The Optical Properties of Two-Dimensional Germanane

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Introduction

Recently there has been intense interest in two-dimensional (2D) materials beyond graphene that have a native band gap and stronger spin-orbit coupling. Germanane, the germanium analog of graphane (i.e. hydrogen-terminated graphene), is a new 2D material with a direct band gap that can be tuned via surface covalent functionalization. This makes it promising for electronic and optoelectronic applications. Furthermore, its large spin-orbit coupling makes it possible to explore novel physical phenomena such as quantum spin-Hall effects at room temperature.

Recently, large area germanane films have been synthesized by growing Zintl-phase $CaGe_2$ thin films on Ge(111) wafers by molecular beam epitaxy and followed by chemical processing in acid solution to convert the $CaGe_2$ into hydrogen-terminated germanane [1]. To date there has been little optical characterization of these thin films. One typical measurement of the quality of direct gap semiconductors is photoconductivity.

Experimental

Low-temperature photoluminescence measurements were performed using a 532 nm laser excitation and the spectra are captured using a Czerny-Turner spectrometer equipped with a liquid nitrogen cooled silicon CCD detector (for visible wavelengths) or InGaAs array (for near-IR wavelengths). A white-light source is used to calibrate and correct for the wavelength dependence of the detectors. A broad photoluminescence peak is seen at ~1.45 eV at 10K. As this as at the edge of both the silicon CCD camera and the InGaAs arrays, it is necessary to check both detectors to make sure that the signal is not a detector artifact. The photoluminescence is Stokes shifted approximately 50 meV from the theoretical band edge of 1.5 eV. Further study of the band edge of germanane is needed before much can be drawn from this. Temperature dependant photoluminescence (Fig. 1(c)) shows a steady decrease in intensity until approximately 200K. There is little wavelength shift seen.

Acknowledgment

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References

[1] Pinchuk, I. V.; Odenthal, P. M.; Ahmed, A. S.; Amamou, W.; Goldberger, J. E.; Kawakami, R. K., Epitaxial co-deposition growth of $CaGe_2$ films by molecular beam epitaxy for large area germanane. Journal of Materials Research 2014, **29**, 410-416

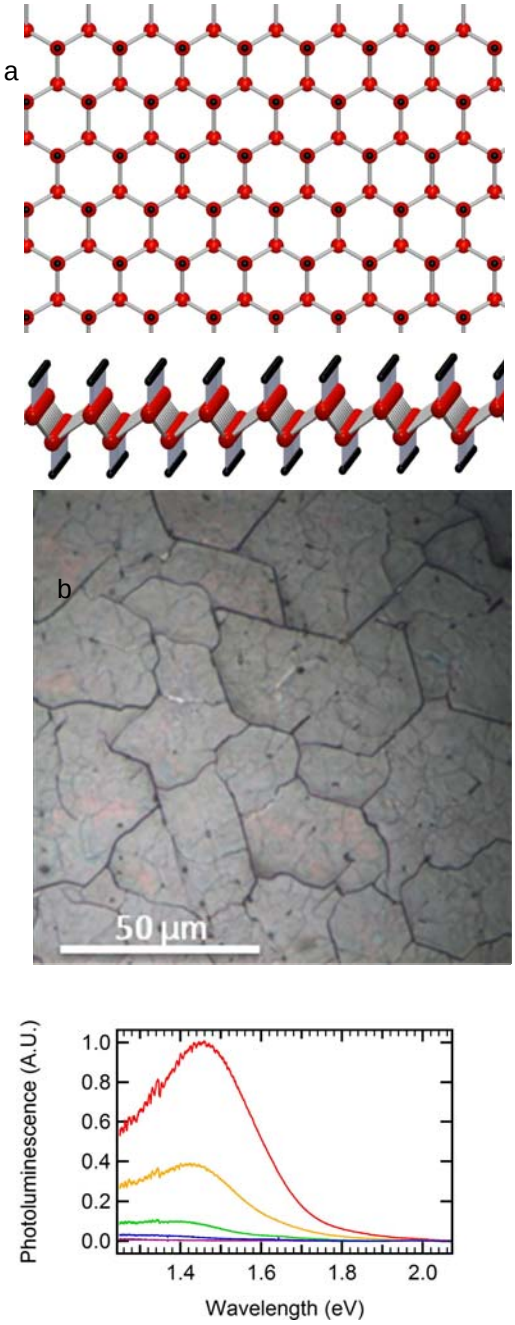

Fig.1 (a) Top and side view of a germanane sheet. (b) Optical micrograph of a germanane film. (c) Photoluminescence of a germanane at 10K (red) , 50k (orange), 100k (green), 150 (blue) and 200 (purple).