III-V semiconductor epitaxy based on machine learning and in-situ feedback control

Chao Zhao[1], Chao Shen[1], Bo Xu[1], Zhanguo Wang[1]
[1] Institute of Semiconductors, CAS

Introductions

Traditional molecular beam epitaxy (MBE) material growth optimization usually adopts a time-consuming trial-and-error approach. Although numerical simulation methods are introduced, they still rely on fixed growth parameters output from the model to guide subsequent material growth. [1-2] So far, there are limited reports on dynamically adjusting growth parameters based on feedback control during the material growth process. In addition, further optimization and fine control of the growth process are required to achieve film growth with stable performance. [3]

Methods

This study takes self-assembled quantum dots as the research goal to verify the feasibility of the variable parameter growth method under feedback control and open up a new paradigm for semiconductor epitaxial growth. Through machine learning technology, the surface reconstruction time series images obtained in situ are correlated with the quantum dot information obtained by the atomic force microscope.

Results

During the material growth process, the output results of the machine learning model guide the dynamic optimization of parameters, achieving real-time feedback control of the growth parameters and successfully adjusting the quantum dot density. [4]

Conclusion

Compared with traditional methods, our method has in-situ adjustment capabilities and reliability, which can significantly accelerate the material optimization process and improve the repeatability of MBE growth. Its concepts and methods are expected to be applied in the growth process of various materials and will bring profound changes to the microelectronics and optoelectronics industries.

References

[1] Currie K R, LeClair S R and Patterson O D, Self-Directed, Self-Improving Control of a Molecular Beam Epitaxy Process, IFAC Proceedings Volumes, 1992, 25(28), 83-87

[2] Currie K R and LeClair S R, Self-improving process control for molecular beam epitaxy, The International Journal of Advanced Manufacturing Technology, 1993, 8(4), 244-251

[3] Feng J, Yang F, Wang Z, et al., Growth of SrTiO3(110) film by oxide molecular beam epitaxy with feedback control, AIP Advances, 2012, 2(4)

[4] Chao Shen, Wenkang Zhan, Kaiyao Xin, et al., Machine-Learning-Assisted and Real-Time-Feedback-Controlled Growth of InAs/GaAs Quantum Dots, arXiv preprint arXiv:2306.12898