated together, then all the missing material together is called a void or a vacancy cluster defect. This missing material can affect the physical properties of the film such as conductivity[1] and film strain[2], which can impact the growth behavior of thin films. Improving the current understanding of thin film growth by studying and modeling basic systems that show interesting growth phenomena is the focus of my research. Of particular interest is missing material buried below the film's exposed surface [2,4] which can come in the form of vacancies, vacancy clusters, overhangs, or voids that are possibly connected to the surface. There is a wealth of research in the area of thin film growth and yet the lack of evidence for missing material below the exposed surface has prevented a proper understanding of the growth mechanisms leading to the incorporation of vacancies during thin film growth. Theoretical growth models intentionally remove voids, overhangs, or vacancies through mechanisms such as downward funneling[5]. X-rays are able to penetrate beneath the surface and reveal the existence of missing material. Through X-ray reflectivity measurement, I show there is significant evidence for missing material below the exposed surface, that has to be considered to properly in order to understand thin film growth mechanisms.