Work Function and Electronic Structure Measurements on Nitrogen-doped LaB_6 Thin Film Prepared by RF Sputter Deposition

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Lanthanum hexaboride (LaB6) is one of the best thermionic emission materials, because of its low work function. (Figure 1) Therefore, the LaB6 has been widely used as an electron source material for electron microscopes and electron beam lithograph apparatus. However, for realizing the lowest work function of 2.3 eV, the single crystalline bulk material had been persuaded to be absolutely necessary for preventing surface degradation by oxidation. But, recently, a LaB_6 thin film exhibiting the low work function was developed with radio frequency (RF) sputter deposition using a nitrogen-doped (N-doped) LaB_6 target.[1] However, fundamental properties of the film, such as crystallinity, local electronic structures and chemical stability, are still unknown.

On the N-doped LaB_6 thin film formed on SiO_2, we have performed work function and electronic structure measurements by STM. All the measurements were performed at 77 K after annealing at 500 ℃ under UHV conditions.

The surface roughness was estimated to be ~ 0.5 nm over whole area, and the average grain size was approximately 3 nm (Figure 2). The work function and the electronic structures have been derived through I-z and dI/dV characteristics, respectively. We found that, even after air exposure, the work function of 2.35 eV was revived in most areas by annealing at 500℃ under UHV conditions. [2] Furthermore, the characteristic features in the dI/dV spectrum are consistent with the previous photoemission data and the theoretical calculation conducted on the clean pristine LaB_6.[3]

Our results demonstrate that the N-doped LaB_6 thin film revives the low work function status with relatively low-temperature annealing even after air exposure. We anticipate that this film has a potential to realize various high performance electron cathodes exhibiting high efficiency electron emissions.

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[1] H. Ishii et al., ECS Trans. **66**, 23 (2015).
[2] K. Nagaoka et al., JVST **B38**, 062801 (2020).
[3] K. Nagaoka et al., Vacuum **170**, 108973 (2019).

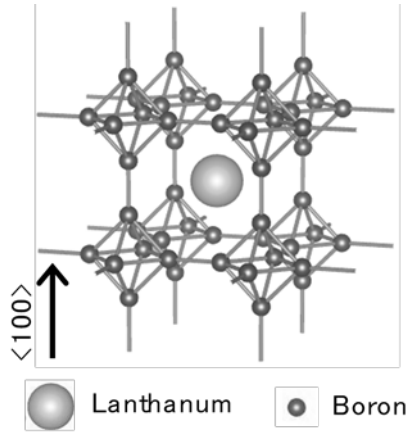

Figure 1: The crystal structure of the LaB_6.

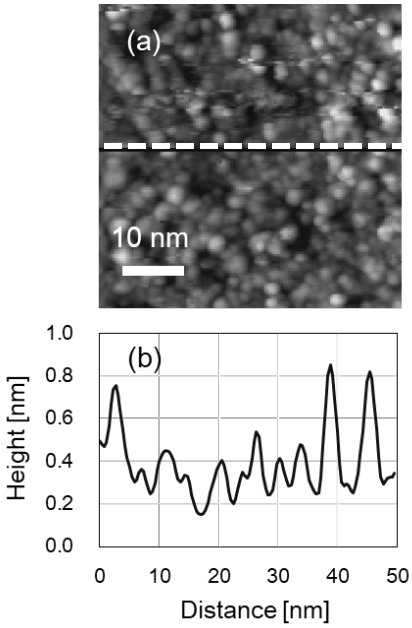

Figure 2: (a) Typical STM image of the N-doped LaB_6 thin film. 50 nm x 50 nm. I = 0.5 nA at Vs = -3.5 V.
(b) The height profile along the white dashed line in (a).