SURFACE-EMITTING BALLISTIC COLD CATHODES BASED ON NANOCRYSTALLINE SILICON DIODES

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1. Introduction

In a previous paper, we reported that a nanocrystalline silicon (nc-Si) diode composed of a thin Au film, a porous silicon (PS), and a Si substrate emits uniformly electrons under a biased condition [1]. The PS diode formed on n^+-Si substrates with a controlled nanostructure operates as a surface-emitting ballistic electron source [2]. This cold cathode can be fabricated by nanocrystallized porous polycrystalline silicon (nc-PPS) films as well [3,4]. As one of the possible applications, a prototype full-color ballistic electron surface-emitting display (BSD) has been developed on a glass substrate [5].
The present paper describes the advantageous features of this emitter and its technological potential.

2. Emission Mechanism

When an electric field is applied to the PS or PPS diode in which nc-Si particles are interconnected via thin oxide films, most of the potential drops should be produced only at the interfacial barriers between neighboring nc-Si, and then the spike-like high-field regions are periodically generated in the depth direction. Under this situation, electrons injected into the PS layer can travel for a long distance via multipletunneling through thin oxide interfacial layers. As a result of this cascade acceleration, hot or ballistic electrons are efficiently generated.

This hypothesis is supported by the experimental data of energy distribution of emitted electrons. As indicated in **Fig. 1**, the observed energy distribution curve is different from thermallized Maxwellian type. The peak energy shifts towards the higher energy side in accordance with increasing bias voltages. At low temperatures at which the tunneling conduction mode is dominant, the energy spread becomes quite small due to a significant reduction of the low-energy tail component. Another evidence has been provided by a transport analysis based on time-of-flight measurements for a self-standing PS film [6].

3. Possible Applications

This ballistic electron emitter has many advantageous characteristics over the conventional cold cathodes: a low-power consumption, an insensitivity to the vacuum pressure, a uniform and energetic emission, a small emission angle dispersion, a fully fast response, and the availability for large-area devices. In **Fig. 2** is shown a schematic of the PPS emitter produced on a glass substrate. The corresponding emission characteristics are shown in **Fig. 3**. Using this emitter as an excitation source of fluorescent screen, a 168×126 pixels simple-matrix full-color flat panel display has been developed without any focusing electrodes.

Due to the capability of efficient generation of ballistic electrons, this emitter is useful not only as a functional electron source, but also for ultraist ballistic electron devices and a novel solid-state luminescent device [7].

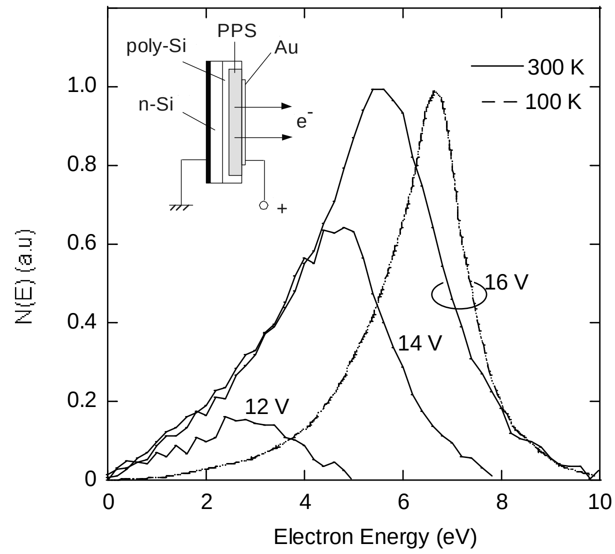

Fig. 1. The energy distribution curves of electrons emitted from an PPS diode at different applied voltages at room and low temperatures. A schematic of the device cross section is also shown. The PPS layer was prepared by photoanodizing a poly-Si film deposited on an n^+-type (100) Si wafer.

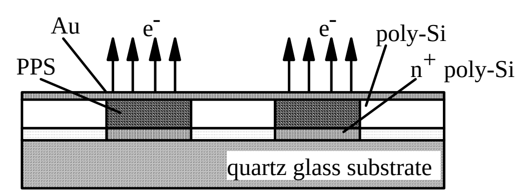

Fig. 2. A schematic of the BSD cross section formed on a quartz glass substrate.

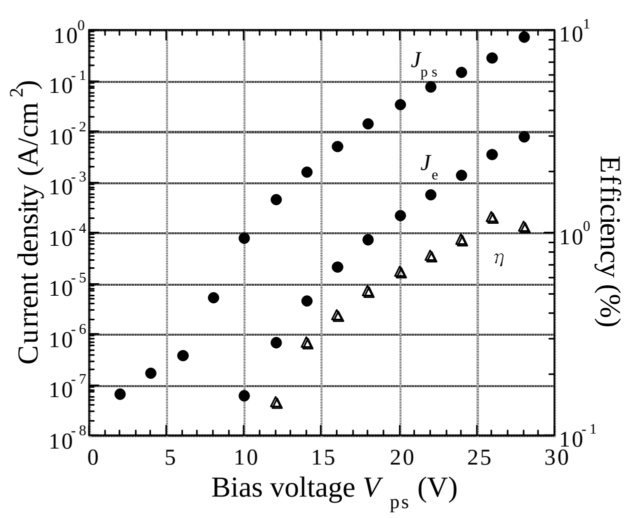

Fig. 3. The characteristics of the diode current J_{ps} and the emission current J_e of the fabricated PPS device as a function of the bias voltage V_{ps}.

References

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