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SEMICONDUCTOR FATIGUE-DAMAGE INDICATOR

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A means of using a semiconductor film element as a fatigue-damage indicator is substantiated. Methods of manufacturing it are described.

In practice, the members (units) of structures are constantly operating at a certain temperature for the most part. High temperatures promote a more rapid wear and the appearance of the fatigue failure of structures, especially of those which are in the stressed-strained state or are subjected to cyclic alternating strains (the temperature of the members also increases due to the strain of the structure itself). Therefore, it is of interest to predict fatigue accumulations in structures subjected to cyclic alternating strains at higher-than-average temperatures.

There are fatigue-damage indicators which contain metallic and semiconductor strain-sensing elements [1, 2]. However, these gauges are difficult to manufacture and they do not ensure high sensitivity and the stability of parameters. For example, the strain gauge factor K in metallic resistance strain gauges has a value of 0.4 in manganin (Cu–Mn–Ni) to 5.5 in platinorhodium [3]. By virtue of the low values of the tensosensitivity the use of wire and foil gauges in strain metering requires rather complex amplifying equipment.

Silicon- and germanium-based semiconductor liquid-crystal gauges have $K \approx 100$–200.

The value of the tensosensitivity in CdS films can attain values of 10^3 at room temperature [4]; however, the electrical conductivity of them is low. A decrease in their resistance, for example, by introducing impurities, leads to a significant reduction in the sensitivity.

We produced polycrystalline films of the semiconductor compound $(Bi_xSb_{1-x})_2Te_3$ for use as fatigue-accumulation gauges. The films were manufactured by the method of open vacuum thermal evaporation of the alloy consisting of 60 at.% Te, 30 at.% Sb, and 10 at.% Bi [5]. A polyimide tape or anodized Duralumin were used as the substrates.

The semiconductor indicator of fatigue damage is shown schematically in Fig. 1. The fatigue-damage indicators produced have a strain gauge factor of $K \approx 10^3$–10^4; the electrical conductivity of the films is ~10 $(\Omega\cdot\text{cm})^{-1}$.

We investigated the influence of the cyclic alternating strains N on the strain gauge factor and the temperature coefficient of resistance of the films. The experimental results have shown that, as the strain number increases at the initial step ($N \approx 5\cdot10^3$), K changes by 10–15% and thereafter remains constant, in practice, while the temperature coefficient of resistance of the films has a pronounced maximum. From Fig. 2 it follows that, as the action of cyclic strains increases, the temperature coefficient of resistance changes by tens of percents and the minimum of the temperature coefficient of resistance shifts to the region of higher temperatures. By the change in the minimum of the temperature coefficient of resistance we can judge the number of loading cycles and the fatigue life of structures, i.e.,

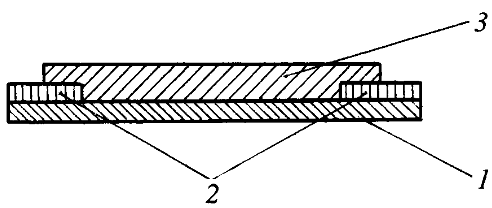

Fig. 1. General view of a semiconductor fatigue-damage indicator: 1) substrate with an anode coating; 2) metal contacts; 3) semiconductor film.

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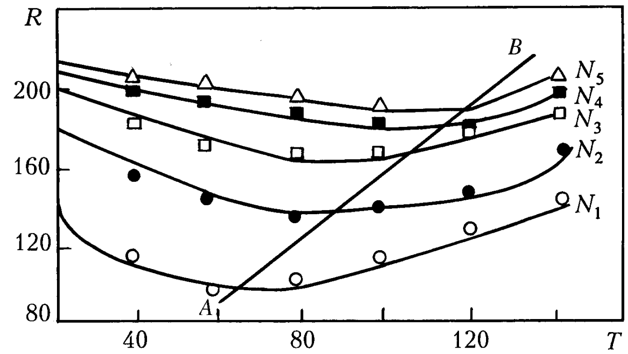

Fig. 2. Temperature dependences of the resistance of films under the action of different numbers of strain cycles ($N_1 = 5 \cdot 10^3$, $N_2 = 10^4$, $N_3 = 1.5 \cdot 10^4$, $N_4 = 2 \cdot 10^4$, and $N_5 = 2.5 \cdot 10^4$). R, Ω; T, °C.

the linear shift of the minimum of the temperature coefficient of resistance from N (Fig. 2, curve AB) enables one to use film elements as the direct indicator of fatigue damage.

The indicator of fatigue damage proposed is cheaper than the existing ones. The use of it will allow more accurate measurements and will improve the life, reliability, and safe operation of different structures.

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