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Electrical Transport Properties in Ternary $NbMoS_2$ Layer crystals

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Abstract

The structural and electrical properties of the ternary niobium molybdenum disulphide ($Nb_{0.75}Mo_{0.25}S_2$) layer nanocrystal with x = 0.25 grown by chemical vapor transport (CVT) have been investigated. The X-ray diffraction (XRD) and Raman scattering measurements indicate the $Nb_{0.75}Mo_{0.25}S_2$ nanoflakes with single-crystalline quality and three rhombohedral (3R) structure. In addition, the electrical characterization of the layer nanoflakes has been performed. The temperature-dependent conductivity shows that the ternary $Nb_{0.75}Mo_{0.25}S_2$ nanoflakes reveals semiconducting transport behavior, which is different from the metallic behavior of the binary NbS_2. The activation energies of 10 meV was also obtained. In addition, the charge density wave (CDW) transition was also observed at the temperature of 55 K in this ternary chalcogenide nanostructure.

1. Introduction

It is well known that NbS_2 has quasi-2D layer crystalline structure and exhibits metallic transport behavior.[1,2] The interesting electrochemical properties of NbS_2 and related ternary compounds have gained the attention of the researchers for the energy storage and lithium battery applications.[3] Due to the problem of significant non-stoichiometry in NbS_2,[3] the high-quality single crystals were difficult to be prepared. In this report, we demonstrate the fundamental study on the structural and electrical properties of the NbS_2 doped with high Mo ratio. The detailed characterization of the high-quality $NbMoS_2$ ternary compound grown by chemical vapor transport (CVT) has been carried out.

2. Experimental

The ternary $NbMoS_2$ layer crystals were grown by CVT used iodine (I) as the transport agent. The crystallization temperature for the growth was set at 960 °C. The bulk crystals were mechanically exfoliated to be the micrometer-sized flakes. The two-terminal and four-terminal $NbMoS_2$ nanoflake devices were fabricated by focused-ion beam (FIB) deposition using platinum (Pt) (100–300 nm) as the contact metal. Individual NbMoS2 nanoflakes were dispersed on the insulating SiO2/n-Si templates with pre-patterned Ti/Au microelectrodes prior to FIB deposition. The voltages and currents of the ion beam for the Pt precursor decomposition were operated at 30 kV and 100 pA, respectively. The as-grown $NbMoS_2$ layer crystals were characterized using field-emission scanning electron microscopy (FESEM), energy-dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD), and Raman spectroscopy. measurements and. The thicknesses of the $Nb_{0.75}Mo_{0.25}S_2$ nanoflakes on the devices were defined by the atomic force microscopy (AFM). Electrical characterization was performed on an ultralow current leakage cryogenic probe station (LakeShore Cryotronics TTP4) at the temperature range of 15–300 K.

Figure 1 shows the (a) XRD diffraction pattern and (b) Raman spectrum of the as-grown $Nb_{0.75}Mo_{0.25}S_2$ powder crystals grown by CVT.

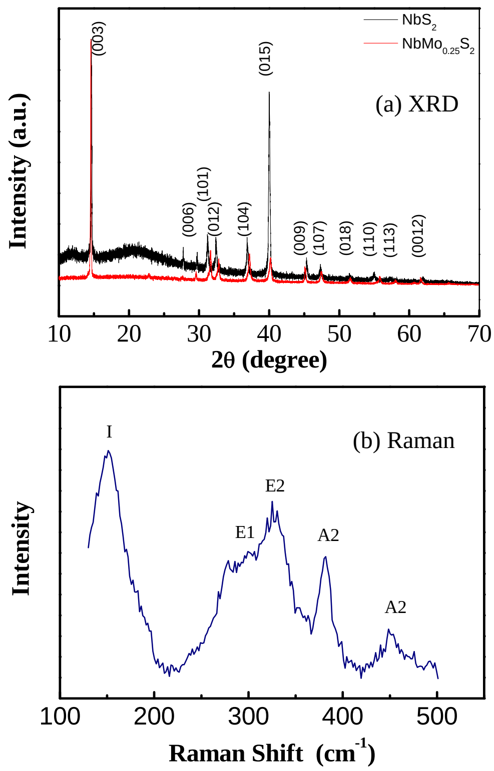

Fig. 1. (a) XRD diffraction pattern and (b) Raman spectrum of $Nb_{0.75}Mo_{0.25}S_2$ powder crystals.

The results indicate the out-plane orientation of the single-crystalline $Nb_{0.75}Mo_{0.25}S_2$ layer crystals. The structural characterization shows the $Nb_{0.75}Mo_{0.25}S_2$ layer crystals with 3R hexagonal structure.

The schematic diagram of the $Nb_{0.75}Mo_{0.25}S_2$ nancrystal device are shown in Fig. 2. The electrical contacts were fabricated by focused-ion beam (FIB) deposition usng Pt metal contact. The I-V measurements at different temperatures for the $Nb_{0.75}Mo_{0.25}S_2$ device with the thickness of ~100 nm. The I-V curves with the commonly linear relationship indicate the good ohmic contact condition of the FIB-fabricated device. The result also shows the temperature-insensitive conductance (i.e. the slope) of the ternary $Nb_{0.75}Mo_{0.25}S_2$ layer crystal.

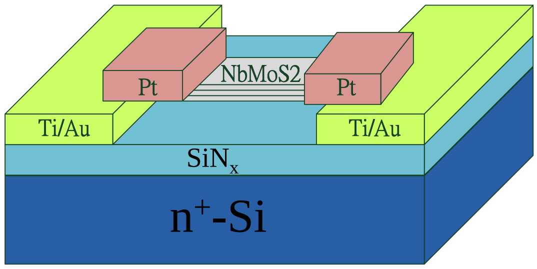

Fig. 2. The schematic diagram of the $Nb_{0.75}Mo_{0.25}S_2$ nancrystal device

Figure 3 shows the Arrhenius plot for the temperature-dependent conductivity of the $Nb_{0.75}Mo_{0.25}S_2$ nanocrystal. The result shows the weak semiconducting behavior and the activation energy obtained by the fitted slope at 10 meV. The charge density wave (CDW) transition was also observed at the temperature of 55 K in the $Nb_{0.75}Mo_{0.25}S_2$ nanocrystal.

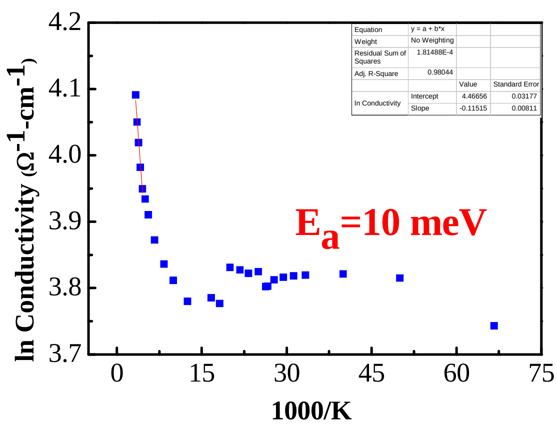

Fig. 3. The Arrhenius plot for the temperature-dependent conductivity of the $Nb_{0.75}Mo_{0.25}S_2$ nanocrystal.

Acknowledgements

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