Chalcogenide glass - carbon nanotube composite

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ABSTRACT

This paper describes the preparation of multi-walled carbon nanotube—chalcogenide glass composite by direct synthesis and the melt-quenching method. The carbon nanotubes—chalcogenide glass composite was characterized by high-resolution transmission electron microscopy (HRTEM), TEM/energy-dispersive X-ray spectroscopy, low energy electron excited X-ray spectroscopy, Raman spectroscopy, spectroscopic ellipsometry, microhardness, and impedance spectroscopy. CNTs–AgAsS2 glass composite possess highly increased ionic conductivity, from $\sigma_{25°C}$ = 4.38±0.0438 x 10^{-6} to $\sigma_{25°C}$=6.57±0.0657x 10^{-6} S.cm^{-1} and decreased refractive index from n=2.652 to 2.631 at the wavelength λ =1.55 μm.

Key words: carbon nanotubes, chalcogenide glasses, ionic conductivity, composites.

1. INTRODUCTION

Chalcogenide glasses have been widely studied due to their interesting and unique electrical and optical properties [1–4]. If undoped, chalcogenide glasses belong to a large family of vitreous semiconductors usually having p-type conductivity [5]. Chalcogenide glasses doped with metals (such as Ag, Cu, Li) [6–8] or their compounds (i.e., AgI, CuS, Li_2S) behave like ionic conductors or even fast ionic conductors (FIC) [9,10] having s>10^{-7}S cm^{-1}.
The study of the ion conductivity of such glasses is extremely important since these glasses are widely used in many existing applications, in particular as parts of solid state batteries [11] and highly selective and sensitive electrochemical electrodes (i.e., Ag^+, S^{2-}, Se^{2-}, etc.) [12,13], PMC (*Programmable Metallization Cell*) memory is one type of RRAM devices that shows a large promise as a future low energy non-volatile solid state memory [14].
Chalcogenide ionic glass conductors usually consist of: (i) a network former (sulfides or selenides, e.g., As_2S_3, GeS_2, Ga_2S_3, $GeSe_2$), which are covalent compounds that generally form glass easily, (ii) a network modifier (e.g., Ag_2S, Li_2S, Cu_2S), which are usually compounds with significant ionic features that do not form glass by themselves but can easily react with a glass former and become incorporated in its network, and (iii) a doping element or salt (e.g., Ag, AgI, LiI), which can be introduced into a vitreous network only if the network already contains a former and a modifier [1].
Carbon nanotube (CNT)-doped materials have an enormous potential in a wide variety of applications [15]. CNTs can dramatically alter the mechanical, optical, thermal, electrical, and electrochemical properties of composite materials at surprisingly low levels of doping [15–17]. This has an enormous impact on a wide variety of potential applications, such as reinforced materials, energy storage devices, sensors, and actuators, just to name a few [15–17]. CNTs are incorporated in polymer matrixes [16] or inorganic matrixes, such as silicates or metals [18,19].
Surprisingly, there has been no report on the CNTs–$AgAsS_2$ glass composite. Including of CNTs in to ion-conductive chalcogenide glasses is expected to change their physicochemical properties due to the incorporation into the glass network by the introduction of: (i) a lighter element (lower atomic weight of carbon vs. Ag, As, and S) leading to a

change in the optical properties and a consequent decrease in the refractive index; (ii) highly oriented and covalently bonded structures of CNTs resulting in increased hardness, which is expected to improve the mechanical properties of $AgAsS_2$ glass; (iii) crystalline, highly conducting structures, which are expected to increase electron conductivity; and (iv) one-dimensional structures such as CNTs, which are expected to increase ion conductivity. In this article, we show that CNTs–$AgAsS_2$ glass composite showed a significant increase in its ion conductivity and a simultaneous decrease of the activation energy of the Ag^+ ion conductivity.

2. CONCLUSION

We have successfully prepared ion-conductive CNTs–$AgAsS_2$ glass composite at relatively low temperature. To the best of our knowledge, this paper represents the first example of conductivity study of CNT–chalcogenide glass composite. Despite a low level of CNTs concentration and a slight change in the CNTs morphology in the glass network, the presence of CNTs brought about rapid improvement of silver ion transport and conductivity, which is expected to offer significant benefits for future battery applications. A likely prospect seems to be the adding of single-walled CNTs in to ion-conductive glasses, which is expected to further enhance ion transport due to the possibility of tailoring the diameter of single-walled CNTs. Further systems Ag-Ge-Se and Ag-Ge-S are under current studies.

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Biography

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He has been studying photoinduced reactions of the metals (mainly Ag) with amorphous chalcogenides for more than ten years. He is an author or co-author more than 140 refereed journal papers; more than 220 lectures and posters on international and national conferences. In the most of the papers he studied chalcogenide glasses (mainly dealing with photodoping phenomena, optical and thermal properties, structure and their application in optics and optical recording, phase-change phenomena, ionic conductive glasses, memories.