Electron Beam Source using Wide Band Gap Semiconductor Photocathode with an NEA surface

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Photocathodes using III-V semiconductors with a negative electron affinity surface (NEA-semiconductor photocathodes) have played very important roles as highly spin-polarized electron sources in several fields of fundamental science[1]. As an electron beam source for a high-energy accelerator, NEA-semiconductor photocathodes achieved high spin-polarization (90%[2]), short beam pulse width (several ps[3]), large emission current (several mA[4]) and small energy spread (~0.2eV[5]) of extracted electrons.

The key technology of NEA-semiconductor photocathodes is that NEA surface enables excited electrons in the conduction band to escape to vacuum as shown in Figure 1. However, the surface of NEA-semiconductor photocathode is damaged by back bombardment of ionized residual gas by photoelectrons[6]. Therefore, the conventional NEA-semiconductor photocathode should be used under quality ultra-high vacuum for maintaining the NEA state.

We considered that the NEA-semiconductor photocathode with large dχ is essential for improvement of the decrease in quantum yield. We suggest that semiconductors with a wide-band gap and a low electron affinity are more suitable photocathode material for a long NEA lifetime.

We fabricated the p-GaN and the p-GaAs samples for an NEA-semiconductor photocathode and measured a change of quantum yield during the NEA activation of samples as shown in Figure 2.

We concluded that a p-GaN semiconductor is expected to be more suitable material for an NEA-semiconductor photocathode with a long NEA lifetime because the surface can reach an NEA state by small Cs effect. We have also developed the 50keV electron gun for NEA-semiconductor photocathodes. We will measure lifetime of samples under large current using the 50keV electron gun.

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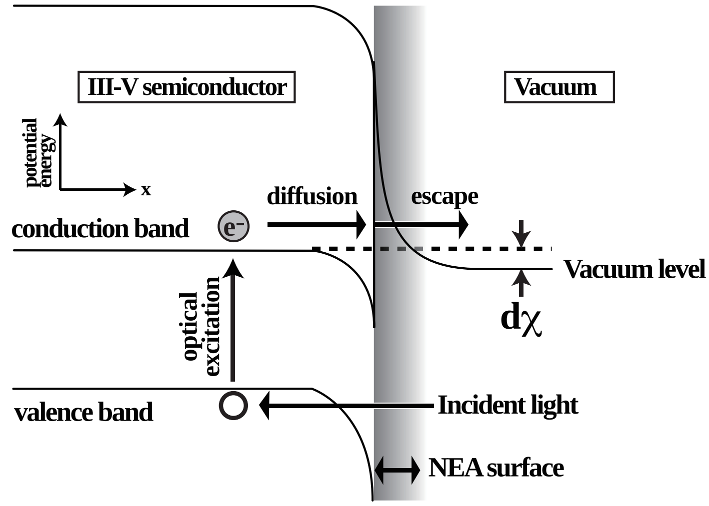

Figure 1: Emission model from NEA-semiconductor photocathode: optically excited electrons drifting toward the surface can escape to the vacuum through NEA surface. In a p-type semiconductor, the vacuum level is pull down to lower energy level by the surface band-bending effect. The surface band-bending depth depends on the band-gap energy. Therefore, a p-type semiconductor with wide-band gap enables to have large dχ when the surface is activated to an NEA state.

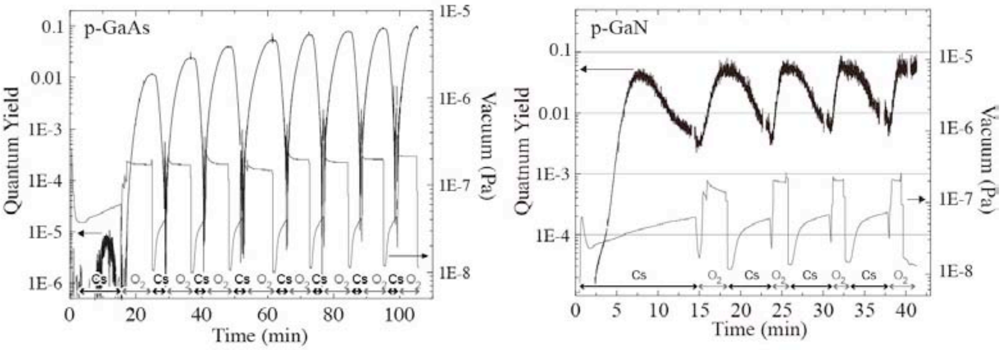

Figure 2: NEA activation processes of the p-GaAs sample (left) and the p-GaN sample (right). The quantum yield reaches a maximum while repeating the increase and decrease by alternate introduction of cesium and oxygen. The quantum yield of the p-GaN sample after the NEA activation was the same as that of the p-GaAs sample. In first cesium deposition process, the quantum yield of the p-GaN sample (4e-2) was higher more than 3 figure than that of p-GaAs sample (1e-5). These results suggest that the surface of the p-GaAs sample dose not reach an NEA state in first cesium deposition process, but the surface of the p-GaN sample reaches an NEA state in first cesium deposition process.