Electrodeposition of NiCr Nanowires Using Anodic Aluminum Oxide

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Abstract

This research highlights fabrication of NiCr nanowires by electrochemical deposition. The deposition was achieved using anodic aluminum oxide AAO template with 70 nm diameter of pores. The anodization was performed using oxalic acid with two steps to obtain AAO template. 72.3Ni27.7Cr nanowires were obtained using nickel and chromium sulfate. The nanowires were characterized by SEM and TEM. The obtained nanowires with 70 nm diameter and 420-500 nm length.
Keywords: Nanowire; NiCr; Electrochemical method; AAO template.

الخلاصه

يشير هذا البحث الى تصنيع اسلاك نانوية لسبيكة نيكل–كروم بواسطة الترسيب الكهروكيميائي. انجز الترسيب الكهروكيميائي على اساس من اوكسيد الالمنيوم المؤنود (AAO) ذات ثقوب نانوية قطرها (70 nm). تمت عملية الانودة للالمنيوم بأستعمال حامض الاوكزالك وذلك بخطوتين من الانودة للحصول على الاساس AAO ثم تلاها ترسيب سبيكة نيكل–كروم من املاح كبريتات النيكل وكبريتات الكروم وكانت نسب العناصر الناتجة للسبيكة هي 72.3Ni27.7Cr . الاسلاك النانوية الناتجة تم تشخيصها بأستعمال المجهر الالكتروني SEM والمجهر الالكتروني TEM.ان الاسلاك النانوية الناتجة تمتلك قطر بمقدار(70 nm) وطول (420-500 nm).
الكلمات المفتاحية : اسلاك نانوية، نيكل-كروم ، الترسيب الكهروكيميائي ، الاساس AAO.

1.Introduction

Nanowires exhibit high aspect ratios of length to width, refer to one-dimensional materials (1D) and have many properties that are not showing in the bulk materials.

Metallic nanowires took a wide range of applications and attracted many researchers to fabricate them and study their properties. There are many methods to fabricate nanowires, but the simplest is electrochemical method using anodic aluminum oxide (AAO) template which provides pores with nanoscale of diameters. Numerous researchers interested by fabricating metal nanowires as single and as alloy such as Mo (Michael , 2000), CdS/Co (Cheonho, 2002), Ag (Yu-Hung, 2004)], Bi (Bisrat, 2007), Au–TiO_2–Au (Edward, 2007), NiCu (Iraj, 2008),CoCrPt (Shamaila ,2009),CuSe (Saidin , 2013), NiCo, AuNi (Gheorghies , 2013) and NiCo/BaFe (Gheorghies , 2015).

1.1.Applications of NiCr Nanowires

Nanowires have large surface area, transport carriers and ions in addition to facile strain relaxation. The applications of one dimension nanowires can be shown in (i) quantum devices (ii) nanostructure of functional materials, (iii) nanophotonics, (iv) nanoelectronics, (v) novel probe microscopy tips, (vi) storage energy, (vii) conversion of energy, (viii) biological and chemical sensing, and (ix) nanobiointerfaces(LANGÅRD, 1994)

The applications of NiCr nanowires in nanomedicine represent nanotechnologies in biomedical, which precisely nanomaterials for diagnostic modalities and novel therapeutic. NiCr nanowires can be used as drug delivery vehicles since they are naturally endocytosed by cells(STERN, 1992).

The present work aims to fabricate NiCr nanowires using AAO template and characterize them by SEM and TEM.

2.Experimental Procedure

2.1.Preparation of AAO Template

Aluminum sheet with thickness (0.5mm) was cut to circle shapes with (20mm) diameter to prepare anodic aluminum oxide template for depositing the nanowires. Cleaning with acetone has been done for Al specimens and to get more active Al surface, the Al specimens were treated with 3M NaOH and then electrochemically polished.

Oxalic acid with concentration 0.3 M was used as electrolyte for anodization. The anodization was achieved in two steps, in the first; the specimen was put in a special cell as shown in Figure (1) and connected to the positive terminal of power supply to act as anode and rod of stainless steel 316L was used as cathode in electrochemical cell. The period time of first anodization had done by applying 30V for 8 hrs. at room temperature and then the specimen was treated with (H_3PO_4+$H_2Cr_2O_4$) mixture to open the pores for 1 hr at 60^oC.

The second anodization was achieved in the same electrolyte for 6 hrs and then the specimens were wished with deionized water and ethanol. The immersion in acetone at 60^oC for 1hr was performed to remove the remained alumina.

2.2.Deposition of NiCr Nanowire

Nickel sulfate $NiSO_4.6H_2O$ 0.35 M, chromium sulfate $Cr_2(SO_4)_3$ 0.1 M and 30 g/L of boric acid H_3BO_3 were used as electrolyte to deposit the NiCr nanowires. The AAO template was acted the cathode in electrochemical cell with Ni rode (purity 99.99%) acts as anode. The voltage of deposition was 1.5 V for 40 min, then AAO templates are dissolving completely by using 6M KOH and dissolving partially by using (10%HCl + 90% ethanol).

2.3.Characterization of Nanowires

Scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) was used for characterization. Transition electron microscopy (TEM) also used to identify the fabricated nanowires. These inspections were achieved for partial and complete removal of template. The partial dissolving of AAO was performed by 10% HCl and ethanol, while complete dissolving was done by 6 M KOH solution.

3.Results and Discussion

The relationship between time and current density of anodization is shown in Figure (2) with SEM image for each stage. Pores with ≈ 70 nm as diameter were obtained for prepared AAO; this diameter was measured using J Image program.

Figure (3) shows the SEM images, these images indicate the nanowires after partial and complete dissolving of template. In partial removal, we can see nanowires in randomly orientations and can't distinguish the phases between Ni and Cr. Also these images demonstrate the growth of multilayer and the plane of the layers is almost perpendicular to the wire axis. The black and white bands seen are not from the individual layers, but are due to the strain contrast between the layers. The modulation wavelength is different from one end of the wires to the other. The average diameter of the wires was measured to be (70-72 nm), which was considered in the J program. The EDS analysis in Figure (4) indicates the weight percentages of Ni and Cr in fabricated nanowires; they are 72.3 wt% Ni and 27.7 wt% Cr.

Figure (5) shows TEM images of NiCr nanowires obtained: (a) partial dissolved and (b) complete dissolved of template. The side view of fabricated nanowires shows the uniformly wires arrays with the same dimensions. This observation is also indicated in TEM image after completely removing of template. The image of single NiCr nanowire can be seen in Fig. (5-c)

4.Conclusion

NiCr nanowires have been fabricated by electrodeposition using anodic aluminum oxide template. The obtained nanowires were characterized by SEM, EDS and TEM with 70-72 nm diameter and 420-500 nm length. The EDS analysis shows the obtaining 72.3Ni27.7Cr nanowires with uniformly arrays of wires.

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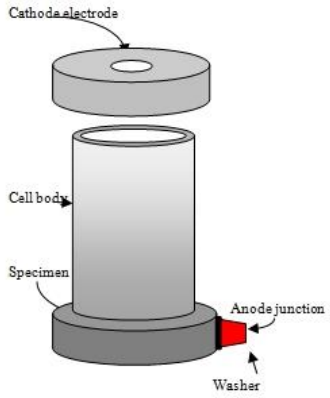

Fig. (1) Electrochemical cell for deposition of nanowires.

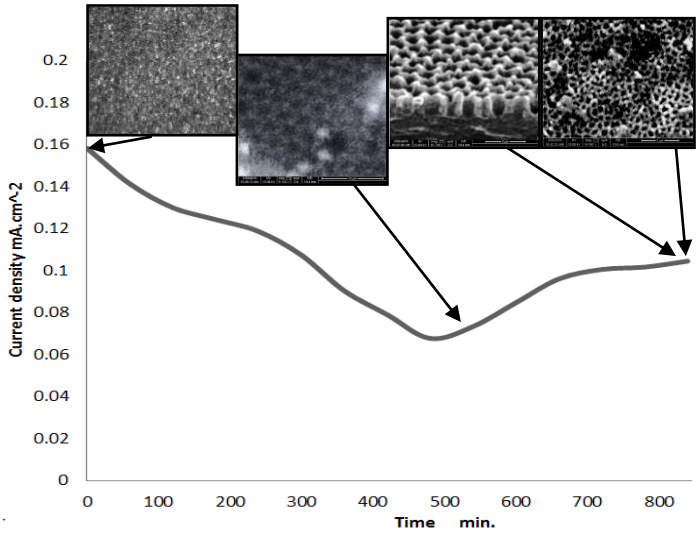

Fig. (2) Current density – time measurements of anodization process.

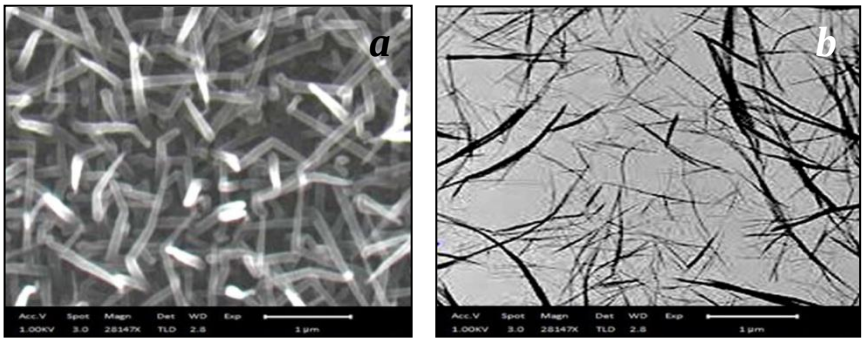

Fig. (3) SEM images for NiCr nanowires; (a) Partial removal of template and (b) Complete removal of template.

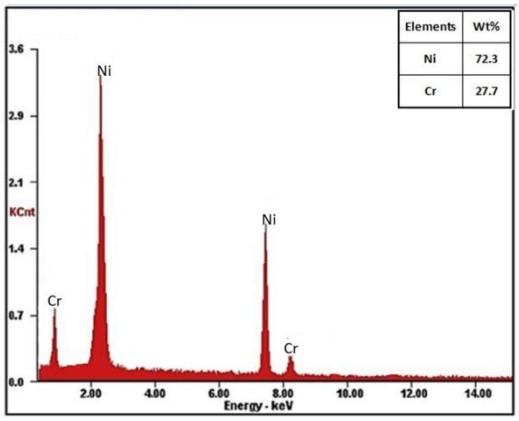

Fig. (4) EDS of fabricated NiCr nanowires.

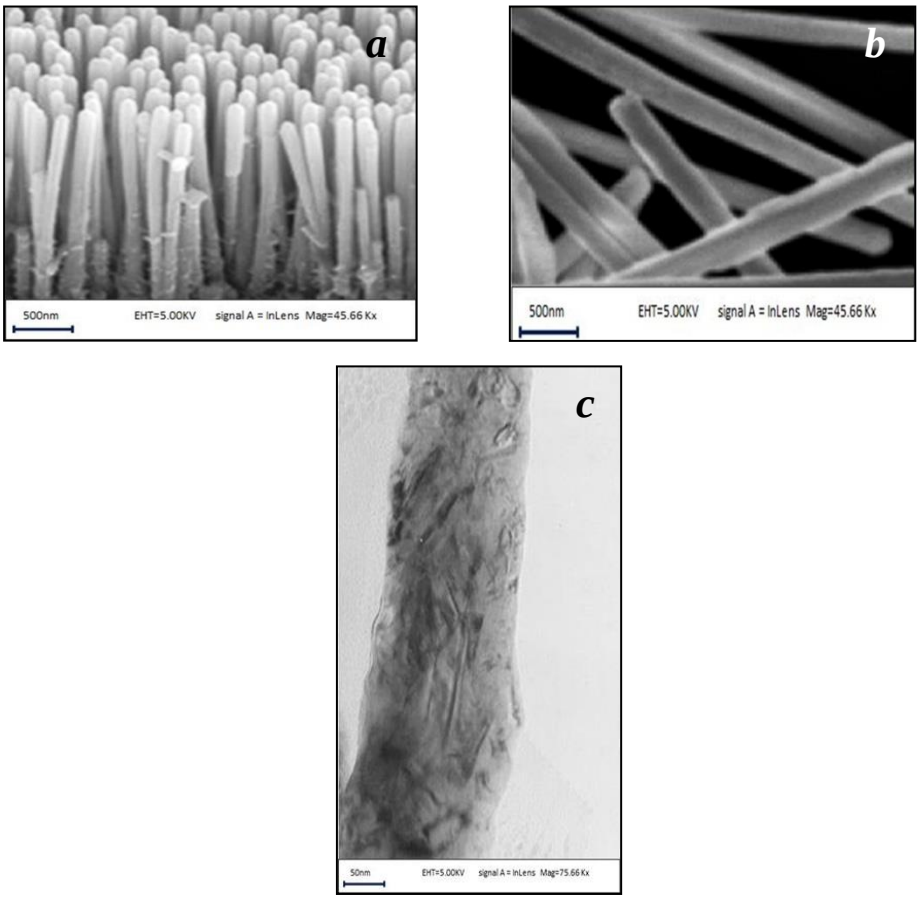

Fig. (4) TEM images of NiCr nanowires; (a) Partial removal of template, (b) Complete removal of template and (c) Single nanowire.