【 December 2014 】

2015

Interdisciplinary Graduate School of Medicine and Engineering, Doctoral Course, University of Yamanashi

Entrance Examination

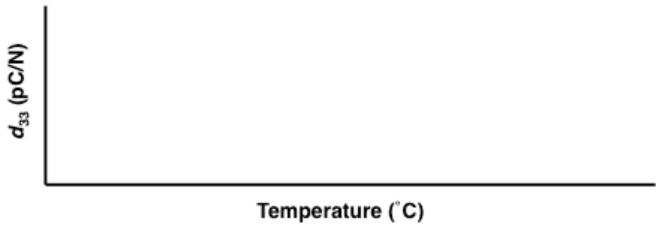
Course or Program	Special Doctoral Program for Green Energy Conversion Science and Technology	Subject	Solid State Physics

Question 1

Crystal structure of ferroelectric lead titanate ($PbTiO_3$) is tetragonal symmetry with tetragonality (c/a ratio) of 1.065, and its electric polarization is 90 μC/cm^2 at room temperature.

1) Calculate electric polarization component along [110] and [111] directions. You can simplify that its tetragonal unit cell can be regarded as pseudo-cube unit cell.

2) The piezoelectric constant, d_{33}, of $PbTiO_3$ is around 50 pC/N at 20 ˚C. Draw temperature dependence of the d_{33} in the temperature range from -100 to 600 ˚C, schematically. You should note that *T*c of $PbTiO_3$ is 490 ˚C.



3) The *T*c of $PbTiO_3$ is much higher than that (130 ˚C) of $BaTiO_3$. Explain the reason why these *T*c is so different, on the basis of role of A-site ion.

Question 2

Material X is oxide insulator with cubic symmetry and positive thermal expansion coefficient. The XRD measurement using material X was performed at various temperatures. It should be noted that crystallite size can be always constant despite temperature.

1) With increasing temperature, whether does the XRD peak position shift to lower angle or higher angle? Answer this question, and explain the reason.

2) With increasing temperature, whether does the XRD peak width at half maximum increase or decrease? Answer this question, and explain the reason.

3) Under DC electric fields, XRD peaks were measured with increasing electric fields. With increasing DC electric fields, whether does the XRD peak position shift to lower angle or higher angle? Answer this question, and explain the reason.

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Question 3

Explain the bondings in solid materials listed below. For each bonding, give a solid material as an example.

Metal bonding, Covalent bonding, Ionic bonding, Van der Waals bonding, Hydrogen bonding

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Question 4

As a simple model for metal, "one-dimensional infinite-depth square wall potential" is used. Let L the length of a crystal and V the potential, where

$$V(x) = \begin{cases} \infty \text{ for } x < 0 \\ 0 \text{ for } 0 \leq x \leq L \\ \infty \text{ for } L < x \end{cases}$$

1) Write down the Shrödinger equation for the system, where $\phi(x)$ is the eigenstate, E is the eigenenergy, and m is the mass.
2) Solve the equation.
3) When the depth of the square wall is finite, a tunneling effect appears. What is a tunneling effect? Give one example of a tunneling effect in solid-state physics.