Electronic Supplementary Material (ESI) for CrystEngComm.
This journal is © The Royal Society of Chemistry 2022

**Supplementary Information**

# Pre-reaction suppressing strategy for α-$Ga_2O_3$ halide vapor pressure epitaxy using asymmetric precursor gas flow

Sunjae Kim[a,b,f,§], Hyeon Woo Kim[c,d,§], Hyeong-Yun Kim[a,e], Dae-Woo Jeon[a], Sung Beom Cho[c,*] and Ji-Hyeon Park[a,*]

[a]Korea Institute of Ceramic Engineering and Technology, Jinju, Gyeongsangnam-do 52851, Republic of Korea

[b]Department of Materials Science and Engineering, Korea Aerospace University, Goyang, 10540, Republic of Korea.

[c]Convergence Technology Division, Korea Institute of Ceramic Engineering and Technology (KICET), Jinju-si 52851, Republic of Korea

[d]Division of Materials Science and Engineering, Hanyang University, Seoul, 04763, Republic of Korea

[e]Department of Material Science and Engineering, Pukyong National University, Busan, 48513, Republic of Korea.

[f]Department of Smart Air Mobility, Korea Aerospace University, Goyang, 10540, Republic of Korea

*Corresponding author:

Ph.D. Ji-Hyeon Park, E-mail: jhp5511@kicet.re.kr

Ph.D. Sung Beom Cho, E-mail: csb@kicet.re.kr

[§]These authors equally contributed to this work.

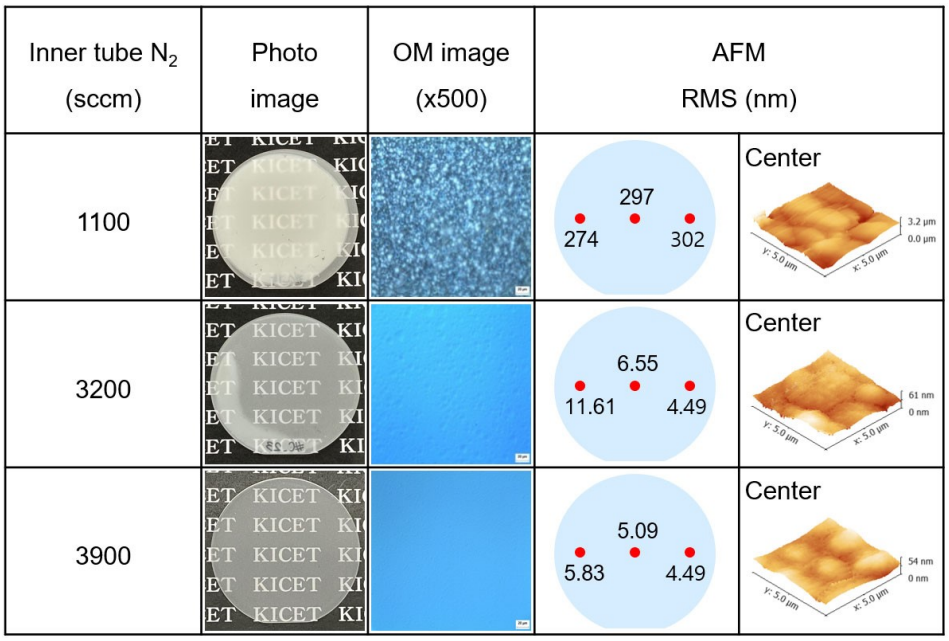


**Fig. S1** Photo, OM, and AFM images showing surface morphologies of the α-$Ga_2O_3$ epilayer according to the inner tube $N_2$ carrier gas flow rate control for asymmetric gas supply to suppress pre-reaction.

Fig. S1 shows the surface morphology of the α-$Ga_2O_3$ epilayer according to different inner tube carrier gas flow rate in the form of photo, OM, and AFM images. At a $N_2$ carrier gas flow rate of 1100 sccm, pre-reaction can occur because the relatively low carrier gas flow rate provides sufficient time for the main precursors to react before reaching the substrate. As a result, $Ga_2O_3$ powder was deposited on the substrate, and the surface RMS value as high as 297 nm was observed. By increasing the flow rate to 3200 sccm, a large amount of powder on the surface of the 2-inch substrate disappeared; however, some powder still exist on the surface, and several pits were observed in the OM image. At the flow rate of 3900 sccm, it displayed a clean surface and low RMS value of 5.09 nm. By increasing the carrier gas, the pre-reaction was effectively suppressed.

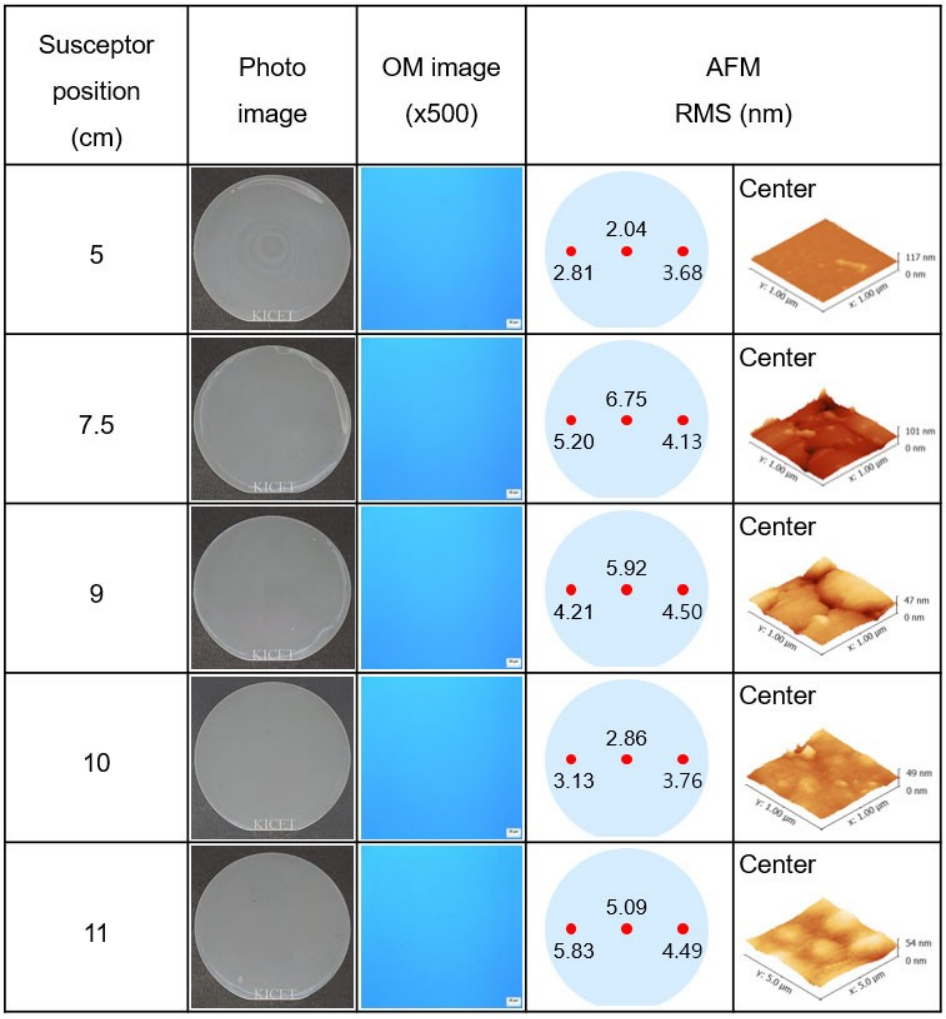


**Fig. S2** Susceptor position control for uniform growth of the α-$Ga_2O_3$ epilayer: Photo, OM, and AFM images.

Fig. S2 shows the surface morphologies of the α-$Ga_2O_3$ epilayer according to different susceptor positions as photo, OM, and AFM images. The distribution of the main precursor in the substrate was controlled by adjusting the susceptor position. The difference in surface roughness according to the susceptor position was insignificant. This is the effect of suppressing the pre-reaction by optimally setting the $N_2$ gas flow rate.

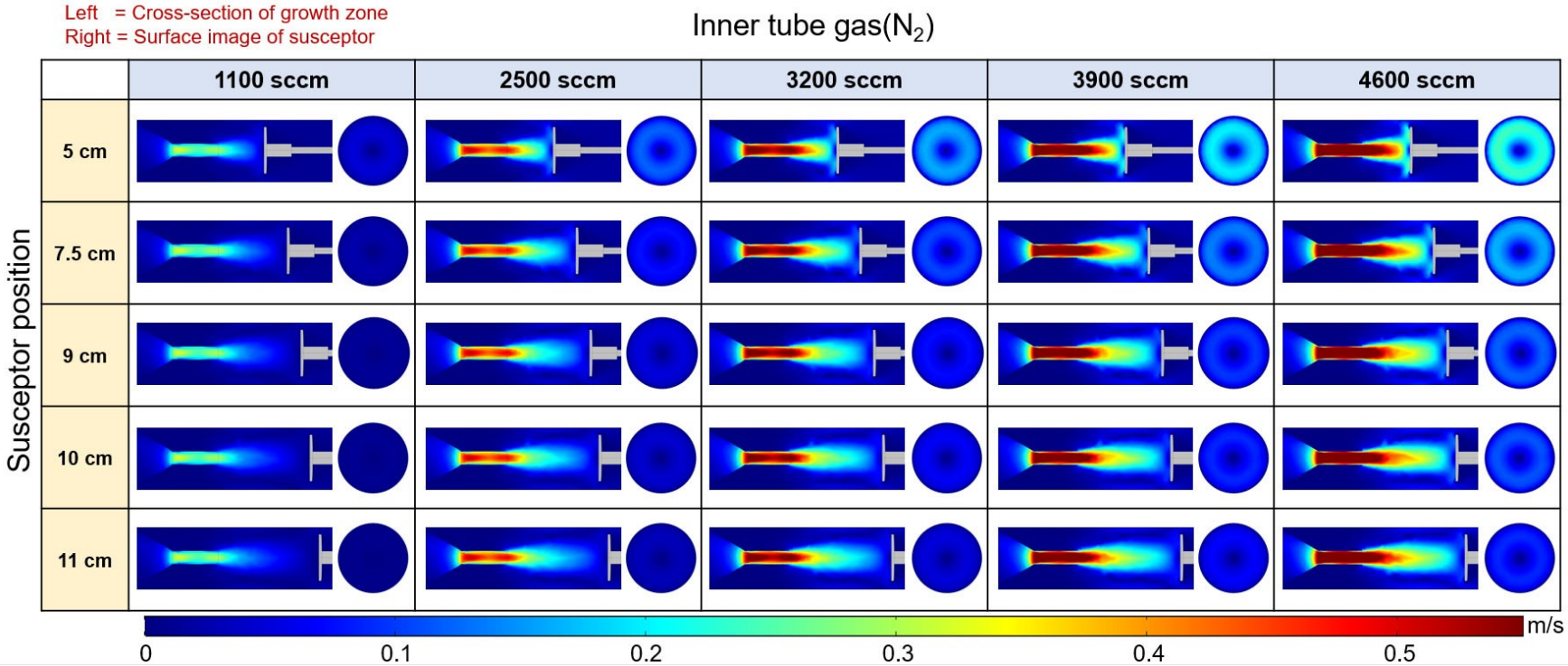


**Fig. S3** Gas velocity simulation with different inner tube $N_2$ carrier gas flow rates and susceptor positions.

Fig. S3 displays the cross-sections of growth zone and surface images of susceptor obtained from the gas velocity simulation for the inner tube carrier gas at different flow rates of 1100–4600 sccm and different susceptor positions of 5–11 cm. To grow a uniform α-$Ga_2O_3$ epilayer, the gas velocity should be 0.038–0.047 m/s and the deviation should be less than 0.02 m/s.

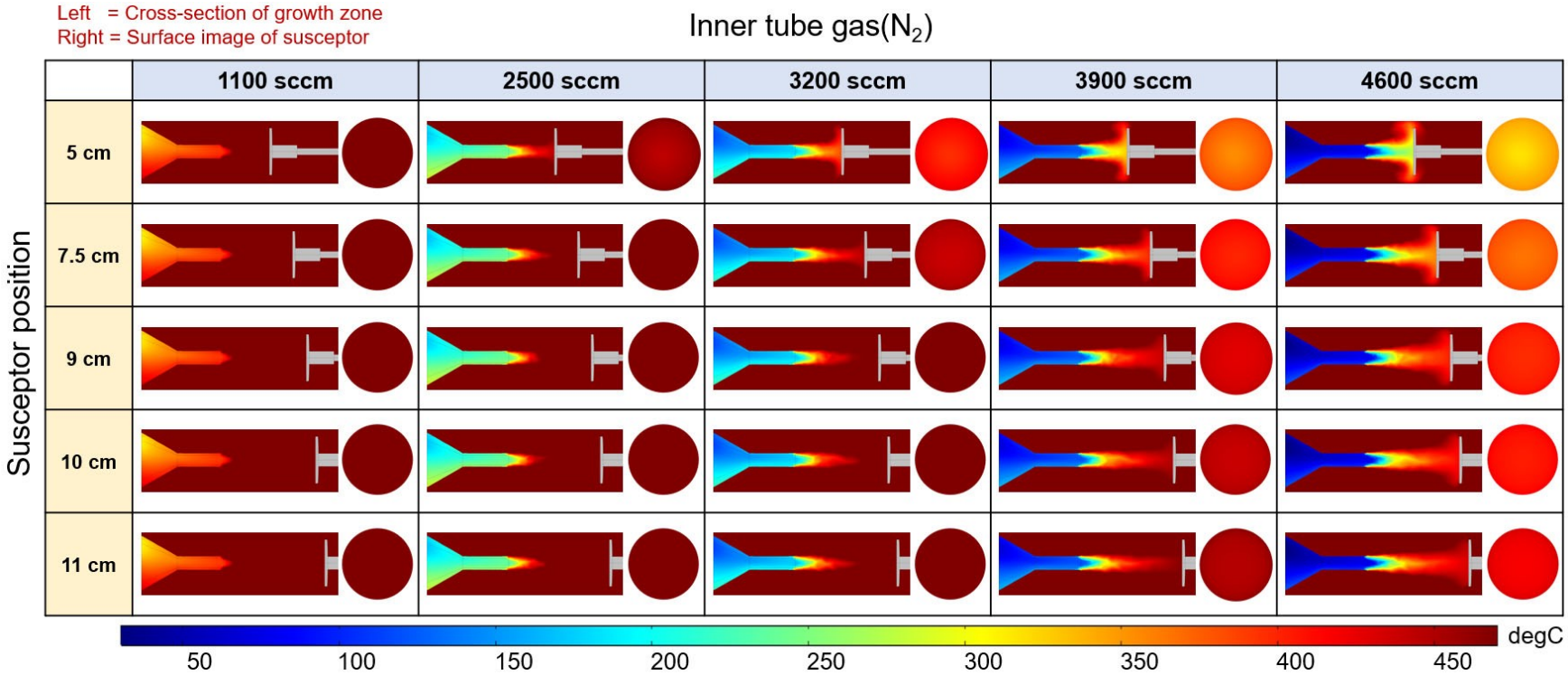


**Fig. S4** Temperature simulation with different inner tube $N_2$ carrier gas flow rates and susceptor positions.

Fig. S4 shows the results of temperature simulation at inner tube carrier gas flow rates of 1100–4600 sccm and susceptor positions of 5–11 cm. A High-quality α-$Ga_2O_3$ epilayer can be grown at a gas temperature of 470 °C and a deviation of less than 1 °C.

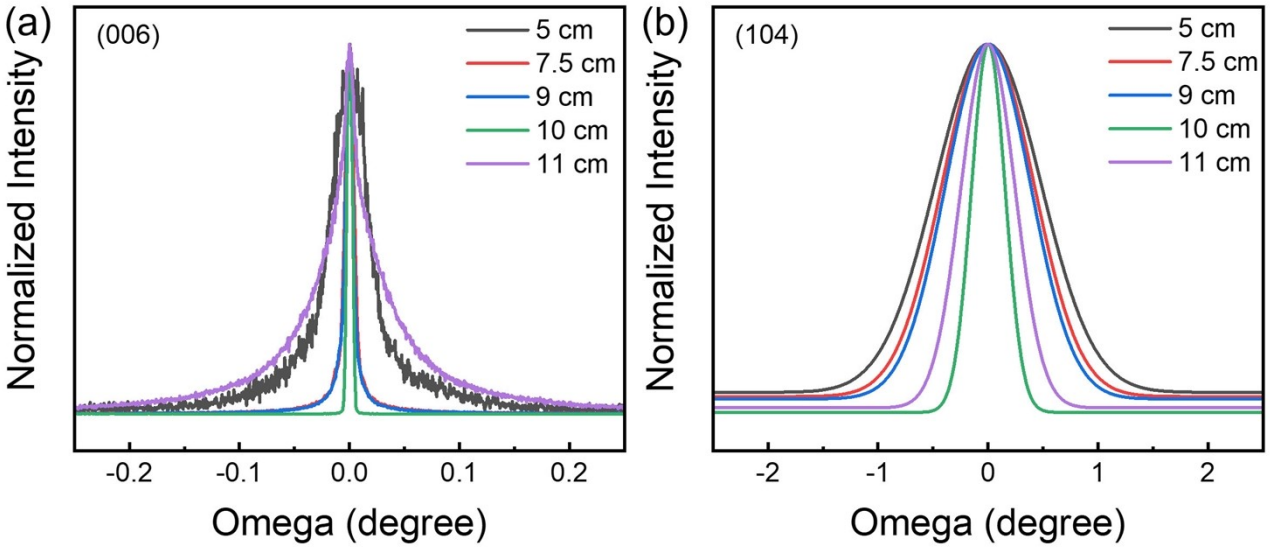


**Fig. S5** X-ray omega rocking curves of the α-$Ga_2O_3$ epilayers grown at different susceptor positions: (a) (0006) and (b) (10-14) reflections.

Fig. S5 shows (0006) and (10-14) reflection X-ray omega rocking curves of the α-$Ga_2O_3$ epilayers grown at different susceptor positions ranging from 5 cm to 11 cm. At different susceptor positions, the (0006) peaks have an FWHM value of 29–155 arcsec, and the (10-14) peak has an FWHM value of 1301–4041 arcsec. FWHM increases as the susceptor position becomes shorter or longer than the proper position. The proper position means the susceptor position under optimal conditions.