The effect of step-flow growth on the surface morphology and optical properties of thick diamond films

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1. Introduction

Thick diamond films with high crystalline quality and low doping are necessary for the manufacturing of high voltage power devices. High growth rates can be achieved by control of the crystal orientation of the substrate. On-axis growth results in large hillocks, visible in optical microscopes. For high-index surfaces where the step density is high, the step-step interaction can lead to the formation of supersteps and even facets. These can be observed as large surface drops along tilted crystal planes, also described as risers. Understanding the step-flow mechanism becomes important for applications involving thick diamond films.

2. Results and Discussion

We present on the various (chevron, step-bunching, step-flow, and island) surface morphologies of thick undoped diamond films grown on a (001) diamond substrate with a 10° miscut along the <100> direction (see plan-view and cross-section images in Fig. 1) and correlate them with their local growth mode and nitrogen content. The high step density for such large miscut angle are found to generate step-bunching leading to step facets. Under step-flow growth mode, step facets exhibit {113} and {013} planes on the chevron, step-bunching, and step-flow regions. An island growth mode is also observed exhibiting {121} step facet. An example of {013} steps are shown in Fig. 2. A possible explanation for the appearance of {113} and {013} planes is the combination of low surface energy and atomically stepped surfaces, see Fig 3.

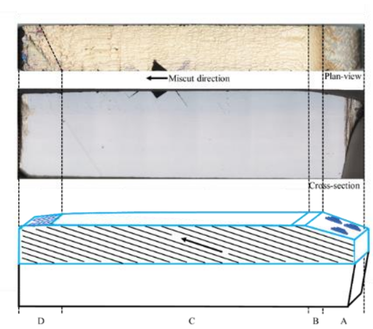

Fig 1.

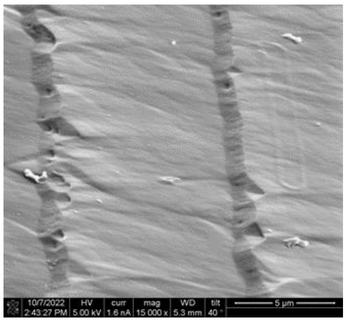

Fig 2.

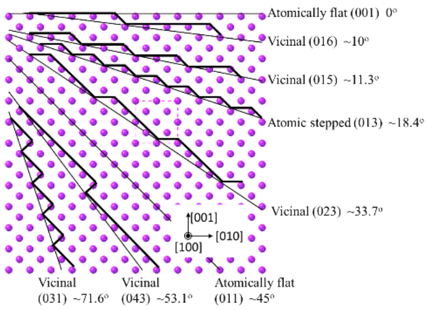

Fig 3.

Cathodoluminescence measurements reveal two dominant optical emissions at 2.154 and 3.189 eV in all regions (see example in Fig. 4(a)), both related to N-containing complexes, $(C_2)_iN^-$ and NV^o, respectively. The emission intensity of the 3.189 eV peak increases with nitrogen and is highly localized on the step facets. Nitrogen incorporation is found to vary across the surface of the film (see Fig. 4(b)) exhibiting the highest content in the chevron region (see Fig. 4(c)) due the higher number of steps and large density of unoccupied bonds.

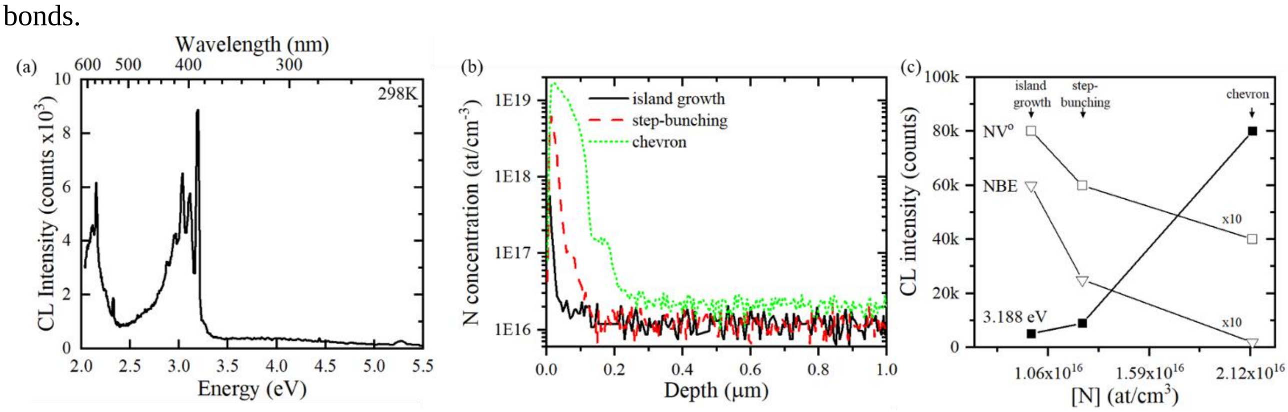

Fig 4.