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DEVELOPMENT OF POLARIZED ELECTRON SOURCE USING GaAs-AlGaAs SUPERLATTICE

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Abstract

We have measured a polarization of photoelectrons emitted from a GaAs-AlGaAs superlattice. The polarization of 52.5+0.3(stat.)+5.0(sys.)% was obtained at a photon wavelength of 775 to 800nm. This polarization is interpreted that electrons excited from the heavy hole state only.

A spin polarized electron beam is a very powerful tool to study the electroweak interaction by electron positron colliders at high energy.[1] In linear colliders, for example the JLC[2], polarized electrons can be introduced to a interaction point without depolarization during acceleration, therefore a development of the polarized electron source is very important.

The polarization of 49% was obtained by a photocathode of a bulk GaAs with negative electron affinity (NEA) surface excited by circulary polarized photons[3]. However the intrinsic upper limit is 50% because of a spin degeneracy of hole stats at G point. The degeneracy is separated in superlattice, the one can get then intrinsic upper limit of 100%. The photocathodes of GaAs-AlGaAs superlattice (SL) are developed by several groups[4,5,6] to get highly polarized electrons, however no one achieved the polarization greater than 50%. We have tested the photocathode of GaAs-AlGaAs superlattice of which parameters are optimized according to the method presented by Ref.7. The SL photocathode was made by Molecular Beam Epitaxy (MBE) method. The SL structure is shown in figuer 1. First a 50nm layer of a GaAs buffer was grown on a GaAs substrate to make a flat surface. On the GaAs buffer a 1μm layer of AlGaAs was inserted to avoid low polarized (less than

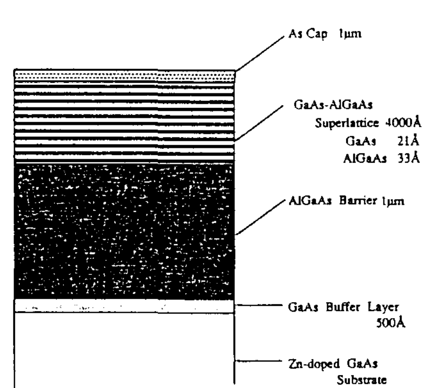


figure 1

50%) electrons coming from the GaAs substrate. Then, GaAs-AlGaAs SL layers were grown. The layer thickness of GaAs (AlGaAs) was 21Å(33Å), respectively. The final layer of the SL was GaAs. The surface of the SL is covered by Arsenic for protection against atmosphere. Band structures of the SL calculated by a method in ref.7 are summarized in figure 2.

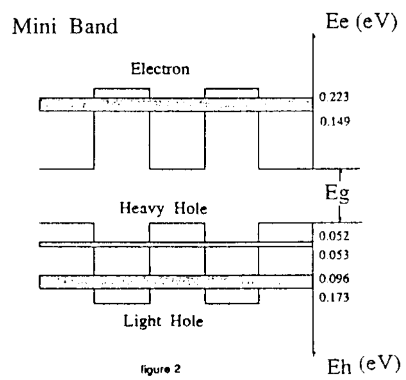


figure 2

The electron spin polarization was measured by the Mott scattering using the apparatus[8] shown in figure 3. The Titanium:Sapphire tunable-laser, excited by Ar-Iron laser, with 1/4 λ plate supply circular-polarized monochromatic photons. The photoelectrons emitted from the superlattice are accelerated to 4 KeV. Up to here, electron beam is polarized longitudinally. Next the electrons were bedded 90o by a spherical static electrode, then those spin were rotated to have transverse polarization. Finally, the electron beam is accelerated to 90 KeV and introduced to the Mott Analyzer with the Au foils. Cesium and Oxigen were used to activate the SL surface in NEA. Before the NEA activation, the As cap was removed by heat cleaning at temperature of 400oC. It was confirmed that the heat cleaning process dose not destroy SL structure(7).

A figure 4 shows electron spin polarization as a function of laser wavelengths. One can see two flat regions on the electron polarization. It was interpreted that a flat region in λ=775-800nm with average polarization of 52.5+0.3+5.0% is a contribution from the electrons excited from the heavy hole band only, and that in λ=700-743nm with 33.0%+0.5+5.4% is from the electrons excited from the heavy hole band and the light hole band. The first error is statistical error and the second is systematical one. The quantum efficiency was measured to be $7.7x10^{-3}$% ($1.09x10^{-4}$%) at 775 nm (800nm). In the region whose wavelength is longer than 800nm, we could not measure polarization because the quantum efficiency is too small. The width of the first flat region of 25nm (this

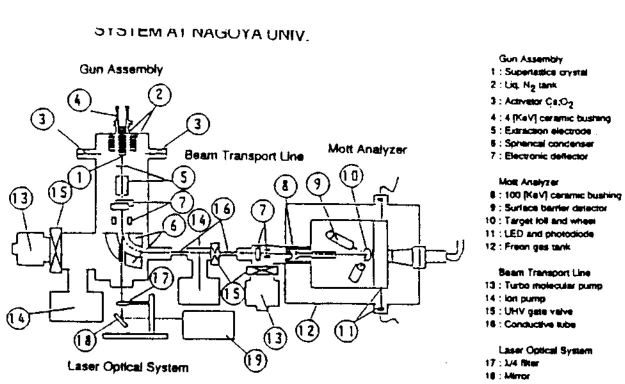
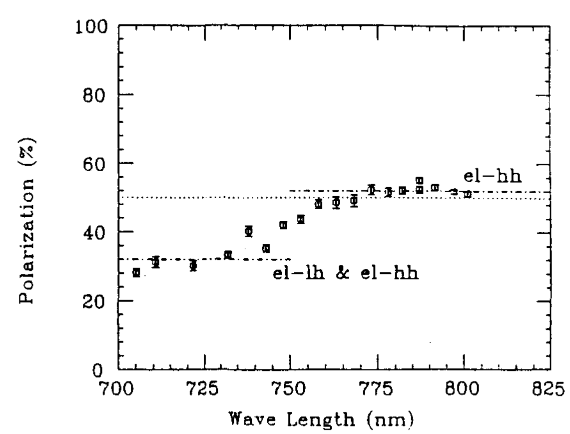


figure 3



corresponds 50meV) agrees with the calculated energy gap between the top of heavy hole band and the top of the light hole band (43.4 meV) as shown in figure 2. There are no measured points below 700nm of wavelength because our laser dose not work there.

The result of photoluminescence at room temperature is shown in figure 5. The large peak at 750nm is those from the SL. The small peak at 675nm corresponds the photoluminescens come from AlGaAs barrier layer of 1mm which is located behind the SL. A endpoint at longer wavelength side (about 800nm) agrees well with a point at nearly zero quantum efficiency. That shows we actually extracted the electrons excited at the threshold energy.

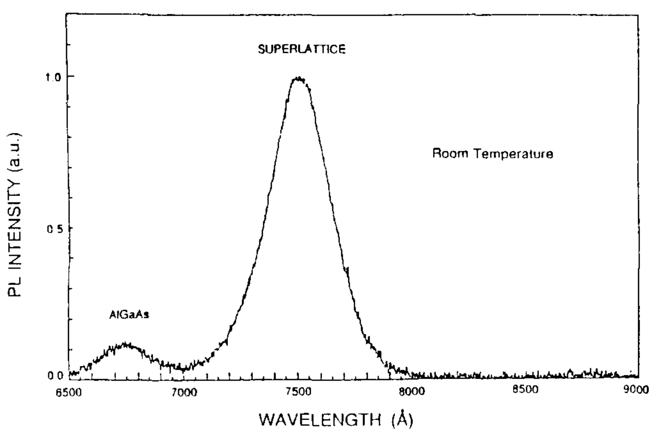


figure 5

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