High mobility in amorphous ZnO_xS_y thin films

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Introduction: Amorphous oxide semiconductors (AOSs) have been extensively studied because of their high electron mobility. Conventionally, AOSs are alloys of metal oxides of which conduction band minima (CBM) consist of metal s-orbitals. Recently, very high mobility over 100 $cm^2V^{-1}s^{-1}$ was reported in a mixed-anion compound, ZnO_xN_y [1][2]. Although the origin of high mobility has not been fully understood, one hypothesis is that CBM of ZnO_xN_y is spatially more homogeneous than conventional AOSs because it is composed of only Zn 4s-orbital. This hypothesis suggests high mobility in other amorphous mixed-anion compounds such as oxyfluoride and oxysulfide. In this study, we fabricated amorphous ZnO_xS_y thin films and investigated their electrical transport properties.

Experimental: ZnO_xS_y thin films were fabricated by pulsed laser deposition on glass and Si substrates. XRD and atomic force microscopy measurements were performed to check the amorphous state. Chemical compositions of the films were evaluated by SEM-EDX and transport properties were examined by 4-wire resistance and Hall measurement.

Results: Firstly, we fabricated ZnO_xS_y films by ablating ZnS target under O_2 atmosphere. However, chemical composition analysis and X-ray photoelectron spectroscopy revealed that the obtained films were zinc sulfites ($Zn(SO_x)$) due to oxidation of sulfur. Then, we tried alternate deposition of ZnS and ZnO targets under vacuum, and succeeded in obtaining ZnO_xS_y over the whole anion range (Fig. 1a). Figure 1b is a phase diagram of the ZnO_xS_y ($0 < S/(O+S) < 1$) thin films deposited with various laser fluence. While the end members, ZnS and ZnO were crystalized, their alloys became amorphous in a wide range under low laser fluence conditions.

The resistivity of the amorphous ZnO_xS_y films increased with increase of S content or decrease of laser fluence (Fig.1b). The films fabricated with higher laser fluence showed larger electron concentration N_e probably due to introduction of oxygen vacancies. Hall mobility μ_H vs N_e plot (Fig. 2) showed that the μ_H of the amorphous ZnO_xS_y films reached to 10-15 $cm^2V^{-1}s^{-1}$. These results indicate that amorphous ZnO_xS_y is a promising amorphous semiconductor. On the other hand, its mobility is essentially lower than ZnO_xN_y, especially in high *Ne* region, suggesting that CBM composed of only single Zn 4s orbital is not sufficient for realizing very high electron mobility.

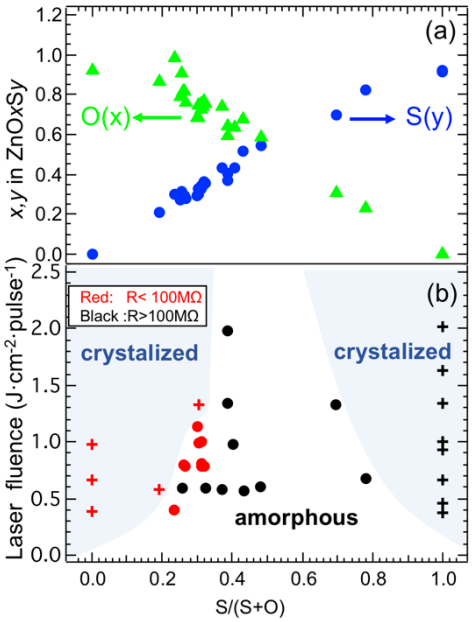

Fig. 1. (a) Chemical composition and (b) phase control of ZnO_xS_y thin films. Circles and crosses in Fig. 1(b) represent amorphous and crystallized films, respectively.

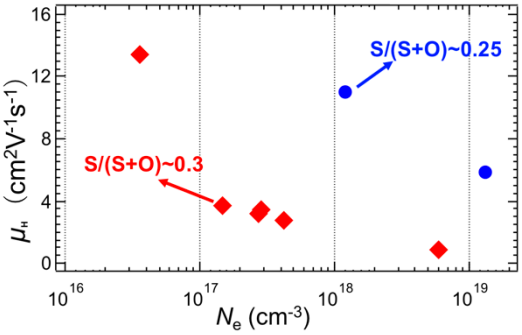

Fig. 2. Transport property of ZnO_xS_y films with anion ratio of S/(S+O)~0.25 and S/(S+O)~0.3

[1] Kim *et al.*, Sci. Rep. **3**, 1459 (2013).
[2] Yamazaki *et al.*, Appl. Phys. Lett. **109**,262101(2016).

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