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Electron field emission from narrow band gap semiconductors (InAs)

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Abstract
We propose to use InAs for the development of effective electron field emitters on the basis of a new technological approach for the preparation of highly textured surfaces which allows one to obtain peculiar fine rod-like micro- and nanostructures. A decrease of the current–voltage characteristics slope by a factor of 3.5 was observed in the Fowler–Nordheim plot with increasing applied voltage. This significant change in the slope is discussed on the basis of two different mechanisms: the inter-valley hot carrier redistribution and the existence of two arrays of nanocathodes with different radii of the top. The developed InAs nanostructures may also find applications in IR-sensitive displays, submicron sources of irradiation and devices with variable bands and barriers.

1. Introduction

Narrow band gap semiconductors such as InAs, InSb, β-Sn, carbon nanotubes and a set of graphite-enriched carbon and diamond-like carbon (DLC) materials are of great interest from both fundamental and application points of view. Many of these materials are widely used in optoelectronic devices for IR spectral range, resistive gas sensors, laser media, etc. Nowadays, in connection with the growing role of vacuum micro- and nanoelectronics, it becomes important to search for narrow band gap semiconductors as promising materials for high efficiency electron field emission (EFE) cathodes. It is known that a well-conducting carbon mixture of nanotubes and nanoplates demonstrates very good EFE properties [1–5], and it is a promising material for the fabrication of large area flat displays [5]. In this case, micro- or even nanosize tip cathodes have been used.

We propose to use a narrow band gap material with high electron mobility InAs, as a quite stable and rather perfect material with a well-developed technology of crystal growth, for the fabrication of effective electron field emitters. We developed a new technological approach for the preparation of highly textured surfaces which allows one to obtain peculiar fine rod-like micro- and nanostructures [6, 7].

2. Theoretical consideration

III–V semiconductors are characterized by a multivalley structure of the conduction bands (C-bands) with rather different energy separation of the valleys in the energy scale. Such a complicated band structure can be evidenced in the field emission phenomenon. The energy barriers for EFE from main and satellite valleys are different. In spite of low energy barriers of the upper valley, its input in the emission current can be remarkable only after hot electron filling. The barriers for electron emission can be estimated from the relation [8]

$$\chi_0 + E_g \approx 5.5 - \Delta E_v, \qquad (1)$$

where electron affinity χ_0 is the energy interval (barrier height) between the bottom of the conduction band and vacuum level, E_g is the band gap and ΔE_v is a small correction of ~ -0.5 eV to the valance band variation [8].