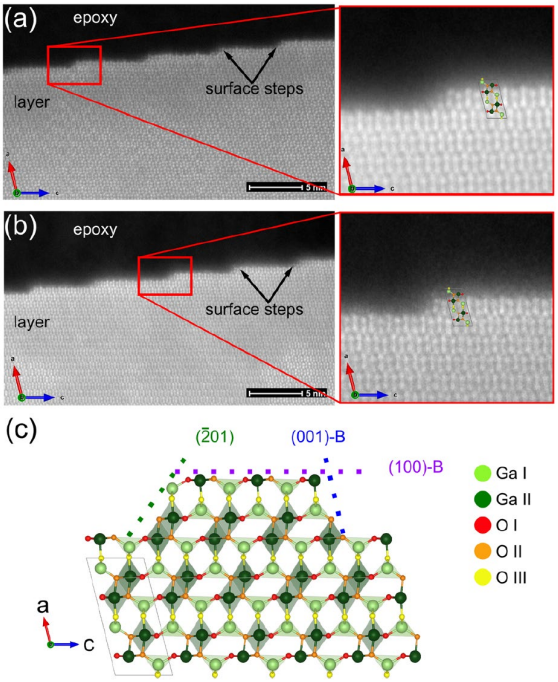

***Figure 5**. [(a) and (b)] STEM HAADF images of the surface of a layer grown on a substrate with $[00\overline{1}]$ and [001] step-down directions, respectively. The magnified regions show the typical step morphology in the [010] projection. (c) shows a stick and ball model of the observed step structure. Bright and dark green balls correspond to tetrahedrally and octahedrally bound Ga columns, respectively. Red, orange, and yellow balls correspond to the 3 different oxygen positions O(I), O(II), and O(III), respectively.*

Conclusions and implications

Our experimental and theoretical work has shown that the differences in surface energies in β-Ga_2O_3 have strong implications on homoepitaxial growth. Faceting originates from surface energy minimization and appears to be reciprocal in case of etching and growth. In fact, a detailed study on surface energy as dependent on the chemical potential still has to be performed by both experiment and theory. Up to now, the (100) surfaces is the only one that shows the desired step flow growth. However, we have also shown that formation of low energy facets at steps and the low symmetry of the monoclinic lattice has strong implications when20choosing the right miscut in β-Ga_2O_3. Unexpectedly the $(\overline{2}01)$ surface has a surface energy that is even lower than that of the second cleavage plane (001). In spite of the fact that substrates with large diameter with these orientations are available it might be worth to study growth on this surface. As in the case of the (100) surface choosing the appropriate miscut might be the key to get high quality layers.

[1] Z. Galazka, R. Uecker, K. Irmscher, M. Albrecht, D. Klimm, M. Pietsch, M. Brützam, R. Bertram, S. Ganschow, and R. Fornari, Cryst. Res. Technol. **45**, 1229 (2010). DOI: 10.1002/crat.201000341

[2] H. Aida, K. Nishiguchi, H. Takeda, N. Aota, K. Sunakawa, and Y. Yaguchi, Jpn. Appl. Phys., Part I **47**, 8506 (2008). DOI: 10.1143/jjap.47.8506

* [3] Z. Galazka, R. Uecker, D. Klimm, K. Irmscher, M. Naumann, M. Pietsch, A. Kwasniewski, R. Bertram, S. Ganschow, and M. Bickermann, ECS J. Solid State Sci. Technol. **6**, Q3007 (2017). DOI: 10.1149/2.0021702jss

[4] G. Wagner, M. Baldini, D. Gogova, M. Schmidbauer, R. Schewski, M. Albrecht, Z. Galazka, D. Klimm, and R. Fornari, Phys. Status Solidi A **211**, 27 (2014). DOI: 10.1002/pssa.201330092

* [5] M. Baldini, M. Albrecht, A. Fiedler, K. Irmscher, D. Klimm, R. Schewski, and G. Wagner, J. Mater. Sci. **51**, 3650 (2016). DOI: 10.1007/s10853-015-9693-6

* [6] M. Baldini, M. Albrecht, A. Fiedler, K. Irmscher, R. Schewski, and G. Wagner, ECS J. Solid State Sci. Technol. **6**, Q3040 (2017). DOI: 10.1149/2.0081702jss

[7] T. Oshima, N. Arai, N. Suzuki, S. Ohira, and S. Fujita, Thin Solid Films **516**, 5768 (2008). DOI: 10.1016/j.tsf.2007.10.045

[8] M.-Y. Tsai, O. Bierwagen, M. E. White, and J. S. Speck, J. Vac. Sci. Technol. A **28**, 354 (2010). DOI: 10.1116/1.3294715

[9] K. Sasaki, M. Higashiwaki, A. Kuramata, T. Masui, and S. Yamakoshi, J. Cryst. Growth 378, 591 (2013). DOI: 10.1016/j.jcrysgro.2013.02.015

[10] K. Nomura, K. Goto, R. Togashi, H. Murakami, Y. Kumagai, A. Kuramata, S. Yamakoshi, and A. Koukitu, J. Cryst. Growth 405, 19 (2014). DOI: 10.1016/j.jcrysgro.2014.06.051

[11] H. Murakami, K. Nomura, K. Goto, K. Sasaki, K. Kawara, Q. T. Thieu, R. Togashi, Y. Kumagai, M. Higashiwaki, A. Kuramata, S. Yamakoshi, B. Monemar, and A. Koukitu, Appl. Phys. Express 8, 015503 (2015). DOI: 10.7567/APEX.8.015503

* [12] R. Schewski, M. Baldini, K. Irmscher, A. Fiedler, T. Markurt, B. Neuschulz, T. Remmele, T. Schulz, G. Wagner, Z. Galazka, and M. Albrecht, J. Appl. Phys. 120, 225308 (2016). DOI: 10.1063/1.4971957

[13] Sasaki et al. Journal of Cryst. Growth 392, 30 (2014). DOI: 10.1016/j.jcrysgro.2014.02.002

[14] Sang-Heon Han, et al. Semicond. Sci. Technol. 33, 045001 (2018). DOI: 10.1088/1361-6641/aaae56

[15] S. Rafique, L. Han, A. T. Neal, S. Mou, M. J. Tadjer, R. H. French, and H. Zhao, Appl. Phys. Lett. 112, 052104 (2018). DOI: 10.1063/1.5017616

[16] V. Bermudez, Chemical Physics 323, 193 (2006). DOI: 10.1016/j.chemphys.2005.08.051

[17] G. Wulff, Zeitschrift für Krystallogr. 34, 29 (1901).

* [18] P. Mazzolini, P. Vogt, R. Schewski, C. Wouters, M. Albrecht, and O. Bierwagen, APL Mater. 7, 022511 (2019). DOI: 10.1063/1.5054386

* [19] R. Schewski, K. Lion, A. Fiedler, C. Wouters, A. Popp, S. V. Levchenko, T. Schulz, M. Schmidbauer, S. Bin Anooz, R. Grüneberg, Z. Galazka , G. Wagner, K. Irmscher , M. Scheffler, C. Draxl, and M. Albrecht, APL Mater. **7**, 022515 (2019). DOI: 10.1063/1.5054943

* [20] A. Fiedler, R. Schewski, M. Baldini, Z. Galazka, G. Wagner, M. Albrecht, and K. Irmscher, J. Appl. Phys. 122, 165701 (2017). DOI: 10.1063/1.4993748

GraFox publications are highlighted by an "*".