CABTER FOUR

OPTICAL PROPERTIES OF SUPERCONDUCTORS

(4.1) Introduction

We used the complex dielectric function to calculate Transmission and reflectance , for a sample of finite thickness ,we have a choice to treat it as ''thick'' (incoherent) or ''thin '' (coherent) in the first case we add intensities of multiple internal reflections while in the second we add

a multiples .The second case allows for interference with fringes in the Transmittance .

(4.2) Transmission

(4.2.1) Transmission slab ''thick'' :

Add intensities .

Compute $$T = \frac{(1-R_{sb})^2 e^{\alpha x}}{1-R_{sb}^2 e^{-2\alpha x}} \qquad (4.1)$$

Where x : thickness α : absorption coefficient

R_{sb} : single bounce reflectance , is defined as :

$$R_{sb} = \left|\frac{N-1}{N+1}\right|^2 \qquad (4.2)$$

(4.2.2) Transmission slab ''fringes'' :

Add amplitudes .

To compute the coherent transmittance , we first calculate the phase gain on passing the sample (on way) .

$$\delta = 2\pi wNx \qquad (4.3)$$

The amplitude transmitted into the slab from vacuum as :

$$t_1 = \frac{2}{N+1} \qquad (4.4)$$

The amplitude transmitted out of the slab:

$$t_2 = \frac{2N}{N+1} \qquad (4.5)$$

And the amplitude reflection at the interface incident from within :

$$r_{in} = \frac{N-1}{N+1} \qquad (4.6)$$

Then the formula for the transmission coefficient (amplitude)[9][10]is :

$$t = \frac{t_1 t_2 e^{-i\delta}}{1-r_{in}^2 e^{2i\delta}} \qquad (4.7)$$

And to get transmittance we calculate :

$$T = tt^* \qquad (4.8)$$

This AIRY formula.

(4.3) Reflectance :

The power Reflectance (single-bounce Reflectance) [8][16] is :

$$R = \left|\frac{N-1}{N+1}\right|^2 \qquad (4.9)$$

(4.3.1) Reflectance slab ''thick'':

Add intensities.

We compute $$R = R_{sb} + \frac{R_{sb}(1-R_{sb})^2 e^{-2\alpha x}}{1-R_{sb}^2 e^{-2\alpha x}} \qquad (4.10)$$

(4.3.2) Reflectance slab ''fringes'':

The t_1 , t_2 $and r_{in}$explained at equations (4.5),(4.6)and (4.7) respectively .

Thus: the front-surface Reflectance as :

$$r_{fs} = \frac{1-N}{1+N} \qquad (4.11)$$

Here : the sing matters , those definitions make r_{fs} negative and r_{in} positive if N >1 .

Then : the formula for the reflection coefficient (amplitude) is :

$$r = r_{fs} + \frac{t_1 r_{in} t_2 e^{2i\delta}}{1 - r_{in}^2 e^{2i\delta}} \qquad (4.12)$$

Finally , to get the reflectance we calculate [9][16]:

$$R = rr^* \qquad (4.13)$$

(4.4) optical conductivity :

From Maxwell's equations:

$$\vec{E} = -\frac{1}{C}\frac{dA}{dt} \qquad (4.14)$$

Where: A: is the vector potential, in a homogeneous superconductors , charge neutrality causes n_c to be constant .From the electromagnetic wave E defined as:

$$\vec{E} = \overrightarrow{E_0} e^{-iwt} \qquad (4.15)$$

From equation (4.14), (4.15) :

$$\vec{A} = -\frac{ic}{w}\vec{E} \qquad (4.16)$$

The electrical current carried is definition by :

$$\overrightarrow{J} = \frac{n_c Q_c v}{m_c}$$

$$= \frac{Q_c}{2m_c}\left(\vec{P}\overset{*}{\Psi}\psi - \psi\vec{P}\overset{*}{\Psi}\right) \qquad (4.17)$$

Where : ; $\vec{P}$ homogeneous momentum , is defined as :

$$\vec{P} = -i\hbar\nabla - \frac{Q_c}{c}\vec{A} \tag{4.18}$$

Hence : $$--i\hbar\nabla\psi = i\hbar\sqrt{n_c}e^{i\phi}\nabla\phi \tag{4.19}$$

Where :ϕ : is potential .

With this equation ,(4.17) becomes :

$$\vec{J_S} = \frac{n_c Q_c}{m_c}\ (\hbar\nabla\phi - \frac{Q_c}{c}\vec{A}) \tag{4.20}$$

Now, for cooper pairs in superconductors materials :

$$Q=-2e \quad , m_c = 2m \quad , n_c = \frac{n_s}{2} \tag{4.21}$$

Where n_s : the superfluied density in a tow-fluid picture .

At zero temperature in clean metals $n_s = n$.

Thus : $\frac{n_c Q_c}{m_c} = -\frac{n_s e}{2m}$ and $\frac{n_c Q_c}{m_c} = -\frac{n_s e^2}{2m}$

with these replacements we arrive at :

$$\vec{J_S} = -\frac{n_s e}{2m}\hbar\nabla\phi - \frac{n_s e^2}{m_c}\vec{A} \tag{4.22}$$

The tow terms in equation (4.22) lead to different physics , the first term proportional to the gradient of phase ($\nabla\phi$), the second term controls electromagnetic properties , we have :

$$\vec{J_S} = -\frac{n_s e^2}{m_c}\vec{A} \tag{4.23}$$

Equation (4.23) is called the London equation . we put that vector potential from equation (4.16.) into (4.23) :

$$\vec{J_S} = i\frac{n_s e^2}{mw}\vec{E} \tag{4.24}$$

As usual . Ohm's law is $\overrightarrow{J_S} = \sigma\vec{E}$ (4.25)

From equation (4.24) and (4.25) yields:

$$\sigma_S = i\frac{n_s e^2}{mw} \quad (4.26)$$

Where σ_S: the optical conductivity from London theory.

(4.4.1) optical conductivity and critical temperature:

From london theory, the optical conductivity of superconductors is given as:

$$\sigma_s = i\frac{n_s e^2}{mw} \quad (4.26)$$

Hence: $n_s = n = 2n_c$ (4.27)

Where: n_cSS : is cooper pairs density .

From equation () the energy gap $\Delta(T)$ superconductors as:

$$2\Delta = 3.5\ k_B T_C \quad (4.28)$$

Where T_C : is critical temperature .

The cooper pairs density (n_s) with energy gap $(\Delta(T))$ as:

$$n_s = \Delta(T)e^{-i\phi} \quad (4.29)$$

Where : ϕ : is the phase .

From equation (4.28) and (4.29).

$$2n_c = (\ 3.5\ k_B e^{-i\phi})T_C \quad (4.30)$$

From equation (4.26) and (4.30):

$$\sigma_s = i(\frac{3.5\ e^2\ e^{-i\phi}}{mw})T_C \quad (4.31)$$

This equation can be explain the increase in optical conductivity with increase in critical temperature ,

(4.4.2) optical conductivity and penetration depth :

The superconducting plasma frequency is defined as :

$$W_{ps}=\frac{C}{\lambda_L} \quad (4.32)$$

Where : λ_L : penetration depth c : speed of light .

Then : $$\lambda_l^2=\frac{c^2}{w_{ps}^2} \quad (4.33)$$

From equation (4.32)and (4.33):

$$\lambda_l^2=\frac{mc^2}{4\pi n_s e^2} \quad (4.34)$$

therefore : $$n_s=(\frac{mc^2}{4\pi e^2}).\frac{1}{\lambda_l^2} \quad (4.35)$$

from equation(4.35)and(4.26) yields :

$$\sigma_s=i\left(\frac{c^2}{4\pi w}\right).\frac{1}{\lambda_l^2} \quad (4.36)$$

This equation can be explain the I decrease in optical conductivity with increase i**n** penetration depth .

(4.4.3) optical conductivity and coherence length:

From **BCS** theory , the coherence length ξ_0)is defined as :

$$\xi_0=\frac{\hbar v_f}{\Lambda(T)} \quad (4.37)$$

Meaning that :

$$\Delta(T)=\frac{\hbar V_f}{\pi\xi_0} \quad (4.38)$$

But from equation (4.29) and (4.38):

$$n_s=(\frac{\hbar V_f\ e^{-i\phi}}{\pi\xi_0}) \quad (4.39)$$

To calculate the optical conductivity sup equation (4.39) in (4.26) yields:

$$\sigma_s = i\left(\frac{2\pi e^2 e^{-i\phi}}{mw\hbar v_f}\right)\cdot\frac{1}{\xi_0} \quad (4.40)$$

This equation can be explain the increase in optical conductivity with decrease in the coherence length .

(4.5) CONCLUSION :

In this work to study the optical properties in the superconductors materials obtain :The transmission depended on the refractive index and reflection shown in equations (4.7) and (8.8).also the reflectance depended on the refractive index and reflection shown in equations (4,12) and (4.13).The optical conductivity is imagery part as shown in equation (4,26). And then we find the optical conductivity is increase by increasing the critical temperature shown in equation (4.31) , and also is decrease by increasing the coherence length as shown in equation (4.40), finally, the optical conductivity is decrease by increasing penetration depth shown in equation (4.36).

(4.6)Recommendations:

To study the optical properties (such as reflectivity, transmittance and optical conductivity ..... etc).We recommend the following proposals :

- Preparation samples for superconductors materials by using any chemical method . this samples are different thickness, then the study the optical properties on this sample by using any spectroscopy devices such as (uv) , then the using the derivation relationships in chapter four
- Design simulation models by using MATLAB software ,where the all equation represent by model . and where in any model the independent variable is describe the input . the dependent variable is describe the output . finally reading values of input and output , then plot relation between them .

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