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Nanopiezoactuator for astrophysics equipment

Abstract

For astrophysics equipment and composite telescope the parameters and the characteristics of the nanopiezoactuator are obtained. The functions of the nanopiezoactuator are determined. The mechanical characteristic of the nanopiezoactuator is received.

Keywords: Nanopiezoactuator, Deformation, Characteristic, Astrophysics equipment

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Introduction

The nanopiezoactuator is used for astrophysics equipment and composite telescope.[1-9] The transformation of the electric to mechanical energy is clearly for nanopiezoactuator.[3-28] The nanopiezoactuator is coming for adaptive optics, interferometry, nanotechnology.[14-43]

Characteristics

For electroelastic actuator the equations of the nanopiezoactuator[4-56] are received

$$(D)=(d)(T)+(\varepsilon^T)(E)$$

$$(S)=(s^E)(T)+(d)^t(E)$$

here (T), (E), (D), (S), (d), (ε^T), (s^E), t are matrixes of mechanical field intensity, electric field strength, electric induction, relative deformation, electroelastic coefficient, dielectric constant, elastic compliance, and transposed index.

Relative deformation S_i of the nanopiezoactuator[1-49] is determined

$$S_i = d_{mi}E_m + s_{ij}^E T_j$$

where d_{mi} is the piezocoefficient.

Differential equation of the nanopiezoactuator[3-56] is received

$$\frac{d^2\Xi(x,s)}{dx^2} - \gamma^2\Xi(x,s) = 0$$

$$\gamma = s/c^E + \alpha$$

where $\Xi(x,s)$, s, x, γ, α, c^E are the Laplace transform of the deformation, the operator, the coordinate, the coefficients of propagation and attenuation, the speed at $E = \text{const}$.

At $x=0$ and $\Xi_1(s)=\Xi(0,s)=0$ the decision is obtained

$$\Xi(x,s) = \Xi_2(s)\,\text{sh}(x\gamma)/\text{sh}(h\gamma)$$

At elastic-inertial load at $x=h$ and $\Xi_2(s)=\Xi(h,s)$ the displacement of the nanopiezoactuator is calculated

$$\frac{d\Xi_2(s)}{dx} = d_{31}E_3(s) - \frac{s_{11}^E M s^2 \Xi_2(s)}{S_0} - \frac{s_{11}^E C_e \Xi_2(s)}{S_0}$$

hence equation of the nanopiezoactuator has the form

$$\frac{\Xi_2(s)\gamma}{\text{th}(h\gamma)} + \frac{\Xi_2(s)s_{11}^E M s^2}{S_0} + \frac{\Xi_2(s)s_{11}^E C_l}{S_0} = d_{31}E_3(s)$$

The function of the nanopiezoactuator by E is written in the form\

$$W_E(s) = \frac{\Xi_2(s)}{E_3(s)} = \frac{d_{31}h}{Ms^2/C_{11}^E + h\gamma\,\text{cth}(h\gamma) + C_l/C_{11}^E}$$

where $\Xi_2(s)$, $E_3(s)$, C_l, C_{11}^E are the transforms of displacement and electric field intensity, the stiffness of load and nanopiezoactuator. The function of the nanopiezoactuator by U is received in the form

$$W_U(s) = \frac{\Xi_2(s)}{U(s)} = \frac{d_{31}h/\delta}{Ms^2/C_{11}^E + h\gamma\,\text{cth}(h\gamma) + C_l/C_{11}^E}$$

For the nanopiezoactuator its reverse and direct coefficients are calculated

$$k_r = k_d = \frac{d_{mi}S_0}{\delta s_{ij}}$$

For elastic-inertial load at mass of load with the load mass much greater than the mass of actuator $M_2 > m$ the scheme of the nanopiezoactuator with one fixed face on Figure 1 is calculated.

The expression by U of the nanopiezoactuator for Figure 1 is calculated

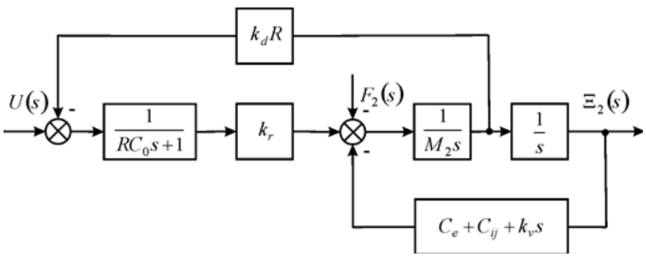

Figure 1 Scheme of nanopiezoactuator.

$$W(s) = \Xi_2(s)/U(s) = k_r/N(s)$$

$$N(s) = a_0 s^3 + a_1 s^2 + a_2 s + a_3$$

$$a_0 = RC_0 M_2,' \quad a_1 = M_2 + RC_0 k_v$$

$$a_2 = k_v + RC_0 C_{ij} + RC_0 C_e + Rk_r k_d,' \quad a_3 = C_e + C_j$$

here k_v - the coefficient of damping.

For the transverse nanopiezoactuator for $R = 0$ the expression by U is determined

$$W(s) = \frac{\Xi_2(s)}{U(s)} = \frac{k_{31}^U}{T_t^2 s^2 + 2T_t \xi_t s + 1}$$

$$k_{31}^U = d_{31}(h/\delta)/\left(1 + C_l/C_{11}^E\right)$$

$$T_t = \sqrt{M/\left(C_l + C_{11}^E\right)} \quad \omega_t = 1/T_t$$

At M = 1 kg, C_l = $0.2 \cdot 10^7$ N/m, C_{11}^E = $2 \cdot 10^7$ N/m the parameters of the transverse nanopiezoactuator are evaluated T_t = $0.21 \cdot 10^{-3}$ s, ω_t = $4.7 \cdot 10^3$ s^{-1} at error 10%.

Mechanical characteristic of the nanopiezoactuator is determined

$$\Delta l = \Delta l_{\max}\left(1 - F/F_{\max}\right)$$

$$\Delta l_{\max} = d_{mi} l E_m$$

$$F_{\max} = d_{mi} S_0 E_m / s_{ij}^E$$

where the maximums $\Delta l_{\max}$ and $F_{\max}$ of the displacement and the force of the nanopiezoactuator are determined.

The relative longitudinal deformation[8-18] is determined

$$S_3 = d_{33} E_3 + s_{33}^E T_3$$

where d_{33} is the longitudinal piezocoefficient.

The mechanical characteristic of the longitudinal nanopiezoactuator has the form

$$\Delta\delta = \Delta\delta_{\max}\left(1 - F/F_{\max}\right)$$

$$\Delta\delta_{\max} = d_{33}\delta E_3 = d_{33} U$$

$$F_{\max} = d_{33} S_0 E_3 / s_{33}^E$$

At E_3 = $0.6 \cdot 10^5$ V/m, S_0 = $1.5 \cdot 10^{-4}$ m^2, δ = $2.5 \cdot 10^{-3}$ m, d_{33} = $4 \cdot 10^{-10}$ m/V, s_{33}^E = $15 \cdot 10^{-12}$ m^2/N for the longitudinal nanopiezoactuator from PZT its parameters received $\Delta\delta_{\max}$ = 60 nm, $F_{\max}$ = 240 N on Figure 2 with error 10%.

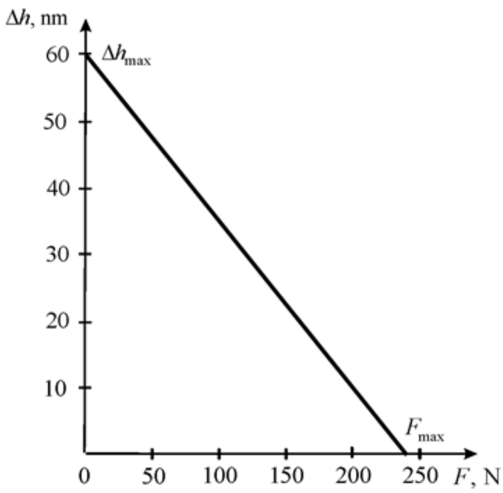

Figure 2 Mechanical characteristic.

The maximums of the displacement $\Delta h_{\max}$ and force $F_{\max}$ for the transverse nanopiezoactuator are received in the form

$$\Delta h_{\max} = d_{31} h E_3 = d_{31}(h/\delta) U$$

$$F_{\max} = d_{31} S_0 E_3 / s_{11}^E$$

where d_{31} is the transverse piezocoefficient.

The static transverse displacement at elastic load is determined

$$\Delta h = \frac{d_{31}(h/\delta) U}{1 + C_l/C_{11}^E} = k_{31}^U U$$

At d_{31} = $2 \cdot 10^{-10}$ m/V, h/δ = 21, C_l/C_{11}^E = 0.1 the parameter k_{31}^U = 3.8 nm/V is evaluated at error 10%.

Conclusion

The deformation of the nanopiezoactuator is determined for astrophysics. The characteristics of the nanopiezoactuator are evaluated for composite telescope. The characteristics for the nanopiezoactuator are calculated.

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