Tuning Electrical Properties of E-beam Evaporated 2D Bi and Derivatives

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Two-dimensional (2D) Xenes have attracted considerable research attention due to their tunable band structure and electrical properties. For instance, bismuthene (2D Bi, Fig. 1) is expected to have high mobility and low carrier density, making it possible to decouple Seebeck coefficient and electrical conductivity for better thermoelectric properties. Nevertheless, experimental study on 2D Bi has been limited due to the lack of cost-effective method to produce large-area uniform samples.

This work explores e-beam evaporation of 2D bismuth in high vacuum (<5×10^{-4} Pa) at a growth rate of ~0.1 Å/s[1]. The successful preparation of 2D Bi with a uniform and smooth surface was confirmed by X-ray diffraction, Raman spectroscopy and Atomic Force Microscopy (Fig. 2). The electrical conductivity of our 2D Bi could reach ~10^5 S/m that is comparable to molecular beam epitaxy (MBE) counterparts[2]. Notably, it has achieved a simultaneous increase in electrical conductivity and Seebeck coefficient as thickness increases (Fig. 3), due to high mobility and low carrier concentration. As a result, an improved power factor (~10^{-4} W/mK) has been obtained for 30-nm Bi. Further improvement on (thermo)electrical properties is on the way with doping or alloying strategy.

The present work has paved an accessible way to prepare 2D Bi and derivatives by e-beam evaporation, which yields tunable electrical properties comparable to MBE. Our study builds a platform to realize high-quality 2D Bi, which may also be suitable in other Xenes with tunable electrical performance for further applications in extensive fields.

Reference:

1. X. H. Sun, et al., Nanoscale, 13(4), 2021.

2. W. Zhong, et al., Nanotechnology, 31(47), 2020.

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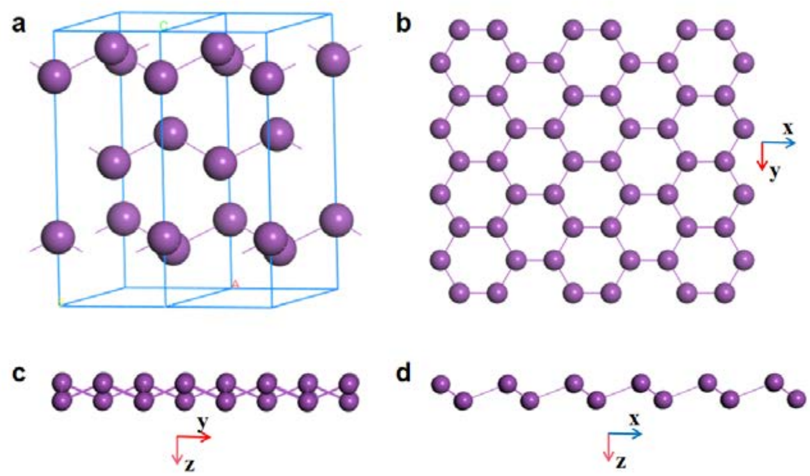

Figure 1: (a) Crystal structure of Bulk Bi. (b) Top and (c&d) Side views of Bi (111). (Reprint with permission from Ref. [1]. Copyright 2021, Royal Society of Chemistry.)

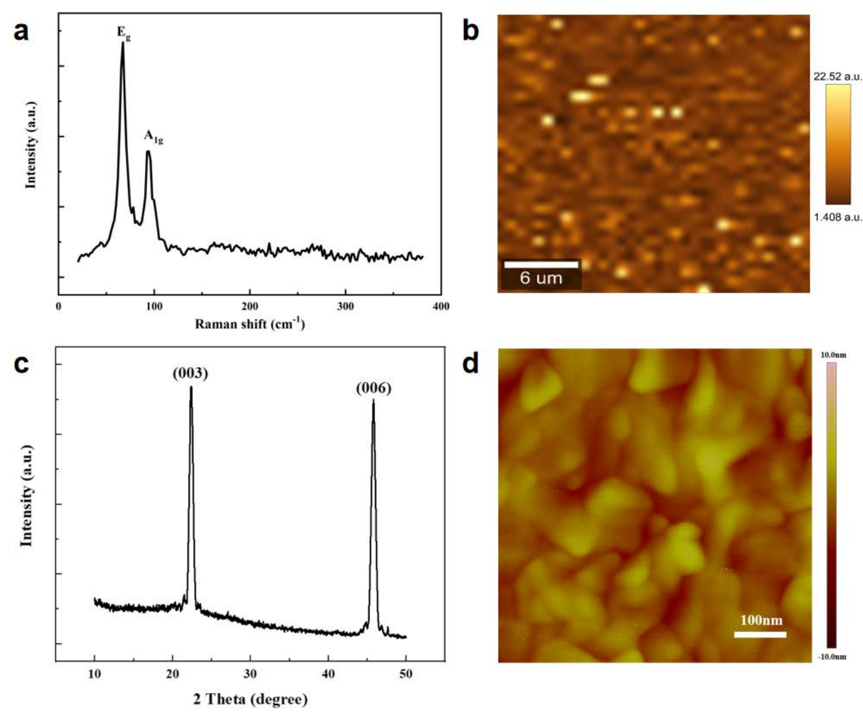

Figure 2: Phase characterization of e-beam evaporated 2D Bi. (a) Raman spectrum, (b) Raman intensity mapping of Eg/A_1g, (c) XRD pattern and (d) AFM image of 20 nm Bi. (Reprint with permission from Ref. [1]. Copyright 2021, Royal Society of Chemistry.)

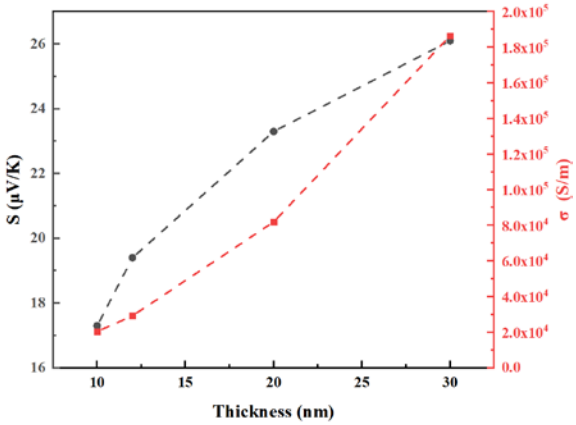

Figure 3: The electric conductivity and Seebeck coefficient of different thickness 2D Bi: A simultaneous increasing trend is obtained as thickness increasing.