The effect of finite strain measure change on second-order piezoelectricity

Grzegorz Jurczak*, Paweł Dłużewski

Very rapid technological development in the electronic branch of the industry observed during last decades, together with the progressive miniaturisation of electronic devices induce increasing interest in the subject of piezoelectric semiconducting heterostructures. In some cases, the linearity of the piezoelectric effect under extreme strain and electric field conditions is challenged for these heterostructures. There are many experimental reports in the literature dealing with nonlinear piezoelectricity as well as theoretical calculations which predict the nonlinear behaviour of such crystalline heterostructures.

If, as stated above, the nonlinearity appears under extreme load conditions, therefore from the point of view of mechanics a finite deformation approach shoud be applied to properly describe the kinematics of the deformed crystal. Thus, problem of the choice of a proper strain measure appears as far as many different finite strain measures can be used to describe deformation of the body. Furthermore, higher order piezoelectric coefficients which are derivatives of the heterostructure energy (deformation in the vicinity of the natural state of the body) over the strain depends on the choice of the strain measure [1,2].

Theoretical prediction shows that second-order piezoelectric coefficients are finite strain measure dependent. Therefore, the use of any finite strain measure in constitutive modelling of nonlinear piezoelectric materials requires an adequate choice of higher-order piezoelectric coefficients. Otherwise, erroneous elastic and electric fields may appear in the case of modelling of nonlinear piezoelectric phenomena, e.g. for quantum heterostructures such as wells or dots. A further implication of that effect is that a complete set of second-order piezoelectric coefficients should contain additional information about the strain measure applied during calculations or measurements.

General transformation formula for second-order piezoelectric coefficients (elastostriction) is derived as well as individual transformation formulae for common crystallographic classes (e.g. cubic, hexagonal).

1. Dłużewski, P. (2000). J. Elast. 60, 119–129,
2. Jurczak, G. (2018) Acta Cryst. A74, 518–523.