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Synthesis and Characterization of Niobium Nitride Nanowires

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Abstract

This project aims to explore the potential of inexpensive in-situ deposition of niobium nitride nanowires to improve electrical conductivity. Transition metal nitrides are well known for attributes such as superconductivity, high melting point, simple structure as well as excellent electrical and thermal conductivities. In particular, niobium nitride possesses exceptional hardness and high reflectivity, as well as being a stable field emitter, making it well suited to applications as a cold cathode material.

Niobium nitrides are formed by the uptake of nitrogen by niobium. This is achieved by the exothermic formation of an interstitial solid solution of nitrogen atoms in the bcc lattice of the niobium. Existing research has established the possibility of preparing niobium nitride by heating niobium in nitrogen or ammonia over a range of temperatures, by heating niobium pentaoxide and carbon in the presence of nitrogen as well as by chemical vapor deposition of other niobium compounds, nitrogen or hydrogen.

For the purpose of this study, a two-step process was used for synthesis. The benefits of a two-step process over direct ammonolysis are apparent, from the greater degree of freedom pertaining to parameter determination. Additionally, characterization of niobium pentaoxide nanowires synthesize under similar conditions is also made possible by terminating the reaction earlier. NbN nanowires were synthesized by annealing niobium pentaoxide nanowires at 850 ^{o}C for 2 hours. Subsequent characterization was done using Raman Spectroscopy, X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The presence of NbN nanowires via the conversion of Nb_2O_5 was ascertained by the absence of sharp peaks at 1000 cm^{-1} for Raman Spectroscopy and XRD plots. Field emission (FE) properties and electrical

properties of NbN nanowires were then measured. NbN nanowires were found to have a high turn-on voltage, stable and relatively good field emission characteristics, demonstrating its potential as a cold cathode material. No current saturation was observed for an applied electric field of 0 to 6.0 V/ μm (5). This suggests a low degree of contact resistance for nanowires produced by this method of annealing, since the passage of electrons is not obstructed. Hence there will only be a small voltage drop between the SiO_2 substrate and NbN nanowires.

Samples containing NbN nanowires were dislodged by ultrasound to form an aqueous suspension of nanowires. A drop of suspension was dripped onto gold-finger substrates, and current-voltage (I-V) measurements of resultant nanowire bridges were taken. NbN nanowire bridges display Ohmic properties, in comparison with Nb_2O_5 nanowires that are semiconducting. Nanowire bridges obtained by heat-drying were denser and had better electrical properties than those obtained by evaporation to dryness. NbN nanowire bridges display Ohmic properties, in comparison with Nb_2O_5 nanowires that are semiconducting.

Further work would include varying the cooling processes to observe any changes or deformation. Additionally, niobium nitride nanowires can be hybridized with carbon nanotubes (CNTs). A more in-depth comparison between niobium oxide and niobium nitride nanowires is also proposed, along with exploration of the nitrification of other transition metals.

評語

1. 利用製程溫度與壓力的調制，測量作為場發射元件的效果，得到不錯的效果。

2. 根據觀察得到的結論是

   (1) 奈米線的密度不能太密時效果較佳。

   (2) 奈米線的結構成辨子狀時效果較佳。

3. 宜針對以上得到的結論，就原理上作更多的解釋或分析。