SC221 Engineered Materials Assignment

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1 If a piezoelectric material is kept under an external electric field E, material will be under stress. Name all types of stresses that are produced, typically.

Answer:

1. Elastic Stress (due to deformation of material's structure)
2. Stress due to Electric Field (of opposite sign to that of Elastic stress)

2

Answer:
The application of an electric field on a piezoelectric material causes a deformation in the materials structure given by:

$$S = dE \tag{1}$$

This strain produces an elastic stress whose magnitude is:

$$T_{elastic} = cS \tag{2}$$

On the other hand, the electric field E exerts a force on the materials internal structure generating a stress given by:

$$T_{piezo-electric} = eE \tag{3}$$

The strain is also produced when displacement gradients occur, or in other words, when the particles displacement increases or decreases in one direction. Therefore, the strain S is defined as the gradient of the particles displacement in the direction considered.
An elastic stress (equation (2)) is against the piezoelectric stress (equation (3))

and tries to avoid the strain of the material. The internal friction that the particles experience in their displacement is also against the piezoelectric stress since it makes the particles displacement more difficult. The stress due to internal friction is usually considered proportional to the gradient of the particle displacement velocity, as in the case of a viscous phenomenon, that is:

$$T_{viscous} = \eta \frac{dS}{st} \tag{4}$$

The equations for the electric displacement and for the internal stress, including the losses in the material, are obtained from Equation (2), (3) and (4) giving:

$$T = eE - cS - \eta \frac{dS}{dt} \tag{5}$$

where,
d = the piezoelectric strain coefficient
E = the magnitude of the applied electric field
c = the elastic constant
e = the piezoelectric stress constant
$\eta = viscosity$

3 Explain how piezoelectric material helps attain the resolution in case of STM.

Answer:

The Scanning Tunneling Microscope (STM) was developed by Gerd Binning and Heinrich Rohrer at IBM. When a metal tip is brought near a conducting surface, electrons can tunnel from the tip to the surface or vice-versa. Because the tunneling probability is exponentially dependent on the distance the contours of the surface can be mapped out by keeping the current constant and measuring the height of the tip. In this way, atomic resolution can be obtained.

The principle of the STM is based on the strong distance dependence of the quantum mechanical tunnelling effect.

Maintaining a constant tunneling current by adjusting the height with a piezoelectric crystal, and monitoring the piezo-voltage while scanning, allows one to image a surface, under ideal conditions, to atomic resolution.