MOBILITY OF ELECTRON IN DNA CRYSTALS BY LASER RADIATION

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Abstract

The mobility of electrons in laser radiated DNA is closed to the energy transfer and energy migration of a biological molecule. Arrhenius [1] has studied the conductivity of the electrons in a biological molecule. But his result is far from the experimental result and meanwhile the relation between some parameters in his theory and the micro-quantities in DNA is not very clear. In this paper, we propose a new phonon model of electron mobility in DNA and use Lippman-Schwinger equation and S-matrix theory to study the mobility of electrons in DNA crystal. The result is relatively close to the experiment result and some parameters in Arrhenius theory are explained in our work.

1   Introduction

Using paramagnetic resonance method, Gordy has studied DNA and found that DNA has the property of semiconductor. Then Duchene[2] measured the energy gap of DNA in 273-313 K and found the energy gap is less than 2ev. Based on above experiment results, Arrhenius deduced the equation of electron conductivity in biological molecule. But his result is not close to the experimental result. We find that the basic reason of this difference is that his explanation of electron transfer is not right. We think that Pullmam's consideration of the DNA molecule being a kind of DNA crystal is good[3]. We think that with electrons being excited to the low energy level in the conduction band, the electrons will act strongly with optic frequency branch of DNA oscillation. Potential trough will form in the area where the electrons are. So these electrons will pass the DNA crystal with the phonon cloud and electron and associated phonon cloud is so called polaron. This is our phonon model of electron mobility in DNA. Using Lippman - Schwinger equation , we get the electron mobility and our result is more close to the experiment result than Arrhenius'.

2   Mobility of Electron in DNA

By means of S–matrix in quantum field theory and Lippman–Schwinger equation[4][5] the polaron-phonon scattering has been discussed and the scattering amplitude expressed by use of matrix elements of initial and find eigen states of hamiltonian. Then we calculate the mobility of electron

in DNA crystals in terms of Lee's hamiltonian and Gurari's polaron wave function[6] . Lee's hamiltonian[7] for electron–phonon interaction is as follows:

$$H = \sum_k a_k^+ a_k \omega + \sum_k \{V_k a_k e^{i\mathbf{k}\cdot\mathbf{r}} + V_k a_k^+ e^{-i\mathbf{k}\cdot\mathbf{r}}\} - \frac{\nabla^2}{2m} \tag{1}$$

$$V_k = -i\frac{\omega}{k}(\frac{1}{2m\omega})^{\frac{1}{4}}(\frac{4\pi\alpha}{V})^{\frac{1}{2}} \tag{2}$$

$$\alpha = (\frac{me^4}{2\omega})^{\frac{1}{2}}(\frac{1}{n^2} - \frac{1}{\epsilon_0}) \tag{3}$$

where a_k^+ and a_k—creation and annihlation operators for free phonons,ω—the branch frequency of the phonon for DNA crystal vibration, V—the volume of DNA crystal, n—coefficients of refraction,ϵ_0—static dielectric constant,k—wave vector of the phonon,r and ∇—coordinates and impulse operator of the electron respectively.

Gurari's wave function for polaron with impulse p_0 and energy $p_0^2/2m^*$ may be written

$$\psi(\mathbf{p_0}) = V^{\frac{-1}{2}} exp\{i(\mathbf{p} - \sum_k a_k^+ a_k \mathbf{k})\cdot\mathbf{r}\}v(\mathbf{p_0})\phi_0 \tag{4}$$

$$a_k\phi_0 = 0 \tag{5}$$

$$< \phi_0|\phi_0 >= 1 \tag{6}$$

$$v = \prod_k (1 + V^{-1}|f_k|^2)^{\frac{-1}{2}}(1 + V^{\frac{-1}{2}}f_k a_k^+) \tag{7}$$

$$f_k = -i(4\pi\alpha)^{\frac{1}{2}}/k(1 + k^2 - 2\mathbf{k}\cdot\mathbf{p}) \tag{8}$$

Finally with the aid of Lippman–Schwinger equation the expression for mobility μ of the electron is derived which is the function of matrix elements relating to initial and final states of scattering particles and eigen state of hamiltonian as well

$$\mu = \frac{1}{2\alpha\omega}(\frac{e}{m})(\frac{m}{m^*})^3 f(\alpha)e^{\frac{\omega}{\chi T}} \tag{9}$$

where χ—Boltzmann constant, T—absolute temperature,m^*—effective mass of polaron and

$$f(\alpha) = \frac{x_r}{(1 + x_r^2)^2} - \frac{x_r^6}{(1 + x_r^2)}(\frac{\partial G_1(x)}{\partial x})_{x=x_r} \tag{10}$$

$$G_1(x) = \alpha\pi x\{2[\frac{1}{1 + x^2 + |1 - x^2|}]^2 - \frac{1}{2}\theta(1 - x)\} - \alpha\{\frac{1}{x^2(1 + x^2)} - \frac{1}{2x^3}tg^{-1}\frac{2x}{x^2 - 1}\} \tag{11}$$

in which x_r is the root of the following equation

$$x^2 = \frac{1}{1 - G_1(x)} \tag{12}$$

Even if it is difficult to accurately measure the m and m^*, we still show that the result given in this paper is better than that given by Arrhenius.

3   Conclusion

In our electron mobility equation (9) f(α) is a slow-variation function , α is coupling constant of electron-phonon , ω is optical frequency of DNA oscillation and m is DNA lattice mass. Using visible light , Szent could not find the electron mobility but when he used the light of 3000$\overset{\circ}{A}$, he found the phenomenon. Now we can use laser beam (wavelength ¡3000$\overset{\circ}{A}$) to observe the move. This is the result induced by multiphoton process. Our result explain some parameters in Arrhenius' result. The radiation of laser on DNA will not only cause the change of electron mobility in DNA but also cause Onsager nonlinear transfer induced by the temperature variation and result in the change in the co-transport system of DNA. This changed DNA may bring about the abnormal development of cells and cause the occurrence of cancer.

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