# Direct MOVPE growth of high-quality h-BN on the wafer-scale: the role of substrate off-cut

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Hexagonal boron nitride (h-BN) is an attractive 2D material for possible applications in electronic and optoelectronic devices based on van der Waals heterostructures, but direct growth of high-quality hBN on the wafer-scale is still the bottleneck for future successful implementation of hBN in industry. Although the growth of h-BN by MOVPE has already been reported [1, 2], there is a fundamental lack in understanding of many basic aspects of growth. In particular, the role of the substrate off-cut, although known to be of major importance for the growth of other materials, has not been fully addressed so far.

In this communication, we present a study that addresses the influence of the sapphire substrate off-cut angle on the final growth of h-BN obtained in a two-step growth procedure [2]. The main process starts with a self-limiting continuous growth (CFG) of a BN buffer followed by flow-modulated epitaxy (FME) in the second step and is used to study substrates with different off-cuts angles for three different CFG times.

Based on results obtained x-ray diffraction and reflectometry, Raman and Fourier-transform spectroscopy, atomic force microscopy and scanning electron microscopy (SEM), we find that a substrate with off-cut angle of 1° clearly yields the highest quality of h-BN layers. Samples with this off-cut have the lowest amount of debris on the surface (see fig. 1), most intense x-ray diffraction signal, minimal Raman phonon linewidth and thinnest amorphous BN part.

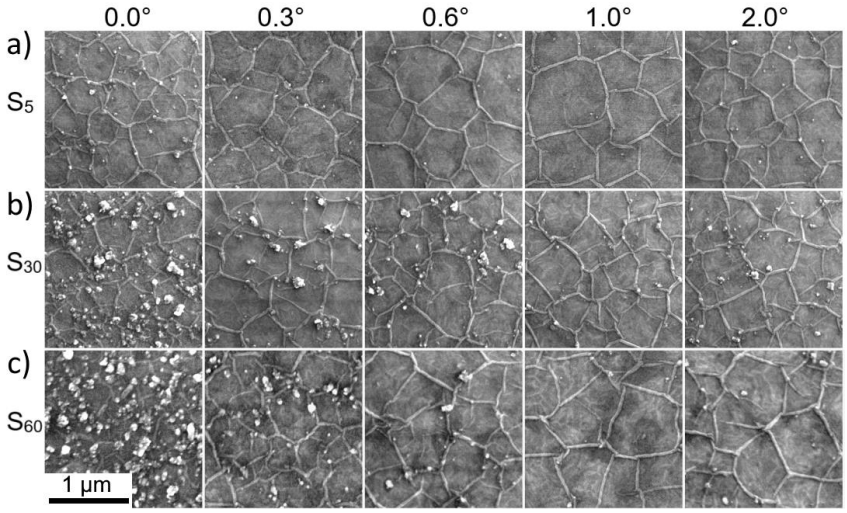


Figure 1. SEM images of the two stage samples grown with 5 min, 30 min and 60 min of the CFG buffer and with a similar 60 min FME final process. a) $S_5$ sample with five off-cuts, b) $S_{30}$ sample with five off-cuts, c) $S_{60}$ sample with five off-cuts.

A detailed analysis of the crystallographic structure of the hBN layers and mechanisms responsible for the existence of an optimal off-cut angle will be discussed.

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[2] A. K. Dąbrowska, et al. 2D Materials **8**, 015017 (2020).
[3] M. Tokarczyk, et al. 2D Materials **10**, 025010 (2023).