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Nanomaterials-Technology of Cadmium Sulphide Nanowire Production by Crystalline Sodium Sulphide Nonahydrate

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The developed method allows receiving cadmium sulphide nanowires safely, cheaply and simply. In this method, sodium sulphide nonahydrate as a solid compound was used. By-products, in the form of toxic gas (hydrogen sulphide), occur in small quantities. The length of cadmium sulphide nanowires averages 60 mm, whereas their diameter is 200 nm on average.

Key Words: Nanotechnology, Nanowire synthesis, CdS, $Na_2S\cdot 9H_2O$.

INTRODUCTION

Examination of the damascene steel conducted recently under electron microscope has showed that its microstructure is also composed of nanoelements, which are probably responsible for exceptional properties of that material. Unusual properties of the damascene steel produced near Damascus are one of the legends of the European Middle Ages.

Crusaders in the Holy Land came into contact with exceptionally sharp and durable sabres and swords with a characteristic wavy pattern on their surface. The process of production of that unusual weapon was kept secret and became forgotten at the turn of the 17th and the 18th century. Works on its identification have been continued as early as from the 19th century. At present, physicists and metallurgists are able to produce steel with similar properties but the secret of mediaeval original has not been discovered yet.

Results of the next analysis of metal samples from a damascene steel pommel have been recently presented by researchers of the Institute of Structural Physics of the Dresden University of Technology (Technische Universität Dresden). The analyzed metal fragment comes from a sabre (shamshir) produced in the 17th century in the forge of Assad Ullah, a famous swordsmith, being at present in the collection of the Berne Historical Museum, Switzerland. German physicists have observed the microstructure of this famous steel under high resolution transmission electron microscope. This system allows identification of objects of the size of a few nanometers. These researchers have spotted in the steel sample the presence of carbon nanotubes and cement nanowires (built of cementite particles), *i.e.*, the elements being known to physicists for just a few years.

Probably, this is the presence of these nanoelements that significantly improves mechanical properties of the damascene steel. Physicists, however, are still thinking about the process by which medieval swordsmiths in the vicinity of Damascus were capable of producing steel blades with such an exceptional microstructure. Contemporary metallurgists are not able yet to develop a method which would allow forging a block of alloy with such a high content of carbon and carbides, representing an exceptionally fragile grade of steel.

The secret of mediaeval process is probably a complex system of the selection of alloy components as well as smelting temperature and that of successive stages of forging. The blocks of steel, of which the damascene weapon was forged, came from India where ore from only specific mines was used for their production, as well as wood of a particular tree species for heating of the melting ore. All details of this process disappeared in the 17th century with the death of last damascene steel blacksmiths.

Today, there are many publications that inform about different methods of receiving nanowires[1-8]. However, publications talking about a non-complex process of receiving nanowires are not much[9-12]. In the experiment described below, a rather simple method of receiving cadmium sulphide nanowires is presented.

EXPERIMENTAL

In order to receive cadmium sulphide nanowires, the following substrates have been applied: (1) cadmium chloride manufactured at the Polish Chemical Reagents Chemical Plant in Gliwice with purity of 99.9 %; (2) sodium sulphide nonahydrate ($Na_2S·9H_2O$) in the crystalline form, manufacured at the Polish Chemical Reagents Chemical Plant in Gliwice with purity of 99.9 %; (3) methyl alcohol manufactured by Chempur® Chemical Reagents in Piekary Slaskie with purity of 99.9 %; (4) acetone manufactured the Polish Chemical Reagents Chemical Plant in Gliwice with purity of 99.9 %.

The synthesis of cadmium sulphide nanowires consists in introduction of 9 g pure cadmium chloride ($CdCl_2$) into a 1 L glass beaker. Then, 20 g of clean fresh distilled and deionized water is added into the beaker. When adding the water, the solution should be stirred until the whole amount of $CdCl_2$ has dissolved at a raised temperature. After stirring, the solution should be cooled down so as to not precipitate in water solution. Then, a freshly distilled acetone is slowly added to $CdCl_2$ solution in a 1 dm^3 beaker by means of a dropping funnel. During instilling, the solution has been stirred with a magnetic agitator. Duration of the stirring with simultaneous instilling has lasted until a visible colloidal solution appeared. After receiving the visible colloidal solution, 100 mL of acetone have been added again and the whole solution has been stirred once more for 1 h. After 1 h stirring, the whole colloidal solution has been subject to drying at a temperature between 353 and 363 K at normal pressure (1013.25 hPa) for 48 h.

In the next stage of cadmium sulphide nanowire production, 200 mL of methanol should be added into a 1 dm^3 beaker, followed by adding 12 g of sodium sulphide nonahydrate and the whole content of dried colloidal cadmium chloride material.

The whole prepared content is introduced into a teflon container in metal casing. After closing it tight, temperature has been raised to 373 K and the container has been left for 24 h. During that time, cadmium sulphide nanowires develop according to reactions expressed in molar units:

$$0.05CdCl_2 + 0.05(Na_2S{\cdot}9H_2O) \rightarrow CdS\downarrow(\text{nanowires}) + 0.1NaCl + 0.45H_2O$$

After 24 h, cadmium sulphide nanowires in the form of precipitate are rinsed with methanol in order to remove residues of non-reacted cadmium chloride and dried at 353 K. It is washed with deionized water and again dried at 380 K. This process has been repeated two times, alternately washing and drying cadmium sulphide nanowires. Following diagram showed the method of formation of cadmium sulphide nanowires Fig. 1.

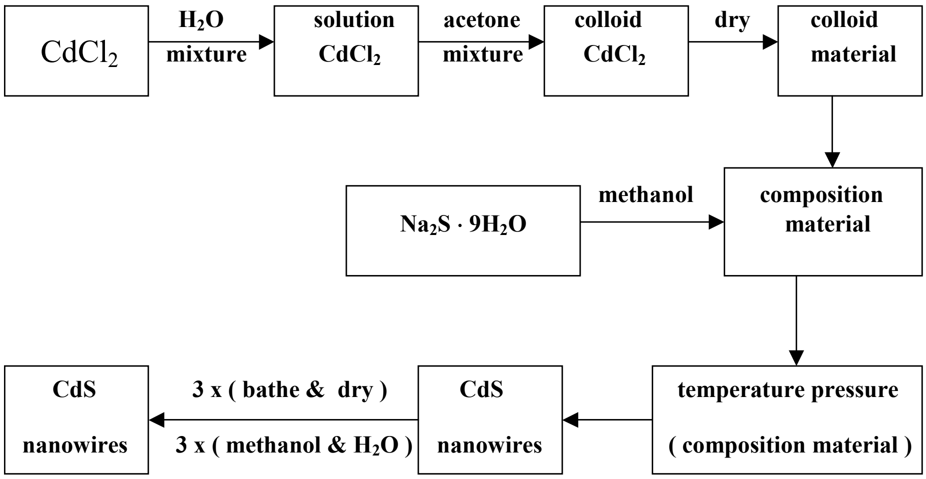

Fig. 1. Diagram showed below presents the method of receiving cadmium sulphide nanowires

RESULTS AND DISCUSSION

Fig. 2 presents the SEM photo of cadmium sulphide nanowires, which have clear shapes of the wire structure. These shapes are regular and cylindrical, typical of nanowires. The length of cadmium sulphide nanowires averages 60 mm, whereas their diameter is 200 nm on average.

During the formation of cadmium sulphide nanowires, a dangerous process in the synthesis of cadmium sulphide nanowires can be uncontrolled increase of temperature, which is also connected with uncontrolled increase of pressure. This whole process should be thus monitored.

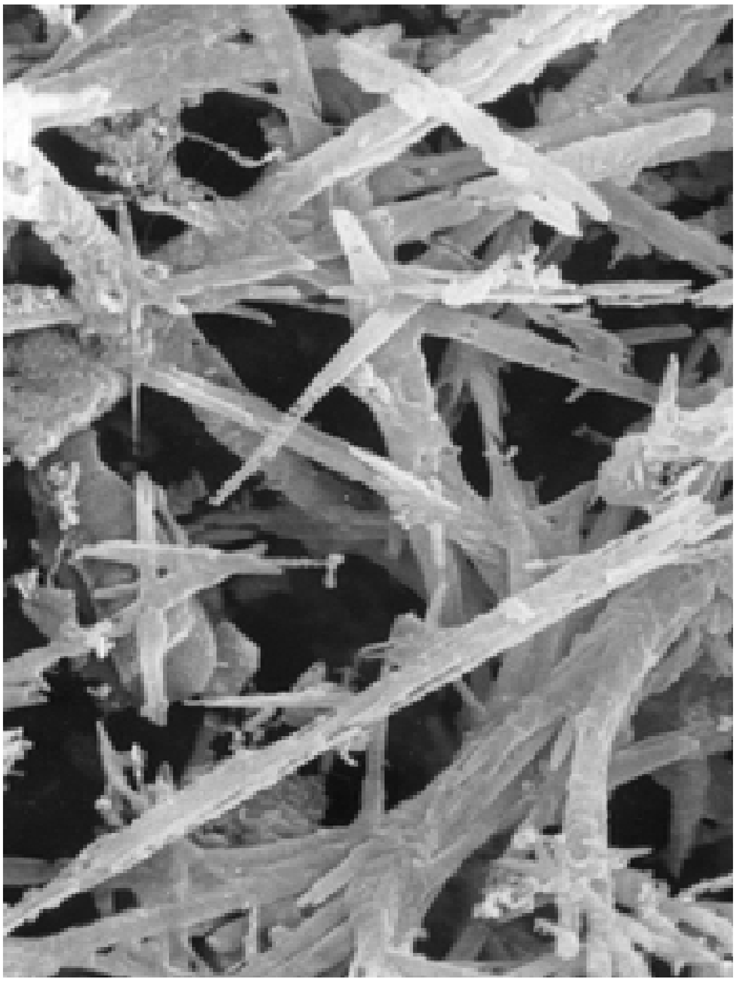

Fig. 2. Cadmium sulphide nanowires made by means of scanning electron microscope (SEM) technique (the average length 50 nm)

After 24 h, when the whole process of synthesis has been completed, the heating should be turned off in the first place and after stabilization of temperature, the final product should be opened with a ventilated fume cupboard switched on.

This is very important for the safety during a possible uncontrolled liberation of toxic fumes of hydrogen sulphide (H_2S).

Conclusion

The synthesis of cadmium sulphide nanowires by means of crystalline sodium sulphide nonahydrate ($Na_2S·9H_2O$) is simple, cheap and safe under controlled temperature. Dimensions of cadmium sulphide nanowires are as follows: length 60 mm on average and diameter 200 nm on average.

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