IOP PUBLISHING JOURNAL OF PHYSICS D: APPLIED PHYSICS

J. Phys. D: Appl. Phys. **41** (2008) 205418 (5pp) doi:10.1088/0022-3727/41/20/205418

Filament discharge enhances field emission properties by making twisted carbon nanofibres stand up

Yuji Hosokawa[1], Yuichiro Shinohara[1], Masashi Yokota[1], Hajime Shiki[1], Yoshiyuki Suda[1,5], Shinichiro Oke[1], Hirofumi Takikawa[1], Takashi Ina[2], Masakatsu Morioki[2], Yohei Fujimura[3], Tatsuo Yamaura[3], Shigeo Itoh[3] and Koji Miura[4]

[1] Department of Electrical and Electronic Engineering, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi 441-8580, Japan

[2] Fundamental Research Department, Toho Gas Co., Ltd., 507-2 Shinpo, Tokai, Aichi 476-8501, Japan

[3] Research and Development Center, Futaba Corporation, 1080 Yabutsuka, Chosei-mura, Chosei-gun, Chiba 299-4395, Japan

[4] Fuji Research Laboratory, Tokai Carbon Co., Ltd, 394-1 Subashiri, Oyama, Sunto, Shizuoka 410-1431, Japan

E-mail: suda@eee.tut.ac.jp

Received 2 July 2008, in final form 13 August 2008
Published 2 October 2008
Online at stacks.iop.org/JPhysD/41/205418

Abstract

Twisted carbon nanofibres, named carbon nanotwists, in a flocculated form were pasted, printed on the conductive silicon substrate and then treated by dielectric barrier discharge using He and N_2 gases. Vertically upright nanofibres were clearly obtained by 'filament discharge mode' in N_2 gas. As the treating time increased up to ~60 s, the height of the nanofibre tips became uniform. Consequently, the field emission property was greatly enhanced and showed a threshold electric field of 4.6 V μm^{-1} and a maximum current of 0.433 mA cm^{-2} at 8 V μm^{-1}.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

The recent development of the synthesis of micro- or nanometre-sized carbon tubular and coiled structures has drawn much attention to the application of these materials in electronics [1–3]. Depending on the catalyst and the process conditions, each of them can be formed from hydrocarbons in chemical vapour deposition (CVD) [4] and plasma-enhanced CVD [5–7]. We have focused on the formation of helical carbon nanofibre (HCNF) and its application to a field emitter device [8]. HCNF is categorized as either a spring-like helix form (carbon nanocoil (CNC)) [9–13] or a twisted form (carbon nanotwist (CNTw)) [14–16], depending on the internal diameter. These materials are applicable to field emission display owing to their high aspect ratio and electrical conductivity [12, 13, 16]. Some techniques for fabrication of field emitter devices, including direct growth [17], screen-printing [18], spraying [19] and electrophoresis [20], are well known. Table 1 shows the drawbacks and advantages of each of these four techniques. Screen-printing and spraying are inexpensive and simple processes with the advantage of large-area treatment. However, HCNF must be made to stand up in the emitter to obtain effective field emission properties.

So far, stand-up treatments including adhesive tape [21], heat treatment [22] and excimer laser irradiation [23] have been reported. Making HCNF stand by adhesive tape application is a simple method, but problems of surface contamination and exfoliation of HCNF from the substrate arise. Laser irradiation is extremely expensive even if it is possible to treat a surface uniformly. In heat treatment, available substrates are limited due to high temperature (~400 °C). A new way to stand up HCNF and thus overcome the problems and drawbacks previously reported is awaited.

[5] Author to whom any correspondence should be addressed.

