

Electron field emission from microtip arrays

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Abstract

Electron field emission measurements from structured cathodes was reported. Silicon (Si) and boron-doped silicon carbide (SiC:B) had been chosen as a base materials for microtip field emission arrays (FEA). Each of single silicon FEAs has been covered by a thin metal layer using chromium (Cr), titanium (Ti) or platinum (Pt) to reduce the threshold voltage of electron emission. Surface of boron-doped silicon carbide and silicon FEAs have also been modified by deposition of multi-walled carbon nanotubes (MWNT). These efforts let improved the emission currents and bring down the turn-on field down to 1.2 V/μm. In contrast to the above, plain cold cathodes prepared as porous silicon (PS) substrates covered by thin MWNTs have also been measured.

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1. Introduction

Field emission, also known as Fowler–Nordheim [1] tunneling phenomenon is seen as a very strong alternative to thermionic emission [2]. This physical phenomenon insists on extracting cold electrons due to applied field (without heating), from cathode through the surface potential barrier. Its efficiency is a thousand million times greater than any other presently known emission process [3]. The density of emitted current strongly depends on the amplitude of electric field, thereby the current is also strongly dependent on cathode surface morphology. What is more, the amount of emitted current is almost solely controlled by the applied field [2]. Beside these advantages of high current densities it is worth to point out that there is no energy consumption in the emission process [3]. The attendance of electron field emission is seen at high electric fields 10⁷ V/cm. It is possible to obtain such high electric fields on very sharp structures as nanotips ($r < 100$ nm) fabricated on the surface of cathodes and bring down the electric turn-on fields. It is caused by the fact that electric

field concentrates at any sharp points present at the surface of cathode [4].

Currently, field emission phenomenon has gained a new life due to exceptional applications in the vacuum micro- and nanoelectronics, in general. This emission phenomenon has found a wide packet of applications such as novel applications in the fine-resolution electron microscopy, Auger spectroscopy, atomic-resolution electron holography, X-ray tubes, field emission displays (FED) or generation of high-power electron beams through phenomenon called as explosive electron emission [3].

Within the space of the last years lots of interesting field cathodes constructions have been presented in the literature. In the majority of cases, cone-like cathodes or plane cathodes with carbon nanotubes (CNT) have been presented. Cone-like sharp emitters (metallic or semiconducting) substantially enhance the electric field and allow high densities of current and stable emission to occur. CNT provide additionally extremely high curvature like ultra sharp emitters and can ensure excellent emission conditions. Beside this, CNT possess a lot of properties which are favorable for field emitters, such as high chemical stability, high aspect ratio and high mechanical strength [5,6]. Based on this approach and by the usage of different fabrication methods, we prepared a series of silicon and boron-doped

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silicon carbide field emission arrays (FEA) modified by different surface layers, including CNT.

2. Experimental

Field emission cathodes have been prepared as two different types. The difference between them relies on the cathode surface morphology. Cathodes of the first type were fabricated as microtip arrays and of the second type as plain substrates of porous silicon (PS). Both of them were covered by multi-walled carbon nanotubes (MWNT).

2.1. Silicon microtip arrays

At first, an array of silicon micro tips have been obtained. The test structure contained 2500 tips on surface area of $1 \times 1 \text{ mm}^2$ (Fig. 1a). Each of the silicon cones had the base diameter of $10 \mu\text{m}$ with the distance interval of $10 \mu\text{m}$ (mask pattern dimensions). The Si FEAs have been formed by dry etching of silicon wafer with crystallographic orientation (100), type n and the resistivity $\rho = 1\text{--}5 \Omega\text{cm}$ (Fig. 1b). The etching process parameters have been set up as follows: $f_{\text{SF}_6} = 12 \text{ sccm}$, $p = 4 \times 10^{-2} \text{ mbar}$ and $P_{\text{RF}} = 150 \text{ W}$ (GIR 300 Alcatel device).

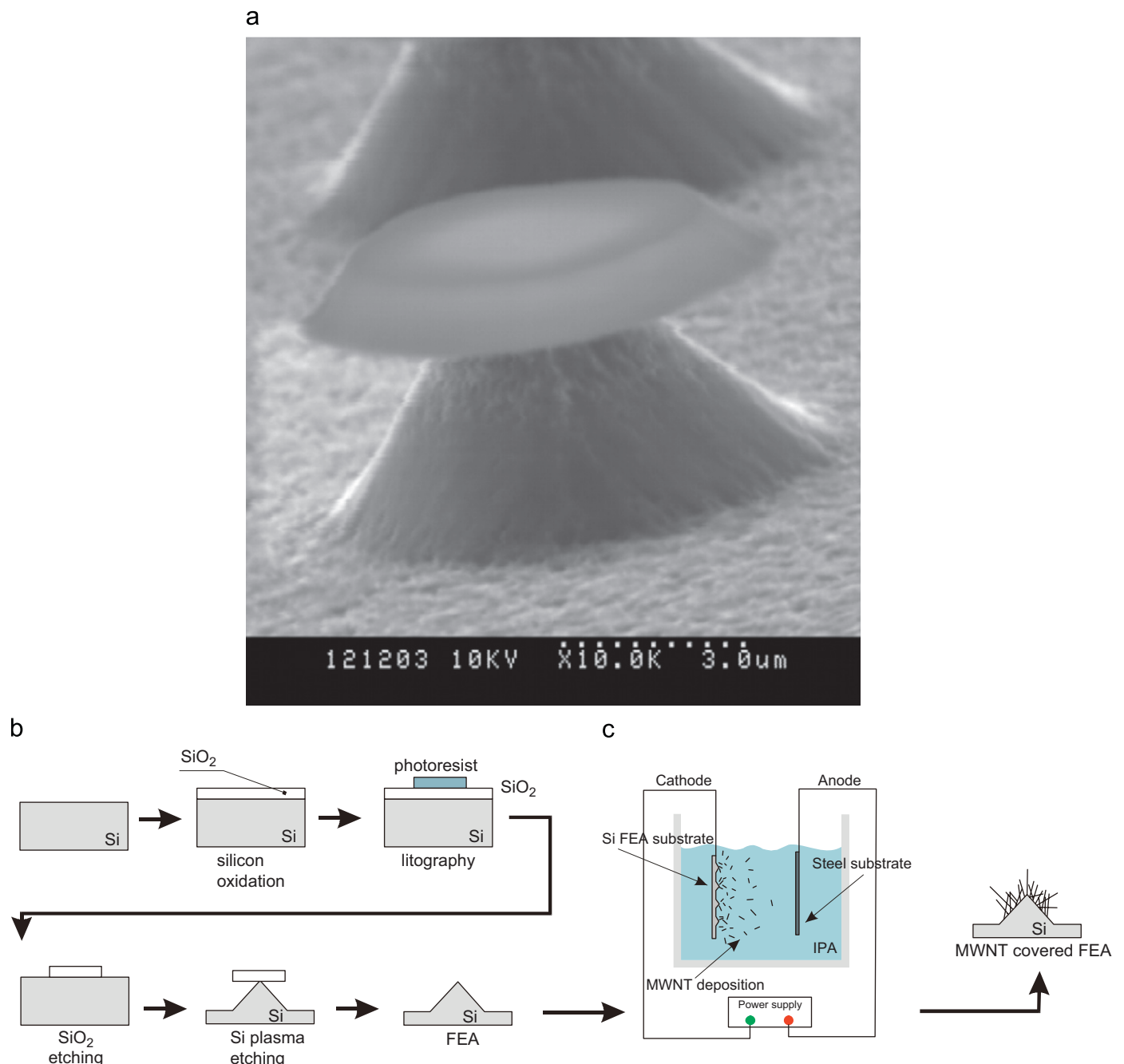


Fig. 1. SEM micrographs of dry etched silicon microtip array with silicon dioxide on top (a), scheme of: simplified fabrication procedure flow chart (b) and MWNT deposition procedure (c).

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