Applied Surface Science 257 (2011) 3607–3611

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Local super-saturation dependent synthesis of MgO nanosheets

Luwei Sun, Haiping He*, Chao Liu, Zhizhen Ye

State Key Laboratory of Silicon Materials, Zhejiang University, Hangzhou 310027, People's Republic of China

ARTICLE INFO

Article history:
Received 15 October 2010
Received in revised form
13 November 2010
Accepted 13 November 2010
Available online 19 November 2010

Keywords:
Magnesium oxide
Chemical vapor deposition
Surface energy
Nanostructures
Super-saturation

ABSTRACT

Well-crystallized MgO nanosheets have been prepared with MgB_2 as a precursor without any catalyst via a simple chemical vapor deposition (CVD) method. The nanosheets are grown parallel to (2 0 0) plane according to the high-resolution transmission electron microscopy profiles. At the same time, MgO nanowires are formed in the different area of substrate, which is the result of the difference in local super-saturation. Consequently, we propose that the growth mechanism depends on the surface energy and the local super-saturation in the system.

1. Introduction

A variety of nanostructures have inspired a number of researchers to explore their novel properties and versatile applications [1,2]. Although nano-materials with various shapes have been synthesized, controllable growth of nanostructures still challenges the scientists in physics, chemistry and materials science. The morphology of some nanostructures has been manipulated by adjusting growth conditions. Since the ordered nanostructures are appreciated in promising applications, such as solar cells [3,4], photo-detectors [5], light-emitting diodes [6], fully understanding the growth mechanism of nanostructures is advantageous in overcoming the difficulties on the controllable synthesis.

The study of two-dimensional nanostructures is an important branch of nano-material science and technology. All kinds of nanosheets, such as TiO_2 [7], MnO_2 [8], ZnO [9], NiO [10], ZnS [11], graphene [12], have been prepared by various methods.

MgO is a typical insulator with a wide band gap (E_g = 7.7 eV at 298 K) with rocksalt structure. MgO (1 0 0) facet is most commonly exposed and has the lowest surface energy [13]. MgO (1 0 0) plane is the most stable in dry environment, which is caused by a simple orthogonal structure with an alternation of Mg^{2+} and O^{2-} ions in favor of physical adsorption instead of chemisorption. Thus, the extensive applications of MgO nanostructures in heat-resistance, adsorption [14], catalysis [15], superconductors [16], magneto resistance [17], passive layer in transistors [18], etc., are orientation-dependent. In principle, (1 1 1) facet in rocksalt structure is so unstable in dry environment and at low temperature that it has a tendency to be faceted or reconstructed due to an electrostatic dipole perpendicular to the surface. The stability of MgO facets has been studied both theoretically and experimentally [13], but many issues are still controversial.

Recently, MgO nanostructures with various desired shapes, such as nanotubes [19], nanobelts [20], nanowires [21], nanoflowers [22,23] and nanocrystals [24], have been obtained. Although a few reports on MgO nanosheets have been published [25], most of them were synthesized in aqueous solution.

In this paper, we report MgO nanosheets prepared by a simple chemical vapor deposition (CVD). The crystallographic orientation of the as-obtained MgO nanosheets is identified on the basis of high-resolution transmission electron microscopy (HRTEM) images. It is also found that the products in different area of the substrate show different morphology, which is attributed to different local super-saturation and surface energy. A diagram is proposed to describe the growth process.

2. Experimental details

The synthesis was carried out in a horizontal quartz tube with a diameter of 4 cm and a length of 110 cm. A mixture of high purity magnesium boride (MgB_2) powder, zinc oxide (ZnO) powder and graphite powder, was loaded into the center of an alumina crucible as the source material. All chemicals are purchased from Sigma–Aldrich without any purification. Here, ZnO was expected

* Corresponding author.
E-mail address: hphe@zju.edu.cn (H. He).

0169-4332/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.apsusc.2010.11.087

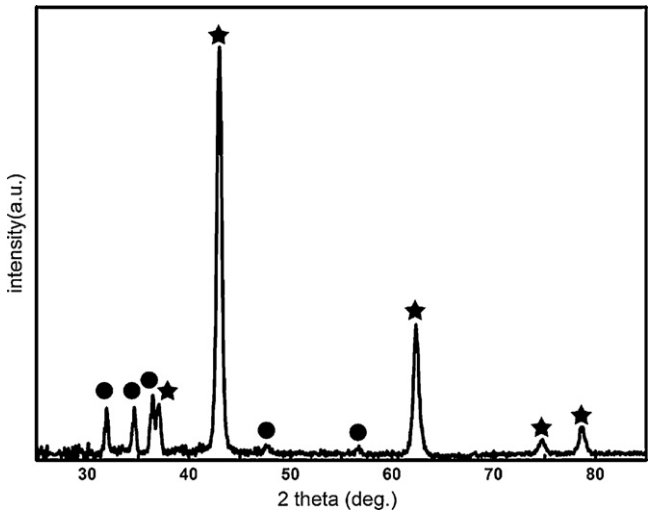

Fig. 1. XRD pattern of MgO nanosheets is shown that pentagram stands for diffraction peaks of MgO; solid dot stands for diffraction peaks of ZnO.

to facilitate the formation of cubic $Mg_xZn_{1-x}O$ alloy. A *c*-plane sapphire supported by two silicon sticks on the alumina crucible was located above the source powders. A rotary pump kept vacuum at 1×10^{-2} Torr (1.33 Pa) until the termination of the reaction. The system was heated under the protection of argon gas and held at 850 °C for 30 min. After the growth, the furnace was naturally cooled down to the room temperature. Some dark grey powder was deposited in the areas masked by the silicon sticks, while light grey powder was found elsewhere (Fig. 2(a)).

The scanning electron microscopy (SEM) examination was performed by Hitachi S-4800 at an acceleration voltage of 5 kV. The transmission electron microscopy (TEM) and high-resolution transmission electron microscopy analysis were carried out with JEM-2010 transmission electron microscope with a point resolution of 0.14 nm operating at 200 kV. The X-ray diffraction (XRD) pattern was measured using Rigaku D/max 2550pc test system.

3. Results and discussion

The typical XRD pattern of our sample is shown in Fig. 1. The dominant peak at 42.96° is attributed to cubic MgO (2 0 0) plane. The intensity of the peak at 62.37° indexed to MgO (2 2 0) plane is

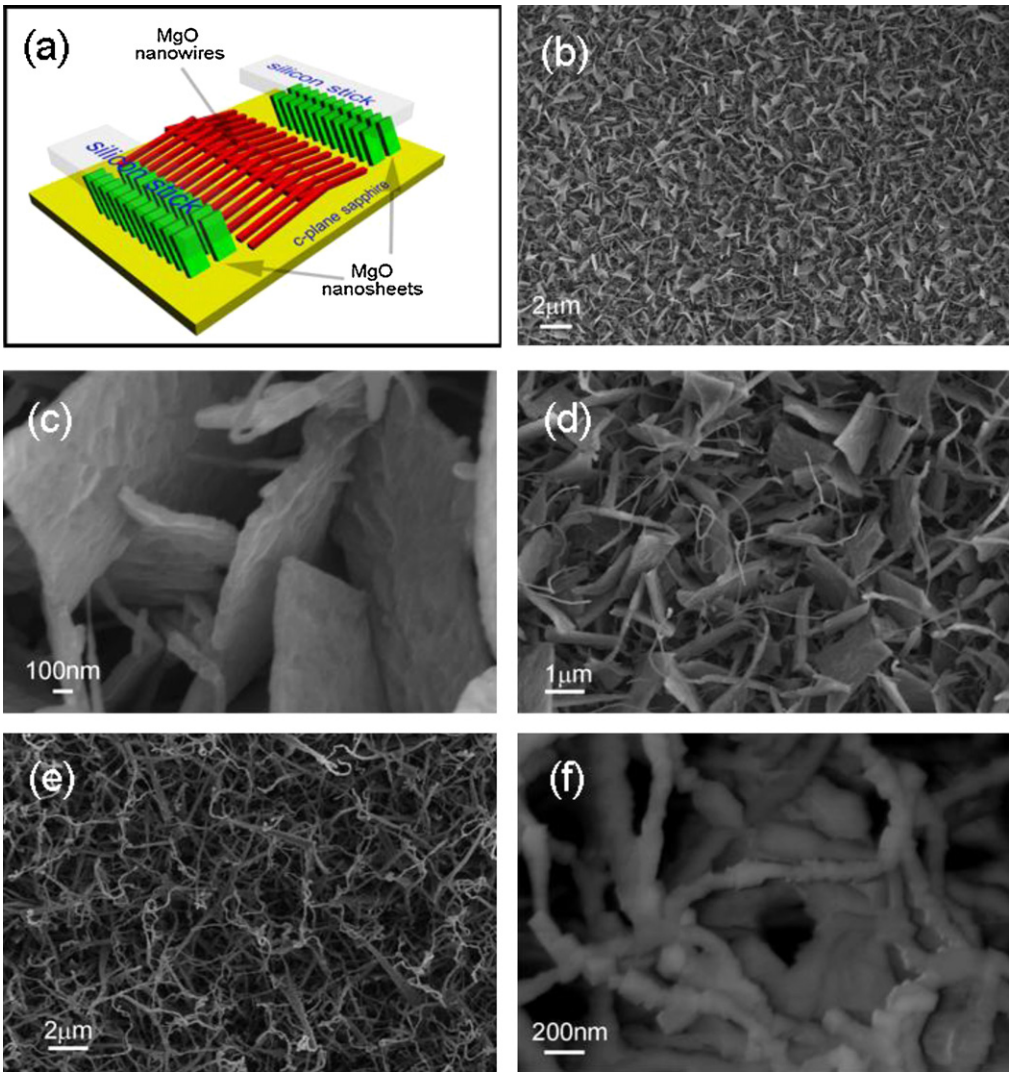

Fig. 2. (a) Schematic visualization of as-obtained MgO nanosheets and nanowires in different area on the substrate, respectively, where we only draw the nanowires and nanosheets in order for simplicity and do not represent the blend of nanosheets and nanowires. SEM images of MgO nanosheets at (b) low and (c) high magnification, respectively. (d) The blend of MgO nanosheets and nanowires, (e) and (f) is MgO nanowires at low and high magnification, respectively.