Electrical Conduction Mechanism of Vanadium Tellurite Semiconducting Glasses (Part 2)

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バナジウムテルライト半導体ガラスの電気伝導機構（第２報）

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Abstract　The $\log(\sigma T)$ - T^{-1} relation (σ : DC electrical conductivity and T : the absolute temperature) was confirmed to be linear at the temperature between 433 and 473K for the $70V_2O_5 \cdot 30TeO_2$ binary pelletized glasses, suggesting that electrical conduction mechanism is small polaron hopping (SPH). The SPH conduction was discussed from view points of the activation energy for hopping of electron and V-ion spacing.

1. Introduction

The dc electrical property for semiconducting glasses containing transition metal oxide have been investigated. The electrical-conduction mechanism at $T > 1/2\Theta_D$ (Θ_D is the Debye temperature) for binary and ternary vanadate glasses were understood by small polaron hopping (SPH) model [1]. On the other hand, the electrical conduction at low temperature (below RT) was interpreted by variable-range hopping (VRH) [2,3]. Previously, the applicability of the VRH model was discussed for the glasses [4]. In the present study, the SPH conduction was discussed from view points of the activation energy for hopping of electron (W) and V-ion spacing (R).

2. Experimental procedure

The process for the preparation of glass samples is described elsewhere [4,5]. The samples used for the experiment were $70V_2O_5 \cdot 30TeO_2$ pelletized glasses (mol%) after annealing at 473K in H_2 gas for 1h and 2h. Sample names and the annealing condition are summarized in **Table 1** [4,5]. The four-point probe method was employed to measure the dc electrical resistivity in air from RT to 473K. A dc current of 0.1-1μA was applied to each sample for the resistivity measurements.

3. Results and discussion

The pelletized glasses were indicated to be W = 0.380 ± 0.0005 - 0.420 ± 0.0005 eV at 433 – 473 K [5]. In the previous reports for vanadate binary bulk glasses, the W values were obtained to be W = 0.23 - 0.30 eV for V_2O_5 - TeO_2 glasses [6], W = 0.288 - 0.317 eV for V_2O_5- Bi_2O_3 glasses [7], W = 0.34 - 0.52 eV for V_2O_5-BaO glasses [8]. The values of the present glasses nearly agreed with these glasses. In addition, V_2O_5-Sb-TeO_2 ternary bulk glasses were obtained to be W = 0.317 – 0.413 eV [9].

These bulk glasses were confirmed that the W depended on hopping distance of the electron (mean V-ion spacing), R and the electrical conduction was small polaron hopping (SPH) between V-ions at RT – 473 K [6-9]. Thus, in the present study, the relationship between W and R should be confirmed for H2-0h, H2-1h and H2-2h.

Table 1. Sample name and annealing condition.

Sample name	Annealing condition
H2-0h	As-quenched
H2-1h	Time:1h, temperature : 473K and H_2 gas
H2-2h	Time:2h, temperature : 473K and H_2 gas

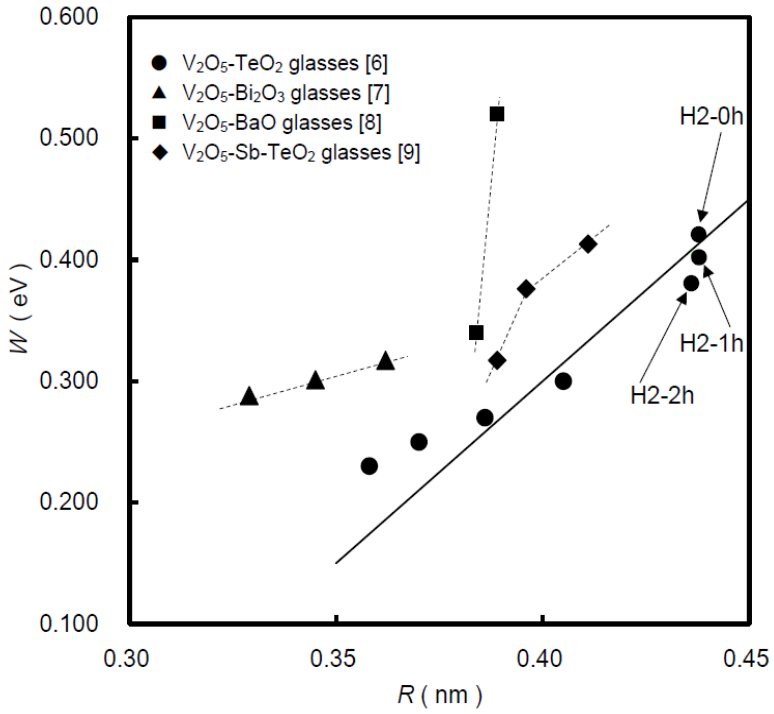

Figure 1. Relationship between the activation energy (*W*) and V-ion spacing (*R*) for the pelletized glasses and vanadate bulk glasses. The solid line is calculated using Eq.(1), and the dotted lines are drawn as a guide for the eye.

Figure 1 shows the relationship between *W* and *R* for H2-0h, H2-1h and H2-2h, together with the relation for the bulk glasses [6-9]. The *W* values increased with increasing *R*, depending on *R* for H2-0h, H2-1h and H2-2h. This result was similar to those for the bulk glasses, suggesting that the SPH occurred between V-ions at 433 – 473 K.

For SPH conduction, the *W*-*R* relation is expressed as follows [10],

$$W = W_0 + a\,(R - R_0) \qquad (1)$$

Where W_0 is the minimum activation energy for the conduction, R_0 the mean V-ion spacing which the data appears to converge, and *a* the slope of the *W*-*R* relation. Sayer and Mansingh reported to be $W_0 \approx 0.15$ eV and $R_0 \approx 0.35$ nm [10]. In fig.1, the solid line was drawn by calculating using Eq.(1). For V_2O_5-TeO_2 glasses [6] and the pelletized glasses, *a* was obtained to be 3 eVnm^{-1}. The *W*-*R* relation nearly satisfies Eq.(1) for these vanadate tellurite binary glasses. From this result, it was confirmed that the SPH occurred for the pelletized glasses.

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