Development of the New Type Polarized Electron Source for SPLEEM

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Abstract.
A new transmission type photocathode and gun for polarized electron source (PES) has been developed to enable the real-time observation of magnetism images during thin film growth by SPLEEM. This photocathode requires for laser lights to be injected from its backside and an electron beam is extracted from its surface side. By this scheme, it is possible to make a small laser spot ($\leq 10\mu m\phi$) on the photocathode. A quantum efficiency for a strained GaAs-GaAsP superlattice photocathode was larger than 0.1% and a brightness higher $10^5 A\cdot cm^{-2}\cdot sr^{-1}$ for an extracted current of $5\mu A$ was achieved by our PES system.

Keywords: spin, brightness, PES, SPLEEM
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INTRODUCTION

Low Energy Electron Microscopy (LEEM) is a powerful tool to observe the growth structure and morphology of ultra-thin metal film on the substrate. Another information of magnetism can be also provided by using polarized electron beam (so called SPLEEM) [1]. Magnetic sensitivity of SPLEEM is based on spin-dependent exchange scattering. Images of the spin-up and spin-down asymmetry can pick up the exclusive features that originate in the magnetism of the sample [2].

In order to enable a real time observation of the film growth, one image should be taken within 0.1 seconds or less that it has been realized already by the conventional LEEM. On the other, it takes 10 seconds by the available SPLEEM, and the real time observation is not possible. In order to overcome such a dilemma, it is necessary to improve the brightness of the PES beam by two order magnitude or more.

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For this purpose, we started to develop a new type photocathode. In the conventional PES apparatus, laser lights hit a surface of photocathode and electrons are emitted backward in the same direction. In this geometry, an electron beam size becomes to be typically more than 1mmϕ due to large laser spot size that is caused by a long distance between a focus lens and the photocathode. In order to minimize the beam spot, a new geometry is proposed as shown in Fig.1, where laser lights transmit the photocathode and electrons are emitted to forward direction. Using this transmission type photocathode, the distance between the focus lens and photocathode can be shorten to be a few mm and the laser spot size less than 10μm can be achieved [3].

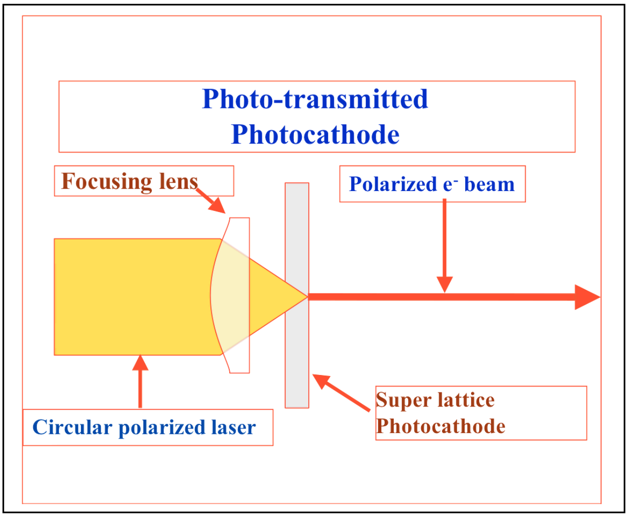

FIGURE 1. Conceptual view of new transmission type photocathode to minimize electron beam size

By construction of a new PES gun with this photocathode, we aim to realize the beam brightness higher than $1\times10^{4}\,A\cdot cm^{-2}\cdot sr^{-1}$ for the beam current of 15μA.

CONSTRUCTION OF POLARIZED ELECTRON GUN SYSTEM

A schematic illustration of our PES system is shown in Figure 2. It consists in four vacuum chambers such as an activation chamber, the gun chamber, and other chambers for measurements of beam brightness and spin polarization. The activation chamber has the vacuum level of 10^{-9}Pa, and the gun chamber maintains the ultrahigh vacuum environment of 10^{-10}Pa near the photocathode surface.

Heat cleaning and NEA activation of the photocathode surface are done in the activation chamber. Then, the photocathode pack is installed in a cathode electrode using load lock mechanism. In the downstream of the gun chamber, the beam brightness is measured, and the beam is deflected by 90 ° angle using a spherical condenser to convent the polarization vector from longitudinal to transverse. The beam polarization is measured by a 100kV Mott chamber analyzer.

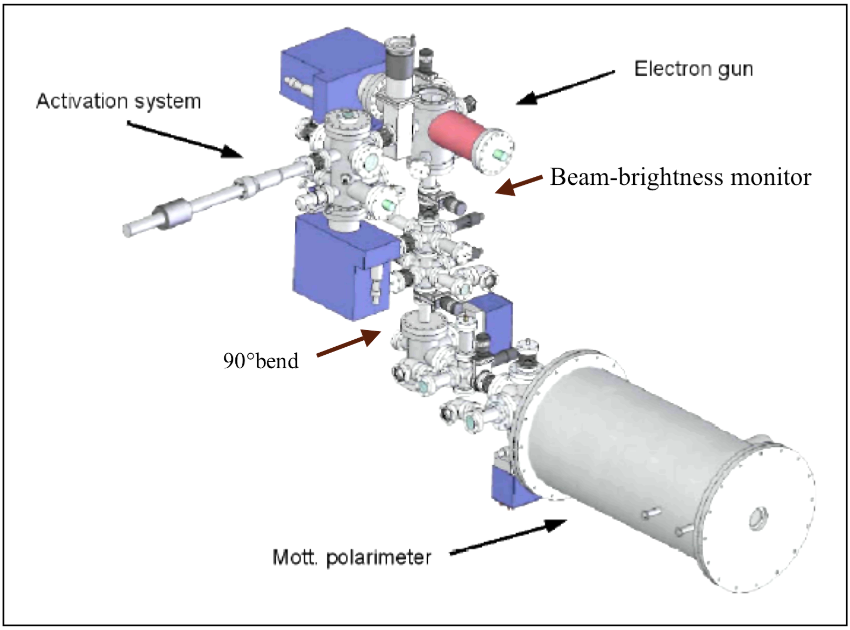

FIGURE 2. Spin-polarized electron source system constructed for SPLEEM

As a beam energy of the LEEM operated at OEC Univ. is 20keV, the same beam energy is chosen for this PES gun. The picture of our electrode is shown in Fig. 3. A gap distance of electrode is set to be 4mm, and the electric field gradient to be 5MV/m. In order to minimize the dark current, Mo and Ti are used for the cathode and the anode materials, respectively. By finishing the electro-buff-compound polishing of the electrode surface [4], the dark current was suppressed to below 6nA level.

FIGURE 3. Electrode structure with a cathode pack

The beam trajectory under these electrode conditions is simulated and an example result is shown in Fig. 4, where the beam spot size at cathode surface and the total beam current are assumed as 3μmϕ and 15μA, respectively.

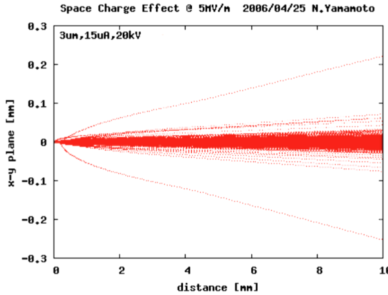

FIGURE 4. An example of simulation results of 20keV beam trajectory

PHOTOCATHODE

The crystal structure of our transmission type photocathode is shown in Fig. 5. The GaAs/GaAsP strained superlattice layer is used to produce the highly polarized electron beam $(\geq 80\%@\lambda = 780nm)$ [5]. As a substrate GaP is chosen, since it has a wide band-gap energy corresponding to 550nm wavelength and is transparent for 780nm laser light.

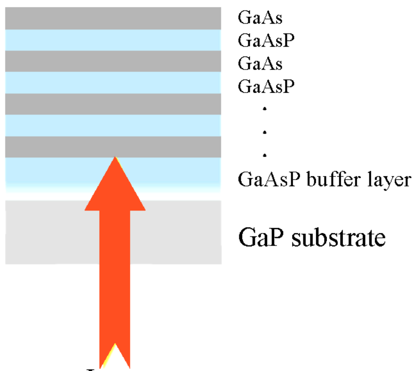

FIGURE 5. The transmission type photocathode with an active layers of GaAs/GaAsP strained superlattice structure

RESULTS OF PES PERFORMANCE MEASUREMENT

The measured QE dependence on the laser wavelength for the transmission type photocathode is shown in Fig. 6, where QE of 0.12% was obtained at wavelength of 777nm. In the activation chamber, QE of 0.11% was obtained at same wavelength using the conventional laser injection scheme. The QE of 0.12% is enough high, to produce the total current of 15μA with our laser system.

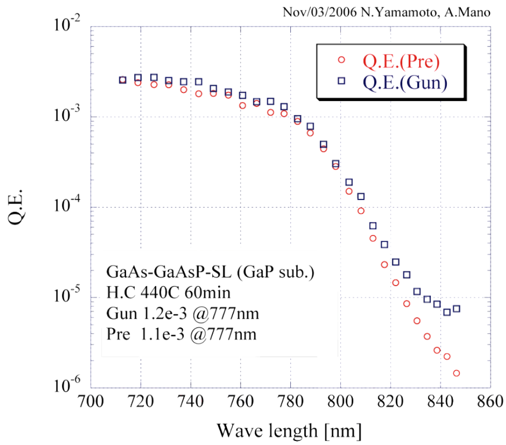

FIGURE 6. The QE spectra of photocathode measured at the gun and activation chambers

The brightness is determined by measuring the beam divergence caused in free drift space, and a numerical value is derived by using a following formula;

$$B = I \cdot \frac{z^2 \cdot D^2}{\pi^2 \cdot S^2 \cdot (D - S)^4}$$

, where B: beam brightness, I: current at gun, S: beam size at photocathode, D: beam size at position of profile measurement, Z: distance between photocathode and the position of profile measurement.

The beam profile at 53.1cm down stream from the photocathode was measured by the beam slit method. For the beam with the laser spot of 6.76μmϕ at photocathode, the diameter of beam spot was 2.44 ±0.1mm for total current of 5μA. With these parameters, the beam brightness was estimated to be $4.6 \times 10^5 \mathrm{A{\cdot}cm^{-2}{\cdot}sr^{-1}}$.

The beam brightness dependence on the total current and beam spot size was measured and is shown in Fig. 7.

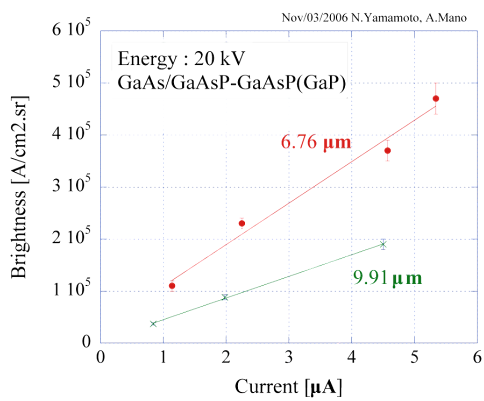

FIGURE 7. The beam brightness dependence on the extracted current and spot size

SUMMARY

The new type PES has been developed for SPLEEM at Nagoya University. The laser spot on the photocathode was made to be minimum ($\leq 10\mu m\phi$) and the high brightness electron beam ($\geq 10^4 A \cdot cm^{-2} \cdot sr^{-1}$) with 15μA beam current could be already produced by the newly constructed 20kV gun.

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