

Fabrication of vacuum tube arrays with a sub-micron dimension using anodic aluminum oxide nano-templates

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Abstract

Vacuum tube arrays with a sub-micrometer dimension were fabricated by using anodic aluminum oxide (AAO) nano-templates. Ni nanowires deposited electrochemically inside the pores of the AAO nano-templates were used as the field emitters. The pores were sealed by means of angled evaporation of titanium. The field emission measurement was carried out in atmospheric environment outside of a vacuum chamber. The field emission characteristics show low turn-on voltages of 11.0–14.0 V. This phenomenon is attributed to the fact that the distances between the tips of Ni nanowires and the anodes are much smaller than those of conventional designs. Curvature in the Fowler–Nordheim plots at low applied voltage region is due to the variation of the enhanced field at each nanowire tip by the distribution in the length of Ni nanowires.

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1. Introduction

Vacuum devices based on field emission have attracted considerable attention in recent years be-

cause they have several advantages over solid-state devices. They are robust at ambient temperature as well as in radiation environments. They have no power dissipation during electron transport because of the ballistic nature of transport in a vacuum [1]. Consequently, vacuum devices can generate higher power at high frequencies. These characteristics guarantee many applications, including active elements for integrated-circuits,

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flat-panel displays, electron guns, and microwave power tubes [2–4].

Most of the field-emission-based vacuum devices are fabricated by the Spindt process. However, it requires sophisticated processing skills and expensive equipment such as selective etching and electron beam lithography. High voltage is required for the operation of these devices because of the inter-electrode distance of several hundred micrometers. In addition, the Spindt process is difficult to apply to a large area. To overcome these difficulties, we have used anodic aluminum oxide (AAO) technology, which is capable of controlling the dimensions of the structure such as pore diameter, pore length, and pore density with a few nanometer resolution without using electron beam

lithography [5–7]. AAO technology can also be easily applied to a large area [8].

In this study, we have fabricated field emitter arrays (FEAs) with integrated anodes by using AAO nano-template. Due to the integrated structure, these vacuum tubes can be operated as stand-alone devices, outside of a vacuum chamber. This work is the basis to devise a novel fabrication process for triode vacuum tube arrays with sub-micrometer dimensions.

2. Experimental

First, a cleaned and electropolished aluminum sheet of high purity (99.999%) was anodized in

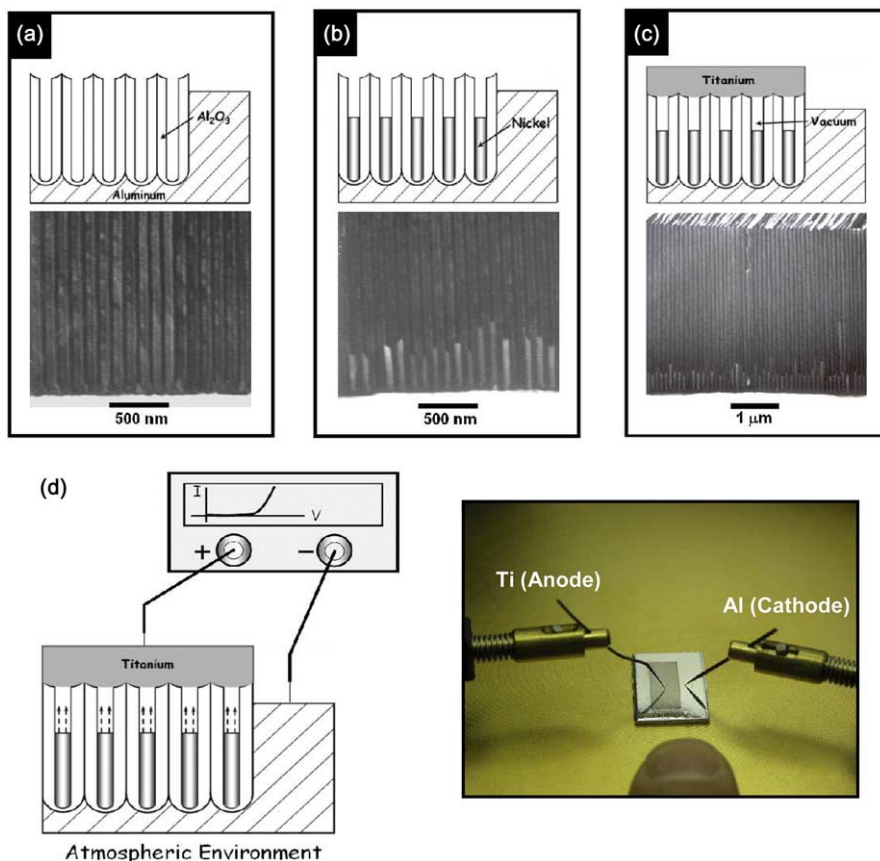


Fig. 1. Fabrication process of integrated diode: (a) AAO template fabrication, (b) electrodeposition of Ni nanowires, (c) angled evaporation of Ti to seal the structure, (d) schematic of a field emission measurement setup.

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