DEVELOPMENT OF STRAINED GaAs POLARIZED ELECTRON SOURCE

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Abstract

We are studying the electron spin polarization(ESP) of photoemitted electron beam from the strained GaAs layer grown on the GaPAs substrate, as a function of thickness of GaAs layer. Three samples(#1,#2 and #3), which had thickness of 0.08, 0.14 and 0.40 μm, were already tested. The maximum ESP of 86%,83% and 67% were observed with quantum efficiency(QE) of 2×10^{-4},8×10^{-4} and 10×10^{-4} respectively, under the conditions that samples were kept at room temperature and the excitation photon wavelengths were around $\lambda \approx$870nm.

1. Introduction

The polarized electron source(GaAs-PES) is the best available, because it has many intrinsic advantages in performance of intensity and time resolution. But, there was also the big drawback, namely the ESP is limited to be 50% because of the degeneracy between a heavy- and light-hole band.[1]

Recently we have broken through this limit. We just obtained the ESP of 86% and 75% by using the new samples of strained GaAs[2] and the GaAs-AlGaAs superlattice[3], respectively.

The next step what we have to do seems to be the systematic study on the parameter optimization of samples for higher ESP and QE. There are at least three free parameters which we can control; 1) the GaAs layer thickness, 2) the magnitude of lattice mismatch and 3) the amount of p-dopant in the strained GaAs layer. The item 2) defines the energy splitting between the heavy- and light-hole bands and the item 3) seems to affect partly the depolarization inside the strained GaAs.

As a part of such a study, we report here the results of ESP and QE measurement of photoemitted electrons from the three strained GaAs samples with the nearly same lattice mismatch and p-doping but different thicknesses of GaAs layer.

2. Experiment

The GaPAs substrate and the GaAs layer were grown in an atmospheric pressure and a temperature of 800°C by the MOCVD reactor of New Materials Research Laboratory of Daido Steel Co.Ltd.[2]

The parameters of three samples are shown in Table 1. For those samples, the energy splittings between a heavy- and light-hole band were nearly same as estimated to be 40,40 and 31 meV, respectively.

GaAs	(Zn-doped 5×10^{18}cm^{-3})	t=0.08, 0.14, 0.40 μm (#1, #2, #3)
GaP_xAs_{1-x}	(Zn-doped 5×10^{18}cm^{-3}) x=0.17, 0.17, 0.13 (#1, #2, #3)	t=2 μm
GaAs	(Zn-doped 5×10^{18}cm^{-3})	t=350 μm

Table 1

Measurements of ESP and QE were done by the PES apparatus constructed at Nagoya University, which consists of a 4 keV electron gun and a 100 KeV Mott polarization analyzer.[4] Each sample was activated to obtain the NEA surface with Cs and O_2 in ultra high vacuum chamber.

Figure 1(a)~1(c) and Figure 2(a)~2(c) show ESP and QE measured as a function of laser wavelength. The maximum ESP (Fig.1) for each sample was obtained around the wavelength of $\lambda \approx$ 870nm which enable the excitation of only heavy hole band. The shoulders of ESP around $\lambda \approx$800nm in Fig.1(a) and 1(b) show that the full contribution from the light-hole band becomes possible at this wavelength. Here, the strained GaAs layer seems to play the same role as an unstrained thin GaAs photocathode. Below the wavelength of $\lambda \approx$800nm, the contamination of photoelectrons from GaPAs substrate becomes dominant and the ESP drops down to the 30% level. These behavior of ESP corresponds very well to that of the QE curve, as shown in Fig.2(a) or 2(b).

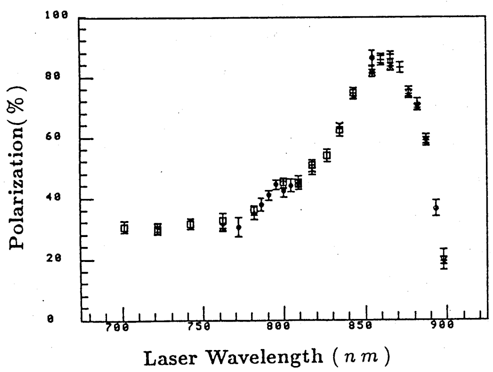

Fig. 1(a)

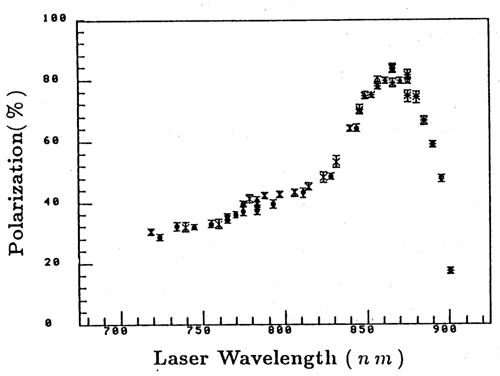

Fig. 1(b)

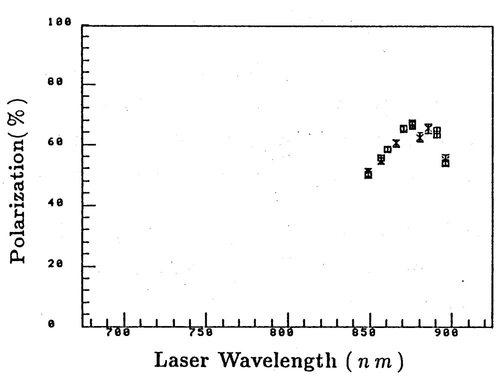

Fig. 1(c)

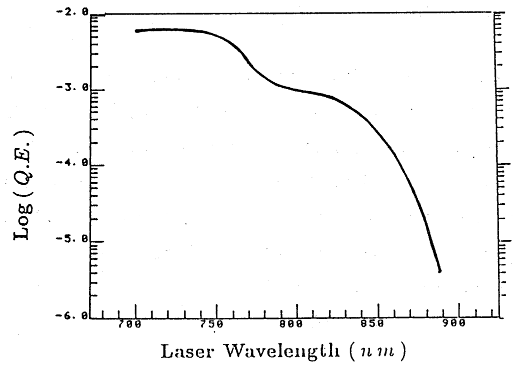

Fig. 2(a)

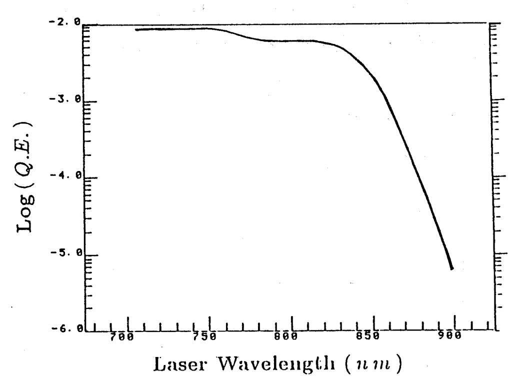

Fig. 2(b)

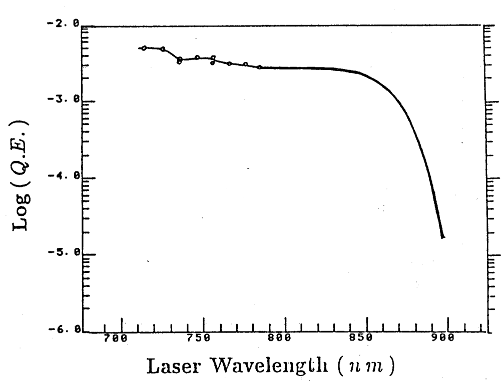

Fig. 2(c)

Fig.3(a) shows the maximum ESP dependence on thickness of strained GaAs layer. The maximum ESP decreases due to the two additive effects; 1) the relaxation of the strain and 2) the depolarization inside the strained GaAs layer,as the layer thickness increases. The QE with which the maximum ESP was obtained increases gradually with the GaAs layer thickness, as shown in Fig.3(b).

The figure of merit defined as $(\mathrm{ESP})^2\times$ (QE) is given in Fig.4, as a function of GaAs layer thickness. It seems to have a peak between the thickness of 0.14μm and 0.4μm,but we continue to take more data points for the definite conclusion about this item. In addition,it must be noted that there is the special case ,where the figure of merit must be indicated by $(\mathrm{ESP})^2$ rather than $(\mathrm{ESP})^2\times(\mathrm{QE})$. For example, the available current is limited by the other condition,namely the depolarization due to the beam heating for the pol.e^- beam experiment using the cryogenic solid polarized target.

3. Conclusion

1) We measured the ESP and QE of photoemitted electrons from the three strained GaAs samples with the nearly same lattice mismatch and p-doping,but different thicknesses of GaAs layer. The maximum ESP tends to decrease and the QE tends to increase as the strained GaAs layer becomes thicker. For the moment,the 0.14 μ m thick GaAs sample seems to have the best figure of merit.

2) We continue the systematic study of parameter optimization of the strained sample for getting the best figure of merit for various kinds of physics experiments. For this purpose,in addition to the thickness dependence of ESP and QE, the dependence on a fraction(x) of GaP_xAs_{1-x} and the dependence on a dopant level of GaAs layer must be studied.

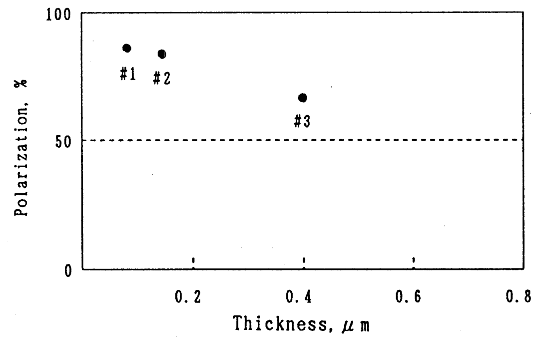

Fig. 3(a)

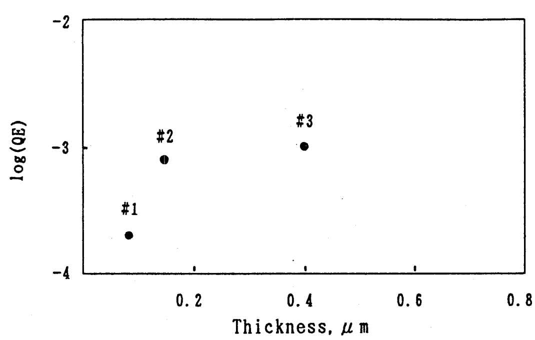

Fig. 3(b)

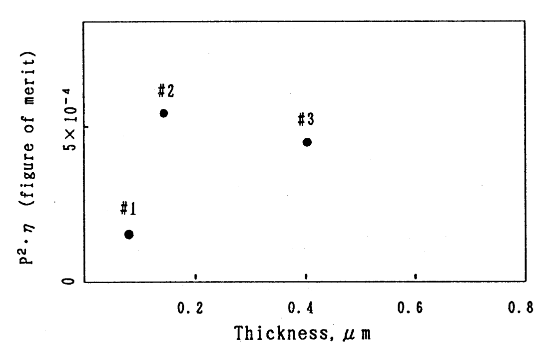

Fig. 4

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