Available online at www.joac.info

ISSN: 2278-1862

Journal of Applicable Chemistry

2017, 6 (4): 492-495

(International Peer Reviewed Journal)

Synthesis of Silver-Na-4 Mica Nanocomposite

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Accepted on 2nd July 2017, Published online on 27th July 2017

ABSTRACT

Metallic silver has been grown in the channels of crystalline structure of sodium fluorophlogopite mica commonly referred to as Na-4 mica. Crystal channels of thickness ~ 1.2 nm have been exploited to grow the metallic nanostructure. Sol gel technique has been adopted to prepare mica crystals which contain Na^+ cations within the interlayer space. This interlayer space has been used as nanochannels. After an ion exchange treatment $Ag^+ \Leftrightarrow Na^+$ the specimens were subjected to an electrodeposition reaction. Temperature variation of resistivity of the nanocomposite exhibit metallic behaviour over the temperature range 160 to 300 K. Voltage-current Characteristics of the nanocomposite also confirms the metallic behaviour of the nanocomposite.

Keywords: Nanowire, Sol gel technique, Template, Electrodeposition.

INTRODUCTION

Science of nanomaterials has emerged to become a frontier area of research due to their novel properties and potential applications. Nanoscience is based on the recognition that the nature and properties of matter on the nanoscale (1- 100 nm) are dramatically different from their bulk form. Bulk materials have fixed properties regardless of their size. But nanomaterials have size and shape dependent properties which make them totally different from bulk materials. The size dependence of behaviour allows us to tailor their properties by tuning their size. Some nanostructures include quantum dots, nanoparticles, nanorods, nanowires, nanobelts / nanoribbons, nanosheets, core/shell nanostructures and carbon nanotubes etc. Nanoscience has enriched us with a new array of materials with a wide range of applications [1,2]**.** Nanowires are important nanostructures which are ideal system to investigate quantum mechanical effects in nanoscale apart from their potential application as interconnects in nanodevices. Several techniques have been adopted so far to grow nanowires. Different Template methodologies have been reported for the growth of nanowires [3-6]. Possibility of exploiting nanochannels provided by the crystal structure as template has also been reported earlier [7,8].

MATERIALS AND METHODS

Channels within the crystalline structure of sodium fluorophlogopite mica have been exploited for the Synthesis of silver-Na-4 mica nanocomposite. Sodium fluorophlogopite mica is commonly referred to as Na-4 mica which has a chemical composition $Na_4\,Mg_6\,Al_4\,Si_4O_{20}\,F_4$, x H_2O and is known to have Crystal channels of thickness ~ 1.2 nm [9]. There are four interlayer cations (Na^+) per unit cell of Na-4 mica and it has ion exchange capacity [10]. Na-4 mica was prepared by sol-gel method. The precursors Al $(NO_3)_3$, 9 H_2O; Mg $(NO_3)_2$, 6 H_2O and Tetraethylorthosilicate (TEOS) were dissolved in ethyl alcohol and the solution was stirred for 3 h. The calculated amounts of chemicals were taken so that a target composition 3 MgO - Al_2O_3 - SiO_2 could be obtained after the necessary heat treatment. The gel was dried at 373 K and calcined at 748 K for 12 h. After grinding the gel powder it was mixed with an equal amount of NaF powder. The mixture was then subjected to a heat treatment at 1163 K for 18 h in a platinum crucible under ordinary atmosphere. The resultant products were washed with de-ionized water followed by saturated boric acid. The powder was then washed with 1(M) NaCl solution to saturate the exchange sites with Na^+. The resultant solid was washed again with de-ionized water and then dried at 333 K for 3 days to get Na-4 mica powder. The latter (powder) was subjected to a $Ag^+ \Leftrightarrow Na^+$ ion exchange reaction by immersing 2 g. of the same into 25 mL of 0.4 (M) Ag NO_3 in aqueous solution to which 0.5 (M) NaCl solution was added. The reaction was carried out over a period of 4 weeks at 303K with intermittent shaking. The ion-exchanged powder was separated from the solution by a centrifuge. The ion-exchanged resultant powdered sample was then subjected to electro deposition reaction [11, 12]. To do this, the sample powder was compacted at room temperature with a pressure of 20 tons $cm^{2\ -1}$ to prepare a pellet with 1 cm diameter and 1 mm thickness. Two faces of the specimen were coated with silver paste which acted as the electrodes. 10 Volt DC was then applied across the electrodes for 30 min. duration. The gradual increase of current from nanoampere to milliampere confirms the formation of metal nanostructure in the composite. The material thus prepared is a composite involving the metallic silver possibly in the form of filaments. Presence of Ag^+ ions within the channels only excludes the possibility of percolation of Ag nanoparticles within the grain boundary.

RESULTS AND DISCUSSION

Variation of DC electrical resistivity of the electrodeposited sample was studied in the temperature range 160 to 300 K. Figure.1 shows the variation of resistivity with Temperature. The metallic nature of electrical resistivity variation of the nanocomposite is evident from the figure. Electrodeposition brought about the growth of metallic silver probably in the form filaments. Though the material is a composite involving the metallic silver, metallic electrical conduction behaviour has been obtained because of the percolation of silver nanoparticles. As the Ag^+ ions are present within the channels of the mica crystals, percolation of metallic silver is only possible through the channels of crystalline structure. However, resistivity of the silver nanocomposite is large as compared to its bulk value. This happens due to the size effect of nanostructuring [13]. It has been reported earlier that decrease in the size of the metal nanoparticles increases the resistivity [14].

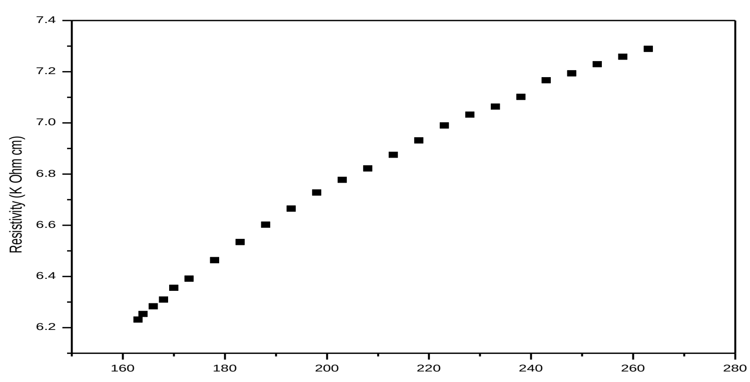

Fig 1. Variation of dc resistivity as a function of temperature

This is due to the size effect of the nanostructuring. Voltage – current characteristics have also been studied. Figure.2 shows the Voltage – current characteristics of the nanocomposite. Symmetrical and linear V- I characteristic curve indicates the metallic behaviour of the nanocomposite. The metal filaments are believed to form by the chain of silver nanoparticles.

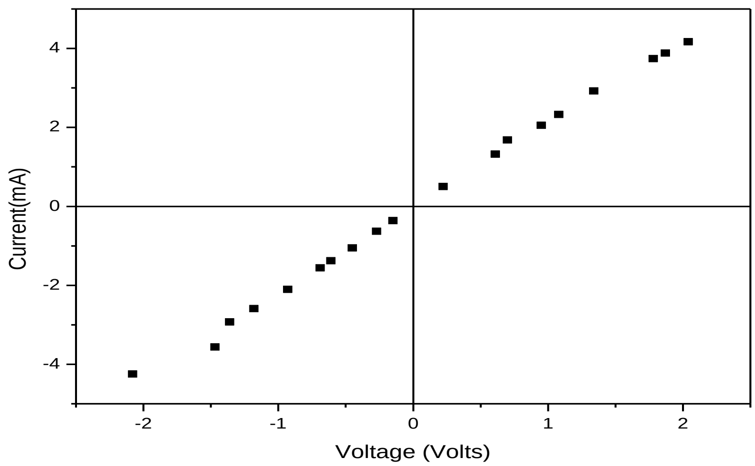

Fig 2. Voltage–current characteristics of the nanocomposite.

APPLICATIONS

Nanowires are important nanostructures which are ideal system to investigate quantum mechanical effects in nanoscale apart from their potential application as interconnects in nanodevices.

CONCLUSIONS

In summary, silver-Na-4 mica nanocomposite has been synthesized where silver filaments in the form of nanowires are likely to form in the channels of Na-4 mica. For this Na-4 mica was grown through sol-gel technique. The sample was then subjected to ion exchange followed by electrodeposotion. Variation of DC electrical resistivity with temperature shows the metallic behaviour of the nanocomposite. V- I characteristic also confirm the metallic nature.

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