The results obtained above can be used as a diagnostic of semiconductor materials and for the excitation of surface waves with the aid of a dielectric waveguide.

LITERATURE CITED

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SWITCHING WITH MEMORY IN METAL-(VANADIUM-MOLYBDENUM GLASS)-METAL STRUCTURES

V. M. Kalygina, V. I. Gaman, and O. E. Modebadze

The temperature dependences of the dc and ac (10^2-2·10^4 Hz) conductivity, the dielectric constant, and the coefficient of dielectric losses were measured for four compositions of glasses in the system V2O5-MoO3-CaO. The metal-(vanadium-molybdenum glass)-metal structures exhibit switching with memory in the range 90 ≤ T ≤ 500 K. The switching parameters virtually do not depend on the temperature. For some samples an S-shaped section with negative differential resistance is observed on the volt-ampere characteristic (VAC) in the conducting state at temperatures T < 150 K.

Glassy oxide semiconductors (GOS) of the system V2O5-MoO3-CaO are of interest for several reasons: firstly, they do not contain the usual vitrifier (V2O5 is the main vitrifier); secondly, these glasses contain two transition-metal oxides, each of which can give rise to transfer of charge carriers along heterovalent ions of the transition element; and thirdly metal-(vanadium-molybdenum glass)-metal structures exhibit switching with memory.

In the system of interest glassy alloys are formed in a narrow range with the following ratio of the components (in mole %): V2O5 - 37-45; MoO3 - 41-45; CaO - 13-18. Reducing the V2O5 concentration to 36.17 mole % transfers the alloy outside the region of vitrification.

The temperature dependence of the dc conductivity for GOS of the indicated system is described by a smooth curve of Inσ versus T^{-1}. At high temperatures the curve can be approximated by a straight line. As the V2O5 content increases the conductivity increases, and the activation energy E, calculated from the formula \( \sigma = \sigma_0 \exp\left(-E/kT\right) \) for the high-temperature section of the dependence of Inσ on T^{-1}, decreases (Table 1).

At frequencies ranging from 10^2 up to 2·10^4 Hz and in the temperature range 260-310 K one polarization process is observed; it gives rise to excess (compared with σ) conductivity for ac current (\( \sigma_p \)).

The frequency and temperature dependences of the polarization component of the conductivity (\( \sigma_p = \sigma_0 - \sigma \)), the dielectric constant \( \varepsilon' \), and the coefficient of dielectric losses \( \varepsilon'' \) are analogous to the corresponding curves obtained for other systems of GOS [1, 2]. The activation energy of the polarization process, found by the method of equal capacitances, is...
TABLE 1. Dependence of the Conductivity at T = 300 K, the Activation Energy, and the Preexponential Factor on the Composition of GOS

<table>
<thead>
<tr>
<th>Composition of GOS, mole %</th>
<th>(\sigma(300, K))</th>
<th>(E,, eV)</th>
<th>(\sigma_0,, \Omega^{-1}m^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(_2)O(_5)</td>
<td>Mo(_3)O(_2)</td>
<td>CaO</td>
<td>7.4 (\times) 10(^{-5})</td>
</tr>
<tr>
<td>45.17</td>
<td>41.51</td>
<td>13.32</td>
<td></td>
</tr>
<tr>
<td>42.21</td>
<td>47.06</td>
<td>10.73</td>
<td>3.3 (\times) 10(^{-3})</td>
</tr>
<tr>
<td>36.77</td>
<td>45.47</td>
<td>17.76</td>
<td>6.0 (\times) 10(^{-6})</td>
</tr>
</tbody>
</table>

Fig. 1. Temperature dependence of the switching parameters: 1) threshold voltage; 2) erasing current.

(0.38 \pm 0.02) eV. The static and high-frequency dielectric constants for the observed polarization process equal 20 and 8, respectively, and their values are close to that of \(\varepsilon^p\) for glasses of the systems MoO\(_3\)-P\(_2\)O\(_5\) [3] and (70-x) V\(_2\)O\(_5\)-xMoO\(_3\)-30 P\(_2\)O\(_5\) [4]. As the concentration of the ions of the transition metal, which determines the semiconductor properties of oxide glasses, is increased, \(\sigma_0\), \(\varepsilon^S\) and \(\varepsilon^p\) increase.

Bead structures with parallel wire electrodes 100 µm in diameter and an active layer with thickness 10 µm < d < 30 µm were fabricated based on vanadium-molybdenum GOS. All structures, irrespective of the composition of GOS, exhibit switching with memory in the temperature range 90-500 K.

The samples were switched on a sinusoidal signal. The voltage on the structure and a load resistance \(R_L = 10^5 \Omega\) connected in series were increased until the sample was in a state with high conductivity (HC). The feature distinguishing the sample studied from structures based on GOS with other compositions as well as chalcogenide glasses is the absence of the first switching effect, i.e., they do not require preliminary electric activation. The voltage necessary for the first switching is practically equal to the threshold voltage \(V_t\) necessary to switch the structure into the conducting state in subsequent switching cycles. The dc VAC for samples in a state with high resistance (HR) are described by a linear dependence of the current on the field strength right up to 4 \(\times\) 10\(^6\) V·m\(^{-1}\) both prior to the first switching and after several switching cycles. The resistance of the structures in the HR state at \(T = 300\, K\) equals 2 \(\times\) 10\(^8\) \(\Omega\). After the sample is switched into the HC state its dc IVC is also described by Ohm's law in the temperature range 90-500 K. The resistance of the structure \(R_{HC}\) at 300 K equals 10\(^3\) \(\Omega\). Thus the resistance of the samples changes by five orders of magnitude as a result of switching. The threshold switching voltage \(V_t\) and the erasing current \(I_e\) are virtually independent of the composition of GOS and more strongly on the thickness of the active layer.

For some samples based on the GOS under study, irrespective of the composition, switching with memory is observed in the narrower temperature range 150-500 K. For \(T < 150\, K\) the samples exhibit monostable switching (Fig. 2). As the temperature is lowered the voltage \(V_s\) corresponding to the start of negative differential resistance increases. The effect is reversible:

Analysis of the histograms of the number of switchings versus \(V_t\) and \(I_e\), including 100 measurements, shows that the spread in the parameters decreases as the thickness of the GOS film decreases. The values of \(V_t\) and \(I_e\) depend less strongly on the composition of GOS and more strongly on the thickness of the active layer.

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