
# Scale-dependent pull-in instability of functionally graded carbon nanotubes-reinforced piezoelectric tuning nano-actuator considering finite temperature and conductivity corrections of Casimir force

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# Scale-dependent pull-in instability of functionally graded carbon nanotubes-reinforced piezoelectric tuning nano-actuator considering finite temperature and conductivity corrections of Casimir force

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**Abstract** A scale-dependent analytical model is presented to solve the nonlinear pull-in instability of functionally graded carbon nanotubes (CNTs) reinforced nano-actuator with piezoelectric layer considering high order-corrected electrostatic pressure and finite temperature and conductivity corrections of Casimir force. Based on Eringen's nonlocal elasticity theory considering the long range forces among atoms, and geometrical nonlinearity, the electro-thermo-mechanical coupling governing equation of nano-actuator is derived, and solved by utilizing natural mode function and Galerkin's decomposition method. The higher-order corrected model of electrostatic force with fringing field effect accounting for large gap and geometrical nonlinearity is employed. The results indicate that pull-in voltage decreases with increase of positive piezoelectric effect but increases with increment of negative piezoelectric effect. Pull-in voltage declines as the piezoelectric layer thickness of nano-actuator increases. Casimir force appears in more significant effect on the pull-in voltage of nano-actuator than that of van der Waals force, which shows that the analysis of nanoscale devices cannot neglect the influences of intermolecular forces within sub-micron separations. Finally, the coupling influences of van der Waals force and Capillary force on pull-in voltage are compared.

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