Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.764-765

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# Precise Control of Growth of VCSEL Structure by using MBE in-situ Reflectance Monitor

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## 1. Introduction

MBE can control the thickness of grown films at atomic scale but has some problem in reproducibility due to the change in the growth rate with the consumption of the source materials. That makes it difficult to fabricate the structure of vertical-cavity surface-emitting laser (VCSEL) which requires highly precise control of growth. In this paper, we report a new method to control the fabrication of VCSEL structure by using a MBE in-situ reflectance monitoring system.

## 2. Experimental[1]-[3]

The MBE in-situ reflectance monitoring system was illustrated in Fig.1. Light come from the halogen lamp irradiated the substrate in MBE, and its reflection was taken out through an optical fiber and monitored in real time by the spectrometer. Fig.2 shows the structure of VCSEL. It consists of a 35-pair Si doped $Al_{0.1}Ga_{0.9}As$ /AlAs bottom DBR, the optical cavity composed of a GaAs active layer sandwiched between top and bottom cladding layers, an oxide layer, a contact layer, and a 22-pair undoped $Al_{0.1}Ga_{0.9}As$/AlAs top DBR. The center wavelength of DBR and the resonant wavelength of the cavity were set 870 nm. By using the MBE in-situ reflectance monitoring system, MBE growth was controlled to obtain precise thickness of each layer for a desirable optical performance.

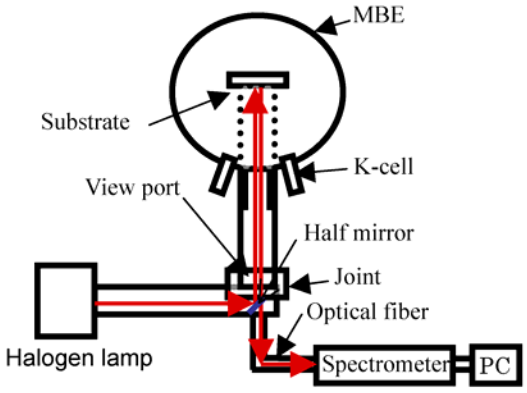


Fig.1 *In-situ* reflectance monitoring system

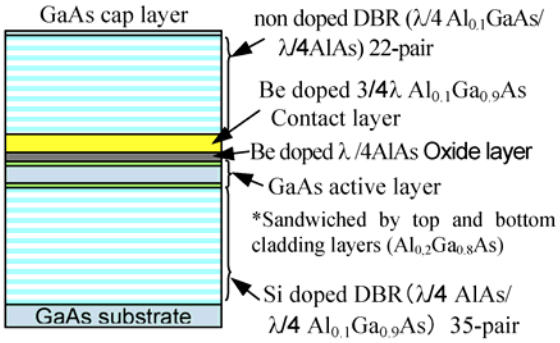


Fig.2 VCSEL structure

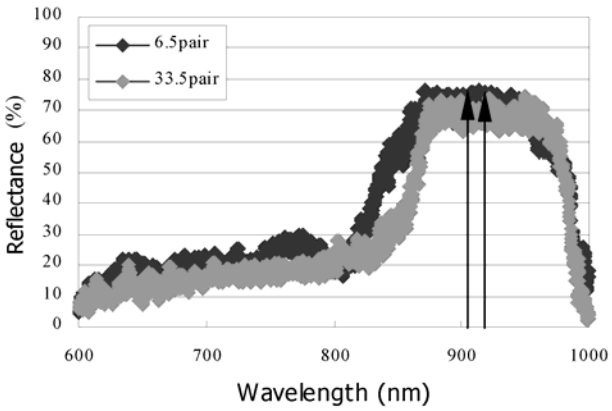


Fig.3 Reflectance of DBR in the growth by *in-situ* monitoring

## 3. Results and Discussion

The reflectance spectrum of the structure of DBR was shown in Fig.3. The target center wavelength was corrected to 920 nm, considering that reflective index shifts as temperature changed in the growth. When the bottom DBR grew by 6.5-pair, the center wavelength was shortened as 905 nm. By adjusting the MBE growth time, the DBR with the center wavelength of 920 nm was successfully achieved after 33.5-pair growth as shown in Fig.3. The reflectance spectrum of the cavity structure was shown in Fig.4.

In-situ growth monitoring showed that the dip resulted from the cavity wavelength moved as the growth proceeded. When it reached 920 nm, we stopped the

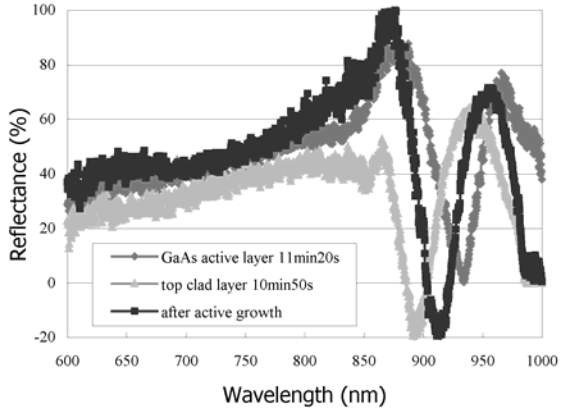


Fig.4 Transition of resonant wavelength with cavity growth by *in-situ* monitoring

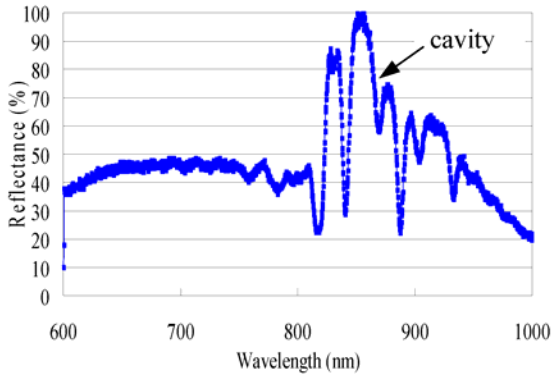


Fig.5 Reflectance at room temperature after growth

growth of the cavity structure to establish the resonant wavelength of the cavity of 920 nm. The reflectance spectrum of the structure of VCSEL at room temperature shown in Fig.5 indicates three dips appeared in the reflectance spectrum of the upper DBR. Two of these at 840 nm and 887 nm, were resulted from the reflection of the interface of the cladding layer, and the other at 865 nm was considered as a resonant wavelength of the cavity. The lasing characteristic of the fabricated VCSEL using the wafer was shown in Fig.6. The VCSEL was oscillated under the pulsed-wave condition at room temperature ($I_{th}$=45mA, duty ratio=0.3%), and its oscillating wavelength was 864 nm which was almost the same as the resonant wavelength of the cavity.

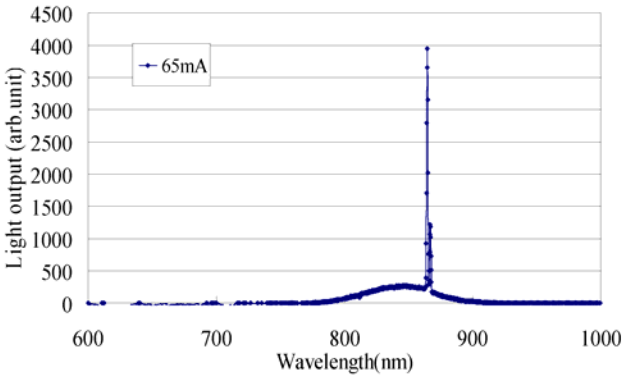


Fig.6 Oscillation spectrum of VCSEL

## 4.Conclusion

The fabricated layer structure like VCSEL can be precisely controlled by using the MBE in-situ reflectance monitoring system. Since the optical property is directly measured by our system, it greatly helps the laser structure to assure the designed optical performance of the laser.

## Acknowledgement

This work was partly supported by Grant-in-Aid for Priority Areas (B) “Realization of dislocation-free epitaxy with the aid of nanochannel” No.14350172 and the 21st century COE program from the Ministry of Education, Culture, Sports, Science and Technology.

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