Nanotechnology **27** (2016) 295204 (5pp) doi:10.1088/0957-4484/27/29/295204

Memristive GaN ultrathin suspended membrane array

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Received 8 January 2016, revised 29 February 2016
Accepted for publication 7 April 2016
Published 13 June 2016

Abstract

We show that ultrathin GaN membranes, with a thickness of 15 nm and planar dimensions of $12 \times 184\ \mu m^2$, act as memristive devices. The memristive behavior is due to the migration of the negatively-charged deep traps, which form in the volume of the membrane during the fabrication process, towards the unoccupied surface states of the suspended membranes. The time constant of the migration process is of the order of tens of seconds and varies with the current or voltage sweep.

Keywords: memristor, GaN, semiconductor membranes

(Some figures may appear in colour only in the online journal)

1. Introduction

Although the memristor was predicted a long time ago, experimental evidence of it only occurred when nanotechnologies had reached a certain degree of maturity. A memristor is a unique circuit element, the fourth fundamental circuit element, which plays a similar role to the inductance (L) and capacitance (C). Unlike the inductance and capacitance, however, the memristor is a nonlinear circuit element, displaying a voltage–current dependence with a distinct footprint—a pinched hysteretic behavior of the current when the voltage is varied from negative to positive values [1]. Moreover, the resistance of the memristor depends strongly on the history of the applied voltage. Since the memristor remembers its previous state when the excitation is off, it is non-volatile and strongly related to resistive switching memories, which are considered to be the next generation of electronic memories. As such, memristors could be used in reconfigurable logic circuits [2] or in neuromorphic systems [3] in order to mimic the synapses, which are the fundamental key components of neural systems.

These and other applications have initiated a rush for inventing various memristive devices, with several memristor classes being already identified. For instance, there are CMOS-compatible memristors based on (i) resistive switching memories in oxides such as TiO_2 and WO_3, (ii) electrochemical metallization (redox memristors), and (iii) phase change materials [4, 5]. The memristive behavior is encountered in many materials, in which different physical effects are present. The ultimate memristor is a gate-tunable single atomic sheet of matter such as MoS_2, in which the memristive behavior is due to the variation of carrier density as a function of the gate voltage [6].

GaN, also termed 'new silicon', is presently the second most important semiconductor after Si, and has well-known applications in high-frequency and power electronics. In the form of nanowires and nanotubes, GaN has an increasing number of applications in the area of nanoelectronics [7]. GaN memristors would further increase the applications of

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