Spin-Polarized Electrons Extracted from GaAs Tips using Field Emission

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Polarized electron source (PES) has been researched and developed for a future linear collider project. The polarized electron beam is produced by using photoemission from GaAs-type semiconductors. This type of polarized electron source is based on a combination of two fundamental technologies; optical pumping by circularly polarized light and emission of conduction electrons into vacuum using a negative electron affinity (NEA) surface. Here, the present problems of the PES are improvements of beam emittance and lifetime of NEA surface state. In order to overcome these problems, we started to study a new type of spin polarized electron source using field emission mechanism. First, we tried to use a GaAs crystal that has a pyramidal shape (tip-GaAs). Using the tip-GaAs, electron can be emitted from a small area at the top of pyramid, and the beam emittance is expected to decrease. The emission mechanism also enables the photocathode to extract electrons from the positive electron affinity (PEA) surface, and alleviates the NEA lifetime problem.

The measured electrical characteristics of tip-GaAs and its polarization exhibited distinctive field emission behavior. I-V characteristic of tip-GaAs shows that the electron beam was extracted by field emission mechanism, because a linear dependence was obtained in Fowler-Nordheim (F-N) plot. Furthermore the quantum efficiency (QE) spectrum rose rapidly at 1.6 eV, which did not correspond to the band gap energy of GaAs. The polarization of tip-GaAs was 20-38 % under illuminating with circularly polarized light of 700-860 nm, and the peak polarization was 37.4 ± 1.4 % at a wavelength of 731 nm. These experimental results indicated that spin polarized electrons can be extracted from the conduction band into vacuum by a field emission mechanism. We regard tip-GaAs with field emission as a spin polarized electron photocathode that can produce a low emittance and achieve long lifetime because it avoids the use of NEA surface. It is hoped that this photocathode will be widely applicable to high energy accelerators and analytical instruments such as the electron microscope.

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