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Letter

Formation of NiO nanowires on the surface of nickel strips

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ABSTRACT

In the present investigation, a simple metallographic technique has been introduced to synthesize bulk amount of nickel oxide (NiO) nanowires. These nanowires were formed on the surface of pure nickel strip, which were processed by single roll strip casting (SRSC). The length and diameter of these nanowires were in the range of 3.0–4.0 μm and 80–90 nm, respectively.

1. Introduction

Nickel oxide (NiO) is widely used in catalysis, battery cathodes, electro-chromic films, gas sensors, and magnetic materials. Due to the volume effect, the quantum size effect, the surface effect and the macroscopic quantum tunnel effect, nanocrystalline NiO is likely to possess many better properties than those of micrometer-sized NiO wires. Several techniques have been developed to prepare nanometer NiO in the recent past [1–6]. However, these techniques were used mainly to develop NiO nanoparticles. Yu et al. prepared highly ordered NiO nanowires by sol–gel template method [7]. These NiO nanowires are mainly used as a component in batteries [8,9] and gas sensors [10–13] of various engineering application. However, the present processes to manufacture NiO nanowires have several disadvantages like cost effectiveness, complexity and criticality. Also, there are limitations on bulk production of these nanowires.

In the present investigation, a simple metallographic technique has been introduced to produce bulk amount of NiO nanowires. These nanowires were formed on pure nickel strip, which were processed by single roll strip casting.

2. Experimental

The Ni strip was prepared using a horizontal SRSC process. The casting and roll temperatures were 1610 and 50 °C, respectively. The rolling speed was kept constant at 0.17 m/s (4 rpm). Argon gas was blown at the rate of 25 l/m on the strip surface to avoid oxidation of the alloy.

The dimensions of the sample used in the present investigation were 10 mm × 10 mm × 1 mm. The samples surface was polished using metallographic technique (up to 1 μm diamond paste solvent). The polished sample surface was etched by a reagent having composition conc. HCl (10 ml) + conc. HNO_3 (10 ml) + $FeCl_3$ (5 g) + ethanol (80 ml). The samples were mounted on a conductive polymer covering five faces and exposing one surface (10 mm × 10 mm) to the atmosphere. The sample was then immersed into the reagent for approximately 10 s (exposed surface facing upward).

Primarily, microstructural characterization studies were accomplished using an optical microscope. Scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectrometer (EDS) was used to examine the samples. X-ray diffraction study was carried out to confirm the chemical state of different phases.

3. Results

Fig. 1 shows the optical microstructures of the Ni strip at lower and higher magnification. At lower magnification (200×) huge bright and dark grains are observed (Fig. 1(a)). Grain interior shows black dots uniformly distributed throughout the grain. However, bright islands without black dots are observed inside some grains. At higher magnification (500×) black dots dot free island are clearly visible. Some elongated black features are also observed at the bottom region of the microstructure (Fig. 1(b)). To find the real shape and chemical composition of these features SEM, EDS and XRD studies were carried out.

Fig. 2 shows SEM microstructure of Ni strip surface. Very fine bright wires are observed uniformly distributed throughout the matrix (Fig. 2(a)). It is also observed that each wire grows from

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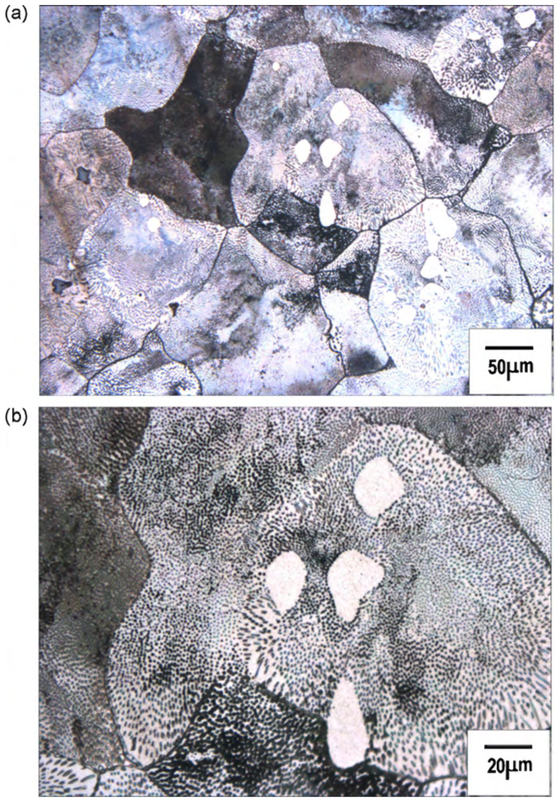

Fig. 1. Optical microstructures at (a) lower and (b) higher magnification of Ni strip surface.

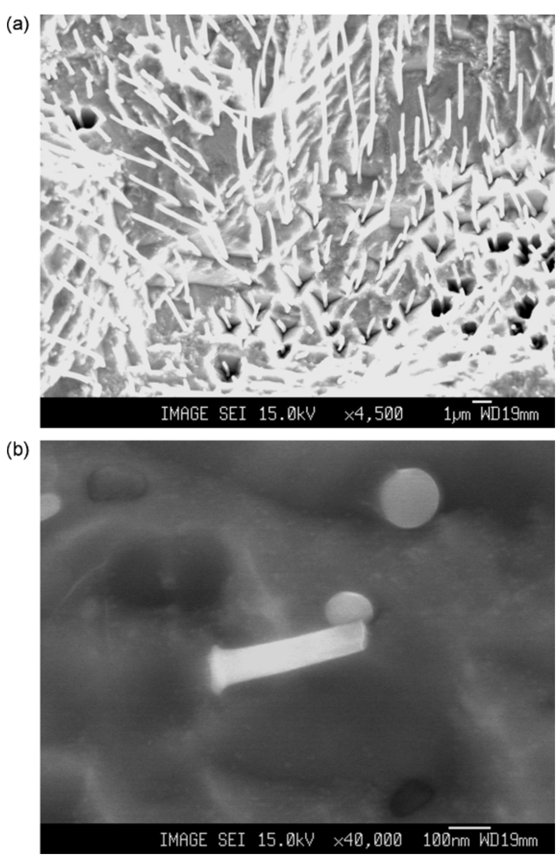

Fig. 2. Scanning electron microstructures of Ni strip surface at (a) lower and (b) higher magnification.

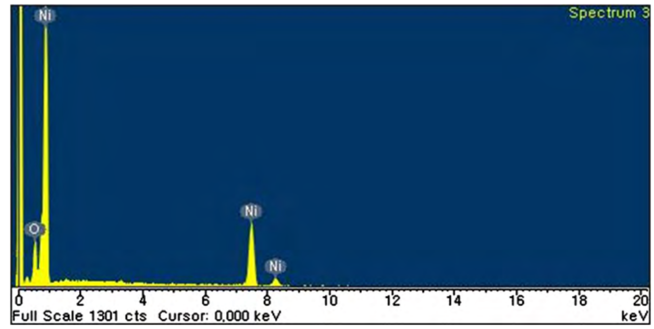

Fig. 3. EDS spectrum on the nanowires.

a pit on the matrix. Fig. 2(b) shows a broken nanowire along with two nanosize particles. EDS spectrum on these nanowires shows the presence of Ni and O as shown in Fig. 3. XRD analysis confirms the presence of NiO phase along with Ni, which is the base metal. Hence, from the EDS and XRD results it can be conclusively said that these nanowires are NiO. Sigma scan image analyzer has been used to measure the average length and diameter of these nanowires. It is found that the length and diameter of these nanowires were in the range of 3.0–4.0 µm and 80–90 nm, respectively.

4. Discussion

The dots observed in optical microstructures (Fig. 1(a and b)) are NiO oxide nanowires, which is clear from SEM microstructure (Fig. 2) EDS (Fig. 3) and XRD (Fig. 4) results. The growth mechanism of NiO nanowires can be explained by the schematic diagram shown in Fig. 5. NiO particles are formed on the surface during SRSC process. In Fig. 2(b) NiO nanoparticles are observed. Interfaces between the particle and matrix are more reactive to etchant solution compared to NiO nanoparticles or matrix [14]. During etching process the interface gets corroded vertically downward direction due to gravity. The volume under the particle has little chance of getting etched by the chemical reagent. This forms cylindrical structures/wires, which gets oxidized readily in normal atmosphere due to its very small size. And hence, NiO nanowires are formed.

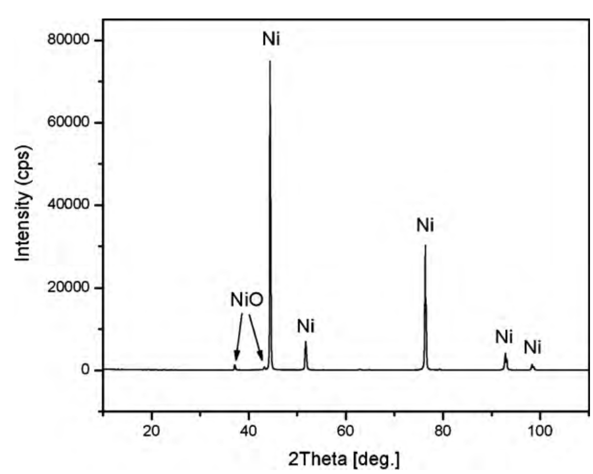

Fig. 4. XRD result of Ni strip.

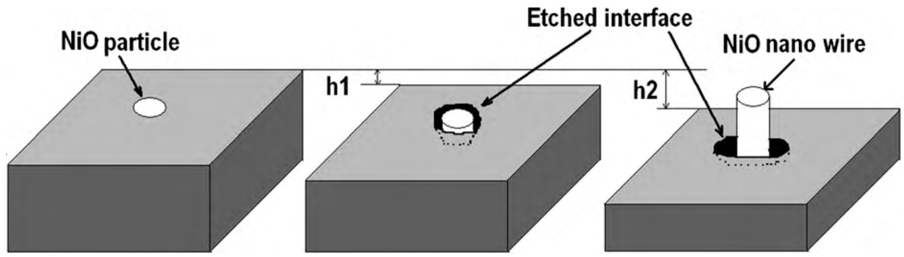

Fig. 5. Schematic of NiO nanowires growth mechanism.

5. Conclusions

Following conclusions can be drawn on the basis of present study.

1. NiO nanowires of 80–90 nm diameter and 3–4 μm length can be synthesized from Ni strips using simple metallographic etching process.
2. Cost effective and bulk production of NiO nanowires is possible by this technique.

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