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Temperature Sensor Based on $Sn_2P_2S_6$ Crystal

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In our work, the model of a low temperature sensor is suggested based on temperature dependences of the alternating current at various frequencies of field. For further analysis and calculations measurements of impedance as a function of temperature *Z(T)* in the interval (5–300) K were used [1].
Temperature dependences of the specific impedance $Z_0(T)$ were calculated at frequency 10 kHz:

$$z_0(T) = Z(T)\cdot\left(\frac{S}{d}\right) \quad (1)$$

where *Z(T)* are experimental values, S is the electrodes area, *d* is samples thickness (in the direction of P_S, [100]). The value of electric field is:

$$E = U_e / d \quad (2)$$

where $U_e = U_m/\sqrt{2}$ is effective value of electric current, U_m is voltage amplitude. Voltage as a function of time is described mathematically by the following equation (at $f = 10kHz$):

$$U(t) = U_m \cdot \cos(2\pi ft + \varphi_0) \quad (3)$$

In the further interval, values of the specific impedance sharply decrease with increasing temperature for all three investigated samples in ferroelectric phase. We described experimental dependences of $log(z_0(T))$ in ferroelectric phase using fourth-order polynomial:

$$\log(z_0(T)) = A(f)_{fe} + B1(f)_{fe}\cdot T + B2(f)_{fe}\cdot T^2 + B3(f)_{fe}\cdot T^3 + B4(f)_{fe}\cdot T^4 \quad (4)$$

where $A(f)_{fe}$, $B1(f)_{fe}$, $B2(f)_{fe}$, $B3(f)_{fe}$, $B4(f)_{fe}$ are coefficients of the equation.
Values of these coefficients are calculated by approximation of experimental dependences of $log(z_0(T))$. Based on impedance investigations and obtained dependence $log(z_0(T)$, temperature dependences of the alternating current *I(T)* are determined for crystals $Sn_2P_2S_6$, $Sn_2P_2(Se_{0.05}S_{0.95})_6$ and $Sn_2P_2Se_6$. Let the effective voltage $U_e = 10V$ is applied to the model sample - a square plate with thickness d = 1mm, with circle Au electrodes (D = 5mm), $f = 10\ kHz$, then, temperature dependence of the current is calculated by the following equation:

$$I(T) = \frac{U_e}{Z(T)} = \frac{U_e}{51\cdot\left(10^{(A(f)_{fe}+B1(f)_{fe}\cdot T+B2(f)_{fe}\cdot T^2+B3(f)_{fe}\cdot T^3+B4(f)_{fe}\cdot T^4)}\right)} \quad (5)$$

The value of current sharply increases from μA to mA values with increasing temperature for all three samples. The character of *I(T)* dependences is non-linear in the whole investigated range of temperatures (5–300) K. From our investigations we would like to conclude that $Sn_2P_2S_6$, $Sn_2P_2(Se_{0.05}S_{0.95})_6$ and $Sn_2P_2Se_6$ crystals are competitive and promising materials for low temperature sensors and sensors of thermal radiation in a wide temperature range from 5 K to 300 K.

	$A(f)_{fe}$, $[10^{-2}]$	$B1(f)_{fe}$, $[10^{-4}]$, K^{-1}	$B2(f)_{fe}$, $[10^{-6}]$, K^{-2}	$B3(f)_{fe}$, $[10^{-8}]$, K^{-3}	$B4(f)_{fe}$, $[10^{-11}]$, K^{-4}
$Sn_2P_2S_6$, $100K \le T \le 300K$, f = 10kHz	(371.1 ± 2.5)	(178 ± 6)	(−168 ± 5)	(65 ± 5)	(−96 ± 3)
$Sn_2P_2(Se_{0.05}S_{0.95})_6$ $0K \le T \le 300K$, f = 10kHz	(472.5 ± 0.1)	(−19.3 ± 0.5)	(−26.3 ± 0.7)	(16.5 ± 0.3)	(−34.6 ± 0.5)
$Sn_2P_2Se_6$, $0K \le T < T_C = 192K$ f = 10kHz	(458.6 ± 0.3)	(−174 ± 2)	(173 ± 3)	(−89 ± 2)	(133 ± 6)

Tab. I. Approximation coefficients of $log(z_0(T))$ dependences by fourth-order polynomial in ferroelectric phase for samples at 10 kHz

[1] I. TYAGUR. *Piezoelectric and Dielectric Studies of Ferroelectric Phase Transitions in $Sn_2P_2(Se_xS_{1-x})_6$*. Liberec: Technical University of Liberec, 2012.