Uninterrupted and reusable source for the continuous supply of vapours

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Method Article

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Abstract

The protocol describes an uninterrupted and reusable source for the controlled growth of nanowires. This is achieved by using a cap (substrate) over the source materials preventing the oxidation of the source. The cap should have high temperature stability and negligible solid solubility with the source materials up to very high temperature typically far more than the reaction temperature required for nanostructure growth. The idea is to protect the source from high temperature oxidation/degradation during growth thereby ensuring continuous supply of vapour for the growth of nanowire without any apparent limitations. Protection of source could also ensure the use of source material in multiple depositions for growth of nanowires. The protocol for growth of ZnO nanowires by using Si cap on Zn powder source is provided.

Introduction

Theoretical descriptions on the catalytic as well as non-catalytic growth of nanowires are available in the literature.¹⁻⁴ The diameter of nanowires is mainly controlled by the size of the catalyst,²⁻⁴ while the diameter of nanowires obtained by non-catalytic growth is governed by thermodynamic limit.¹ On the other hand, the length and hence, the aspect ratio of the nanowires, is expected to increase with growth duration. But the quest to improve aspect ratio is limited by various experimental shortcomings such as catalytic poisoning,⁵ degradation of the precursors and growth in all possible directions.⁶ We have employed a technique wherein the source is protected from degradation ensuring the continuous supply of vapor to overcome the limitations in nanowire growth. This is achieved by placing Si cap (local oxidation barrier) on Zn source ("figure

1":<http://www.nature.com/protocolexchange/protocols/2585/uploads/2449>). See figure in Figures

section.:<http://www.nature.com/protocolexchange/protocols/2585/uploads/2449> Ultralong ZnO nanowires (>300 μm) with huge aspect ratio (>104) are achieved by this method ("figure

2":<http://www.nature.com/protocolexchange/protocols/2585/uploads/2451>). See figure in Figures

section.:<http://www.nature.com/protocolexchange/protocols/2585/uploads/2451> This method also allows the use of multiple sources to increase the vapour flux so that the diameter could not only be controlled thermodynamically but also kinetically ("figure

3":<http://www.nature.com/protocolexchange/protocols/2585/uploads/2452>). See figure in Figures

section.:<http://www.nature.com/protocolexchange/protocols/2585/uploads/2452> The length of the nanowire can be increased by increasing the deposition time and the diameter of the nanowire can be reduced by increasing the temperature and/or vapor flux. The same source material can be used for several depositions of oxide nanostructured materials and suitable combination of materials can help to grow other oxide/sulfide nanostructures and oxide-sulfide branched structures in a controlled way. The method is described below.

Reagents

1. 10 mg of Zn powders \(\text{S.D fine 99.95}\%) 2. Si substrate with 1x1 cm² \(\text{typical dimension could vary according to surface area of powder or needs}\).

Equipment

1. Horizontal tube Furnace \(\text{commercially available one which can go maximum } \sim 1200\text{ }^{\circ}\text{C}\) 2. Alumina work tube 3. Quartz boat with typical dimension 4. Argon gas \(\text{99.99}\%\text{ cylinder with mass flow controller. 5. Substrates }\backslash\text{(glass, ITO coated glass, Si and Carbon nanotubes }\backslash\text{(CNTs) grown on any substrate)}\).

Procedure

1. Zn powder of 10mg is made into pellet \(\text{quantity could vary depending on the needs}\). 2. A Si cap is placed over Zn pellet 3. Si cap with Zn pellet is placed at the centre of the quartz boat. 4. The whole assembly with the quartz boat is placed inside the alumina work tube in a horizontal tube furnace ensuring the assembly with quartz boat is at the centre of the furnace. 5. Substrates for growth of nanowires are placed very close to the source typically 5 mm from the centre on quartz boat. 6. Growth temperature could vary from 550 ~ 900 °C with desired growth time period as per requirement. 7. More than one source with cap could be used for enhancing the growth of nanowire. 8. If suitable platform could be provided and substrate height could be matched with that of the top of source pellet, growth on ultra large area substrate can be realized.

Anticipated Results

Ultralong nanowires with controllable aspect ratio in large area.

Figures

Figure 1

Set up Schematic of the experimental setup. Si cap placed on Zn powder and substrate is placed at particular distance from the source.

Figure 2

Images of nanowires ZnO nanowires on a) Sodalime glass (SLG) b) Multiwalled carbon nanotubes (MWCNT), c) Si, and d) ITO coated glass.

Figure 3

nanowire with different source SEM images of ZnO nanowires on glass obtained by increasing the vapour flux (a) single source and (b) triple source with TEM images in the inset. Schematic of (c) single and (d) triple source configurations.