

Fabrication of One-Dimensional Magnetic Particles Chain of Polycrystalline Nickel under Magnetic Field

Xie.Shengli^{1,2,a}, Xu.Lina^{1,b} and Gu.Ning^{1,c¶}

¹Jiangsu Laboratory for Biomaterial and device, National Laboratory of Molecular and Biomolecular Electronics, Research Center for Nano-scale Science and Technology, Southeast University; Nanjing 210096, China

²Department of Chemistry and Chemical Engineering, Southeast University, Nanjing 210096, China

^axshl1694@163.com, ^bxulina@seu.edu.cn, ^cguning@seu.edu.cn

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Abstract. Nanoscale magnetic materials have been receiving increasing interest for their potential applications. One-dimensional magnetic particles chain of polycrystalline nickel was prepared by a simple template-free method under magnetic field. Based on solution reduction reaction of Ni^{2+} , metallic nickel was deposited and synchronously self-assembled into chains under magnetic field. The results show that the chain of polycrystalline nickel was several micrometer in length and several hundreds nanometer in diameter. VSM measurements indicate the magnetic properties of chains formed can be modulated by the reaction time and the solution concentration. It is suggested that the magnetic field be an effective and tunable way to the fabrication one-dimensional chains of magnetic materials.

Introduction

Nanowire, the basic building block of a nanostructure and foundational part is becoming the focus of intense research. The potential application including magnetic sensors, electro optical and sensing devices and the push to minimize of computational devices are making it more attractive^[1]. Magnetic metal materials such as $\text{Fe}^{[2,3]}$, $\text{Co}^{[4,5,6]}$, and $\text{Ni}^{[7,8]}$ have been studied for many years. Various methods have been developed to prepare the nanoscale magnetic metal particles. The magnetic metal materials can be manipulated by the magnetic field. It has been found that the magnetic field can significantly influence the properties of the magnetic materials.^[9,10]

In this paper, we report the synthesis of polycrystalline nickel under the magnetic field. In the experiment, the reduction reaction was taken place. In the reaction Ni^{2+} was reduced to Ni, synchronously the metal Ni self- assembled into wires in the magnetic field. Nickel would grow easily under appropriate supersaturation along the magnetic field into wires.

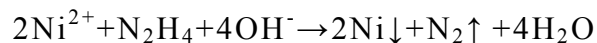
Experimental section

In the experiment, all the reagents are analytical grade or higher. The experiment was carried out as the following steps. Firstly, the solution containing 7.88gL^{-1} NiSO_4 , 12.72gL^{-1} potassium sodium tartrate and 5.0gL^{-1} sodium hydroxide was prepared. Secondly, put the solution in the magnetic field and heat it up to 80°C . Then the reducer hydrazine was added simultaneity with strongly stirring for a while. The color of the solution changed from grass-green stopped the stirring. In the end the solution turned into colorless. The reaction was carried out for 1.5h and 3h until the reaction was finished and the polycrystal nickel formed. Thirdly, the polycrystal nickel was washed with the ethanol and distilled water for several times respectively. Last, the product was dried in a vacuum oven at 40°C and then characterized by the transmission electron microscopy(TEM, JEOL, Japan, Hitachi), selected area electron diffraction pattern(SAED, JEOL, Japan, Hitachi), X-ray powder diffraction (XRD) with Cu $K\alpha$ radiation ($\lambda = 1.54056 \times 10^{-10}$ m) and the scanning electron microscopy (SEM, LEO, 1530). Magnetic hysteresis loops were measured by a vibrating sample

magnetometer (VSM, Model 7300, LakeShore).

Results and Discussions

The chemical reaction for the synthesis of nickel nanocrystallite can be expressed as below.



In this reaction the Ni^{2+} was reduced into Ni. The nickel formed was self-assembled into nanowire under the magnetic field immediately. In this process the nitrogen formed in the reaction could protect the nickel from oxidation.

The sample was prepared for TEM observation. Figure 1 show the image nickel prepared in 1.5h. (a) is the panorama of the wire. (b) is the magnification of the wire. Figure 2 show the image of nickel of the polycrystalline wire and the SAED pattern taken on the surface of a wire and the acicular crystallite on the edge of the wires. From the result we can see the wire approximately 300nm in the diameter and sever micrometer in the length. The wire was composed of sphere which is polycrystal nickel proved by the SAED pattern (Figure 2.c) took on the wire. There are many acicular crystallite on the edge of the spheres which can be proved by the image of the product taken in dark field (Figure 2.d). The TEM image (Figure 1,2) show that the nanocrystal of nickel was self-assembled into wire under the magnetic field. At the beginning of the reaction the wire was made up of the single sphere of nickel. With the reaction doing, the wire became longer and perfect. But the wire all were polycrystal.

The XRD pattern of the product was shown in figure 3. The pattern is influenced by the substrate of silicon wafer. But it can also be concluded that the product was crystalline structure.

The product was dipped on the silicon wafer under the magnetic field for detect. The sample was observed by SEM. The result agreed with the anticipation that the wires would pattern orderly on the silicon wafer. Figure 4. shows the SEM image of the product. The EDX (Figure 4 b) indicates that there are Si, Ni and O elements only on the silicon. The Si and O elements are the composition of the substrate. It is suggest that the product was composed by Ni element.

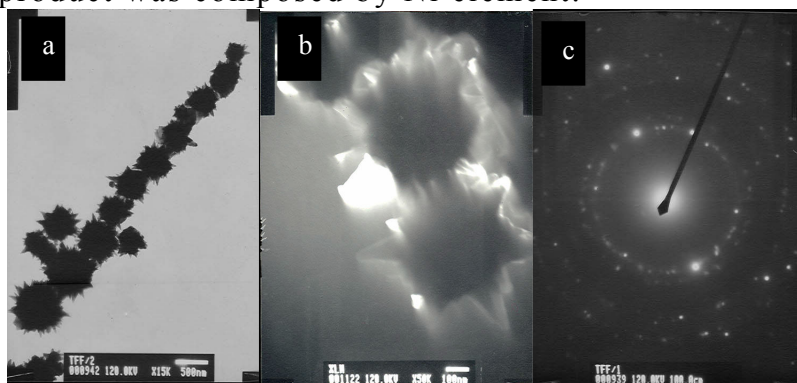


Figure 1. TEM image of the sample formed in 1.5h
 (a) the panorama of the wire. (b) the magnification of the wire. (c) SAED pattern taken on the surface of the product

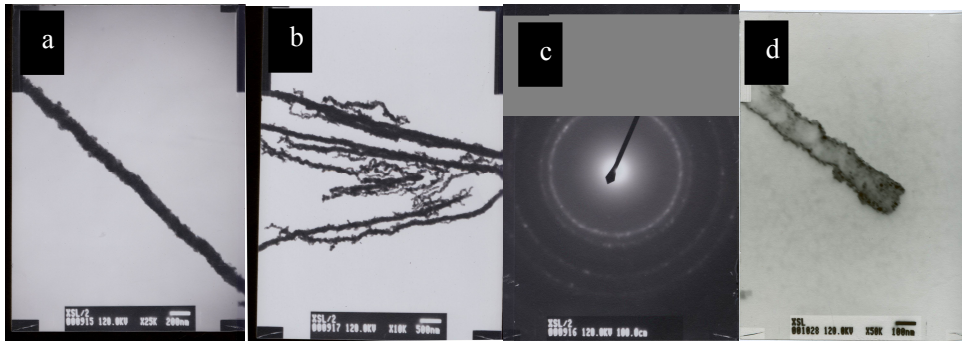


Fig2. TEM image of the sample formed in 3h. (a) (b) the image of the wire. (c) the SAED patterns taken on the surface of the wire. (d) the image taken in the dark field.

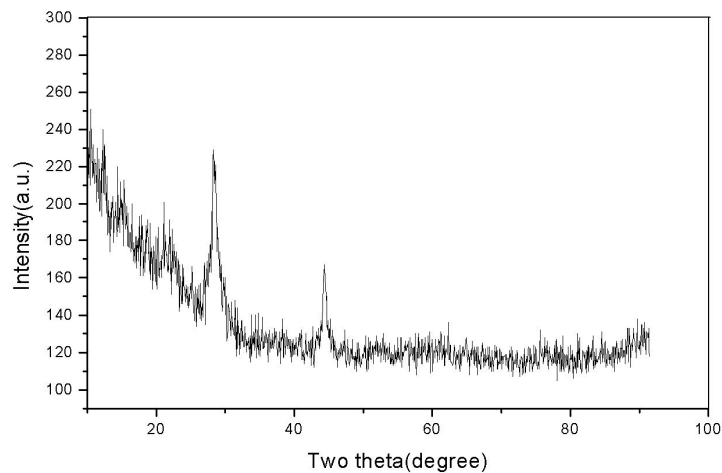


Fig 3. XRD image of the nickel wire obtained in this work.

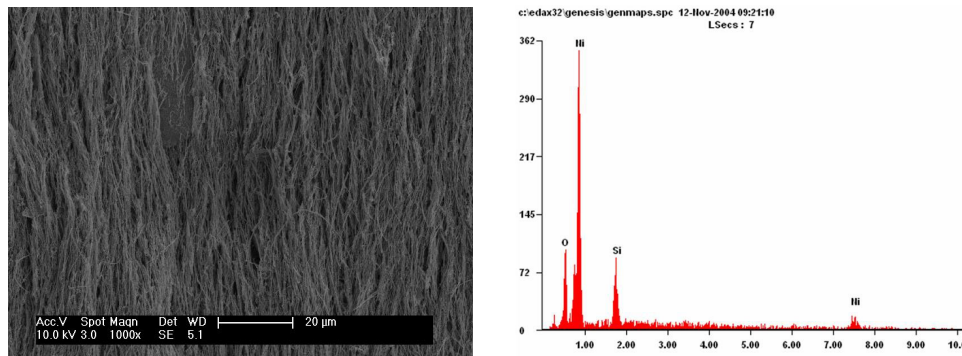


Fig 4. (a) SEM image of the sample. (b) EDX spectra of the sample.

The magnetic properties of the product were investigated by VSM (Figure 5). Figure 5.a presents the applied field parallel to the lengthwise direction of the self-assembled structure. Its coercivity is 173.5G, the saturation value of magnetization is 15.6emu/g and M_r is 1.12emu/g. For comparison, b is perpendicular to the lengthwise direction of the wires. Its coercivity is 179.5G. the M_s is 12.2 emu/g and M_r is 3.8 emu/g. The M_s a was higher than b, but the M_r a was lower than b. The coercivity a was higher than b. Future study will focus on the magnetic properties of the polycrystalline nickel wire.

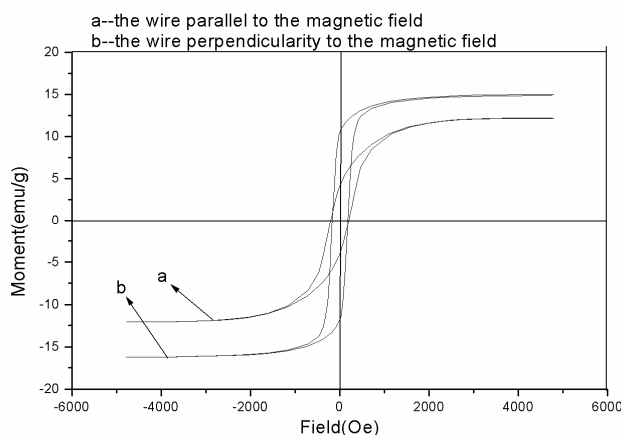


Fig 5. Hysteresis loop of sample made from nickel wire .

Conclusions

In conclusion, polycrystalline nickel nanowire with a several micrometer in length and several hundreds nanometer in diameter was formed in magnetic field. The magnetic properties of chains was different when it was put parallel to the magnetic field and perpendicular to the magnetic field. This method of formation of one-dimensional magnetic particle chain polycrystalline nickel was a template-free and simple one. The wires were influenced by the reaction time. The magnetic field played an important role in the formation of wires. The magnetic field provided the attraction force between nickel crystallites to cause them to grow into wires. The magnetic field would be a determinant to the nanowires' structure, magnetic properties.

Acknowledgement

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