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Design and Characteristics of InGaAs/GaAs MQW SEED Arrays Structure*

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Abstract: The influence of DBR in resonant-cavity on the characteristics of the reflectivity of InGaAs/GaAs MQW SEED arrays has been discussed. InGaAs/GaAs acting as the active region of MQW SEED to gain 980nm work wavelergth has been introduced. A new resonant-cavity structure of the InGaAs/GaAs MQW SEED arrays has been designed and analyzed. The MQW materials grown by MOCVD system have also been measured and analyzed with micro-optical-spot reflection spectra, PL measurement and X-ray measurement. The results of measurement prove the good quality of the wafer and the accuracy of our design and analysis of the structure of the device.

Key words: resonant-cavity; SEED; arrays; optoelectronics devices
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1 Introduction

In the fields of optical interconnection and computation, the high-density silicon CMOS circuit is desired to be integrated with the high performance GaAs-based optoelectronic devices. And some GaAs/AlGaAs multiple quantum well (MQW) self-electro-optic-effect devices (SEED) arrays have been integrated with the silicon CMOS circuit successfully via flip-chip bonding[1,2]. In an optoelectronic device, the MQW structure placed in the intrinsic region of a p-i-n configuration allows for usage of the quantum-confine Stark effect (QCSE) to obtain the light modulation and detection[3,4]. Although the InGaAs/GaAs MQW SEED has been investigated[5], no much attention has been paid to the integration arrays of it with the silicon circuit. In this paper, the structural design and material analysis of the InGaAs/GaAs MQW SEED arrays are proposed at a wavelength of 970nm. In order to gain a big enough absorption coefficient with few MQW, an asymmetric Fabry-Perot (ASFP) structure is employed in the structures of the devices.

2 Design and Analysis of MQW Structure

InGaAs/GaAs MQW SEED wafers were

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grown by MOCVD. A layered representation and relative parameters of the InGaAs/GaAs MQW SEED are shown in Fig. 1. Light was inputted through the GaAs substrate and resonant in ASFP. Followed by the 140nm p-AlGaAs and 50nm i-AlGaAs spacer, the first 9 pairs of Distribute Bragg Reflection (DBR) was grown on the GaAs substrate, which acts as the bottom mirrors. Then the MQW, which consisted of 3 periods of 8nm $In_{0.2}Ga_{0.8}As$ wells and 10nm GaAs barriers, the 110nm n-AlGaAs spacer, and 27 pairs of DBR, which acted as the top mirrors of ASFP, were grown in turn. The calculated reflectivity of the bottom R_b and that of the top Bragg mirror R_t are 92.4% and 99.9% respectively.

GaAs	N	$10^{19}cm^{-3}$	20nm
GaAs	N	$4\times10^{18}cm^{-3}$	49nm
AlGaAs	N	$2\times10^{18}cm^{-3}$	80nm
27×	GaAs	N	69nm
	AlGaAs	N	80nm
AlGaAs	N		110nm
GaAs	i		10nm
3×	InGaAs	i	8nm
	GaAs	i	10nm
AlGaAs	i		50nm
AlGaAs	P		140nm
9×	GaAs	P	69nm
	AlAs	P	80nm
SI	GaAs	Substrate	

FIG. 1 Schematic Representation of Structure of InGaAs/GaAs MQW SEED

The reflectivity at the F-P cavity wavelength (R_{FP}) and the full width half maximum (FWHM) are two important factors influencing the characteristic of SEED. The more R_{FP} is lowed, the larger proportion of the input light can transmit into ASFP. When the wavelength of the input light shifting slightly, the SEED with wide FWHM can work on. According to the layered representation in Fig. 1, the number of pairs of bottom DBR affects both R_{FP} and FWHM of the reflectivity spectrum, as can be seen in Fig. 2. With the number of pairs of bottom DBR increasing, the FWHM decreases, and the R_{FP} at first decreases and subsequently increases for more pairs of bottom DBR. If the number of pairs of the bottom DBR is less than 9, the reflectivity of bottom DBR is low and the resonant effect in ASFP is weak; but the R_{FP}, mainly determined by the top DBR (27 pairs), is very high. On the contrary, the reflectivity of bottom DBR is very high, and only few input light can transmit into ASFP. Although the resonant effect in ASFP is strong, the R_{FP}, mainly determined by the bottom DBR, is very high. In order to get a low R_{FP} and wide FWHM, the number of bottom DBR in the structure shown in Fig. 1 should be selected as 9.

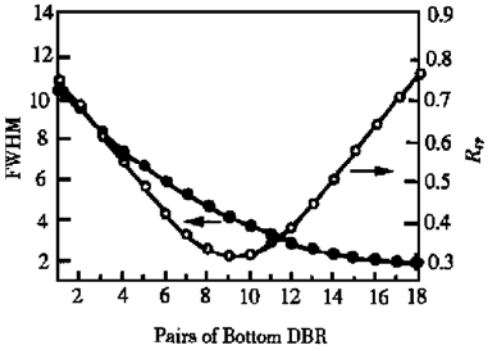

FIG. 2 R_{FP} and FWHM in Reflectivity as Function of Number of Pair of Bottom DBR

The absorption coefficient is calculated by the method[6] given by Huang Yong-zhen and the expression given by Mares and Chuang in their model of a GaAs/AlGaAs SEED[7]. Figure 3 shows the predicted absorption coefficient as a function of

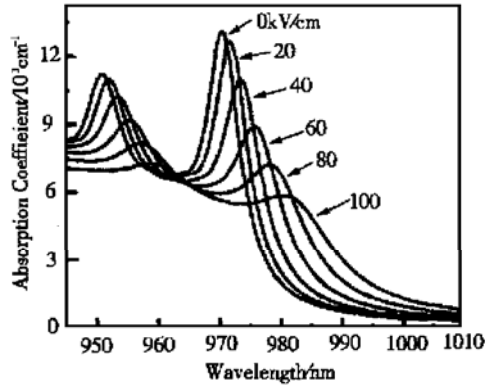

FIG. 3 Theoretical Absorption Spectrum of $In_{0.2}Ga_{0.8}As$/GaAs Quantum Well at Different Biases

wavelength at several reverse biases, as is similar to that of the GaAs/AlGaAs quantum well. For the structure in Fig. 1, R_{FP} increases sharply and a red shift takes place due to the applied reverse bias (Fig. 4). At the zero-bias, the F-P cavity wavelength is relative to the exciton peak, which can induce great absorption in MQW. With the increase of electric field perpendicular to QW, the exciton peaks red shift and the absorption decreases in magnitude, so does the absorption at F-P cavity wavelength in cavity. And the R_{FP} will rise.

3 Experimental Results of MQW Material and Device

Grown by metal organic chemical vapor deposition (MOCVD) in AIX200 reactor system, the ASFP structure reported here was grown on the SI-GaAs(100) substrate, which was rotated during the growth. Photoluminescence(PL) measurement, double crystal X-ray diffraction measurement and micro-optical-spot reflection spectra were carried out to evaluate the quality of the wafers.

In PL measurement, wet chemical etching was used to remove the top DBR over the InGaAs/GaAs MQW. The light source in the PL measurement was Ar^+ laser. The excitation beam of 5mW was focused on the sample sized of 1mm as the weak excitation. There exist two emission bands; one is at 873nm, belonging to GaAs layers above the InGaAs/GaAs MQW, while the other at 966nm corresponds to the InGaAs. FWHM of InGaAs peak was 25.9meV. These data show that the crystal quality of the grown InGaAs/GaAs MQW is so good to apply to an active region of the InGaAs/GaAs MQW SEED.

Figure 4 shows the measured and theoretical reflectivity of the structure in Fig. 1. The F-P cavity wavelength of the measured minimum reflectivity is 968.7nm, which is almost the same as the calculated one. The minimum of the measured reflectivity at zero-bias is about 43.8% and the FWHM of reflectivity is 5.76nm, which are similar to design ones, 36.4% and 5.25nm, respectively. According to the previous discussion, the offset is primarily because that the measured reflectivity of bottom DBR is lower than the calculated one. The results of X-ray diffraction measurement indicate that the bottom DBR is thinner than the design value, and thus the reflectivity at F-P cavity wavelength must be lower than the calculated one. The measurement results above prove the validity of our design.

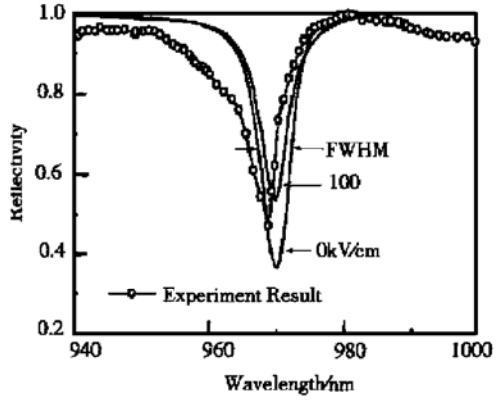

FIG. 4 Experimental and Theoretical Reflectivity of Structure in Fig. 1

4 Conclusion

The influence of the bottom DBR in resonant-cavity on the characteristics of the reflectivity of InGaAs/GaAs MQW SEED arrays has been discussed. A new resonant-cavity structure of InGaAs/GaAs MQW SEED arrays has been designed and analyzed. The MQW materials grown by MOCVD system are measured and analyzed by micro-optical-spot reflection spectra, PL measurement and X-ray measurement. The measured results accord with the design values, as proves the good quality of the wafer and the accuracy of our design and analysis of the device structure.

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InGaAs/GaAs 多量子阱 SEED 面阵结构特性与设计*

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摘要: 讨论了谐振腔中的 DBR 对 InGaAs/GaAs 多量子阱 SEED 面阵光反射特性的影响. 采用 InGaAs/GaAs 作为多量子阱 SEED 器件的有源区, 从而获得了 980nm 工作波长. 设计和分析了 InGaAs/GaAs 多量子阱 SEED 中的一种用于倒装焊的新型谐振腔结构. 多量子阱材料是用 MOCVD 系统生长, 利用微区光反射谱、PL 谱以及 X 射线双晶衍射对多量子阱材料进行了测量和分析, 测量结果表明多量子阱材料具有良好的质量, 证明了器件结构的设计和分析是准确的.

关键词: 谐振腔; SEED; 面阵; 光电子器件

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