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ON ACTIVATION ENERGY OF BOVINE FEMUR BONE

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Abstract: The paper reports data on activation energy of normal and decalcified bovine femur bone. The activation energy was determined by measuring resistivity as a function of temperature. The decalcified bone sample reveal higher value of activation energy, when compared to that of normal bone, exhibiting the role played in influencing activation energy. The paper suggests that semiconductivity in bone is arising mainly from an electron tunneling mechanism between adsorbed water molecules.
Key words: Activation Energy; Bovine bone; Femur; Electrical Resistivity.

1. Introduction

The main supporting structure of the vertebrate body is the endoskeleton of bony tissue. As far as the bony tissue is concerned it is in a stage of continuous remodeling. The anabolic and catabolic processes account for the growth of the skeleton for maintenance and for the participation of bone mineral in the regulation of mineral metabolism in the body. As solid state physics adds extra dimensions to the models of biological mechanisms, the study on solid state physics of bone should become a part of the interdisciplinary armoury of the biophysical sciences. Advances in such studies could certainly be of benefit to branches of medicine.

In 1946, Szent–Gyorgyi [1] proposed that semiconduction properties of proteins were of biological relevance. At about the same time, Baxter and Casie [2&3] were demonstrating that most specimens of moist wool behave as electrical conductors, with their electrical conductivity varying with temperature according to the Arrhenius–type equation in the same manner commonly observed for semiconductors.

Ghousuddin [4] studied activation energy of proteins such as albumin, hemoglobin, pepsin and casein and reported activation energy values in the range of semiconductors and concluded that protein behave as semiconductors. Wahab [5] investigated semiconduction nature of animal scapula.

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A perusal of literature reveals that information on activation energy is scanty. In view of this an attempt has been made to determine activation energy of bovine femur bone by measuring electrical resistivity as a function of temperature.

2. Materials and Methods

Bovine femur bones were collected from a freshly slaughtered animal within few hours. Fleshy material was removed from bone samples. Specimens in the shape of pellets or discs were cut from mid region of the bone. Some bone specimens were decalcified by keeping them in 9% nitric acid for 24 hours. The bone surfaces at the site of electrode attachment were polished with coarse and fine grades of sand paper and were silver coated for better electrical contact. The samples were then allowed to dry at room temperature. Thickness and diameter of the specimens were measured with digital Vernier calipers of L. C. 0.001cm.

The important aspect of measurement of electrical resistivity is the means of holding the sample during the measurement. One of the main requirements placed upon sample holder is that of the geometry of electrodes be such that the distribution of the electrical field is known. For this purpose a sample holder (jig) is constructed in Biophysics laboratory, Nizam College, Hyderabad.

The two terminal cell (jig) consists of two parallel circular plates made up of brass. The diameter and thickness of the plates are 1.2 cm and 0.5 cm respectively. The fixed circular plate electrode is connected to the live terminal of high resistance measuring instrument (Megger), while the movable circular plate electrode at earth potential is moved by means of a micrometer having least count 0.001 cm. This serves two purposes. One is to fix the specimen placed between the electrodes without air gap and the other is to measure the separation of the plates or the thickness of the sample.

To study the variation of resistivity with temperature, fresh and decalcified samples, held with jig, were kept in the oven of temperature range 0 -300^{o}C. The temperature in the oven was varied from 20 - 60^{o}C and resistance of the sample was measured for a temperature interval of 2^{o}C. The temperature of the oven was noted with the kelp of digital temperature indicator.

The activation energy (E) was calculated from the plot drawn between logarithm of resistivity ($\log_e \rho$) on Y- axis and reciprocal of absolute temperature (1/T) on x- axis and using the relation, $\rho_T = \rho_0 e^{E/kT}$, where ρ_T is resistivity at temperature T ^{o}C; k is Boltzmann constant; ρ_0 is resistivity constant related to the material understudy. A typical plot for the sample F1 is shown in Fig. 1.

The activation energy was calculated from slopes of the plots between $\log_e \rho$ and 1/T for 10 samples of each normal and decalcified bovine femur bone and tabulated in Table 1.

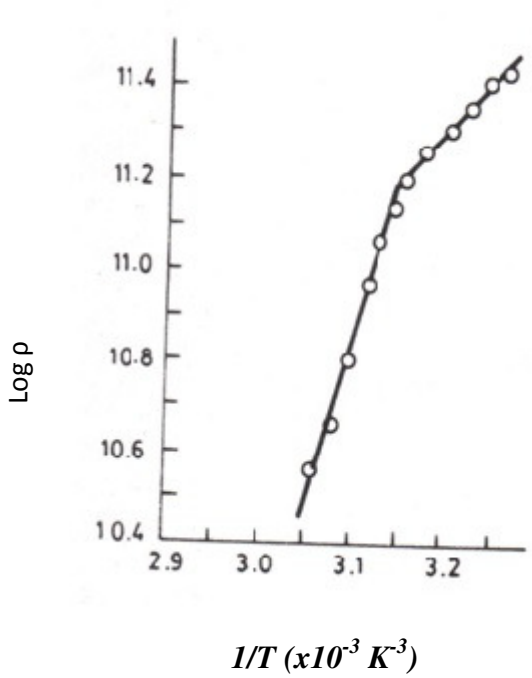

Fig. 1. A typical plot between 1/T and log ρ for bovine femur bone (Sample: F1)

3. Results and Discussion

Table 1 presents the data on activation energy of normal and decalcified bovine femur bone, measured in the temperature range of 35 – 55^{o}C for 10 samples of each condition.

The plots between reciprocal of absolute temperature (1/x) and natural logarithm of resistivity for normal and decalcified bovine femur bone samples give two straight lines with the slopes I and II, slope I is observed in relatively low temperature region and slope II is present in comparatively high temperature region (Fig. 1). Here, slope I is greater than slope I. Slope I may be attributed to extrinsic nature of semiconduction of bone, whereas slope I may be related to intrinsic nature of semiconduction of bone. As is known bone is highly heterogeneous material, its majour components are collagen and apatite, which may contribute substantially to the semiiconduction bone. It is evident from Table 1 that decalcified bone possesses high energy value when compared to that of normal bone, revealing the fact that the presence of calcium phosphate (apatite) in the bone effects its activation energy.

Table 1: Data on activation energy of normal and decalcified bovine femur bone, Measured in the temperature range of 35 – 55^{o}C

Sample Code	Activation Energy (eV)			
	Norml Bone		Decalcified Bone	
	I	II	I	II
F1	0.397	1.164	0.465	1.382
F2	0.343	1.020	0.457	1.357
F3	0397	1.151	0.409	1.363
F4	0.331	0.952	0.441	1.405
F5	0.331	1.058	0.498	1.412
F6	0.320	1.227	0.489	1.398
F7	0.341	1.049	0.502	1.387
F8	0.330	1.132	0.515	1.424
F9	0.395	1.048	0.488	1.419
F10	0.330	1.181	0.509	1.395
Average:	**0.352**	**1.098**	**0.477**	**1.394**
S. D.: ±	**0.032**	**0.085**	**0.034**	**0.022**

It is interesting to note, from the present investigation, that the resistivity of the bone is very high at the order of G**Ω-**m, while activation energy is in the range of semiconductors. Mostly, the resistivity of commonly used semiconductors is in the order of M**Ω-**m.

The activation energy in the range of semiconductors coupled with high resistivity of normal and decalcified bone can be explained as semiconductivity arising from an electron tunneling mechanism between adsorbed water molecules rather than from energy band conduction associated with molecular architecture of bone.

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