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Estimation of various parameters of copper metal

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ABSTRACT

Fermi energy (F_E) , temperature (F_T) and Velocity (F_V) of copper and study for resistance variations at different temperature. Compared with the standard values.

INTRODUCTION

Fermi Energy is an important concept in the study of metals, insulators, semiconductors, and other material properties deeper study in many areas of science,. The concept has understand more about the interactions of electrons, and the correlation between energy states and physical properties.Fermi energy is the maximum energy occupied by an electron at 0^o k. By the Pauli's exclusion principle, we know that the electrons will fill all available energy levels, and the top of that Fermi sea is called Fermi energy, Fermi level term used to describe the top of the collection of electronic energy levels at absolute zero temperature. This concept comes from Fermi – Dirac statistics.

According Pauli's Exclusion Principle, electrons are fermions these are cannot exist in identical energy states. At absolute zero temp. all are pack into the lowest available energy states and build up a Fermi sea . Where no electrons will have enough energy to rise above the surface. This concept of is important for the understanding for the properties of the solids.

At higher temperatures a certain fraction, characterized by the Fermi function, will exist above the Fermi level. For a metal the density of conduction electrons can be implied from the Fermi energy.

.***Objective***

1. To compare experimental cost is very low.
2. To compare producer and method are very easy.
3. To compare experimental and theoretical values are nearer.
4. To compare various parameters of the metal to another metal.

Theory:

Electrons in a single atom occupy discrete levels of energy. No two energy levels or states in an atom and have the same energy .Each energy level contain at most two electrons one with clockwise spin and one with anti clockwise spin. If two or more atoms are brought together their outer energy levels must shift slightly so they will be different from one another. If many atoms are brought together to form a solid. For Pauli Exclusion Principle still requires that only two electrons in the entire solid have the same energy. but only slightly different energy levels, forming a ***valence band***. Then difference between the two different velocities associated with the electrons called the drift velocity. This is super imposed on a much higher velocity or speed known as random velocity, due to the random motion of the electron. which contributes zero current, exists in the presence of field, but in that case there is an additional net velocity opposite to the field.

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The energy of the electron in a metal is quantized. According to quantum mechanics occupy these levels. In doing so, according Pauli exclusion principle, for energy level can accommodate at most two electrons, one with spin up and other with spin down. Thus filling the two electrons occupy the lowest level, two more the next level, and so forth, until all electrons in the metal have been accommodate. The energy of the highest occupied level is called the *Fermi energy level*.

We have thus for restricted our treatment to the temperature at absolute zero. When the system is heated,thermal energy excites the electrons. But this energy is not shared equally by all the electrons. Therefore only those electrons close to the Fermi level because the levels above E_F are empty and hence when those electrons move to a higher level. Thus only these electrons which are small fraction of the total number- are capable of being thermally excited and this explains the low electronic specific heat.

Applications :

- In electrical wires (60%), roofing and plumbing (20%) and industrial machinery (15%).
- Used in power generation, transmission, distribution, telecommunications, electronics circuitry, and countless types of equipment.
- Used in appliance, automotive, cables, and magnet wire.
- Used study of multitude of inherent beneficial properties, like it is high electrical conductivity, tensile strength, ductility, deformation and corrosion resistance, low thermal expansion, solder ability, installation, printing plate in etching, engraving and others.
- Used in material testing like chlorides, oxides and sulphur compounds such test called “eddy test”

Standard constants:

$N_A = 6.023 \times 10^{26}$ per m^3 is Avogadro number
e = 1.602×10^{-19} C = electron charge.
m = 9.1×10^{-31}Kg =Mass of the electron.
h’= h/2π =1.054×10^{-27}ergs
h =6.6×10^{-34} m^2 kg / s = Plank’s constant
1.36×10^{-5} = CVT/SCT, Rate constant for each atmospheric reaction
K= 1.38×10^{-23}J/K = Boltzmann’s constant

For theoretically

1. **Fermi energy**

$E_F = h'^2/2m(3\pi n)^{2/3}$eV

Where n= N_A x ρ /At. Weight

n= Number of free electrons in metal for unit volume

$$E_F = \frac{(1.054\times10^{-27})^2}{2\times9.1\times10^{-31}}\left[3\times(3.142)^2\times6.023\times10^{26}\times\frac{8.96}{63.94}\right]^{2/3}$$

= 0.0610393x178.38013x0.1401313

= $1.52577\text{x}10^{-18}/1.6\text{x}10^{-19}$= $1.52577\text{x}10^{-18}/1.6\text{x}10^{-19}$

= 0.9536

= 9.87eV

2. Fermi velocity

V_F= h' K_F/m, m/s

K_F= Fermi wav factor=$1.358\text{x}10^{8}\text{cm}^{-1}$

V_F= $1.054\text{x}10^{-27}\text{x}1.358\text{x}10^{8}/9.1\text{x}10^{-31}$

=0.1572

=1.57 (10^6)m/s

3.Fermi temperature

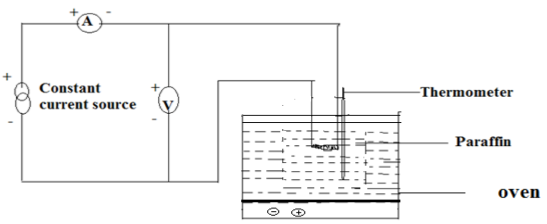
T_F= m $V_F^{\,2}$/2K, ^{o}K

= $0.5\text{x}9.1\text{x}10^{-31}\text{x}(1.57\text{x}10^{6})^2/1.38\text{x}10^{-23}$

= 8.12 ^{o}K

Experimental Setup

- DC regulated power supply
- Digital milli ammeter, voltmeter, Heating arrangements
- Thermometer 0-160 degree, Paraffin oil
- Specimen wires of copper.



Procedure

- Take about specific length, diameter then cross sectional area is calculated, If density of the metal noted from Clark's table.
- The wire is wound over an insulating tube (20mm thickness) to form a coil. The coil is kept inside a suitable test tube and is immersed in pre heated liquid paraffin. The two ends of the coiled wire is connected to a power supply through a milliameter. And milli voltmeter is across the coil.

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- A thermometer is immersed in the beaker containing liquid paraffin and coil. When the thermometer attains steady temperature it is noted.
- The power supply is switched on then voltage and currents are noted In regular intervals of 5 degrees until temperature reach up to 85 degrees.
- A graph is drawn taking temperature in degree ^{O}K along x-axis and resistance along y- axis The slope of straight line is calculated.
- Experiment is repeated for different dimensions of specimen wire.

<u>CALCULATIONS: Practically</u>

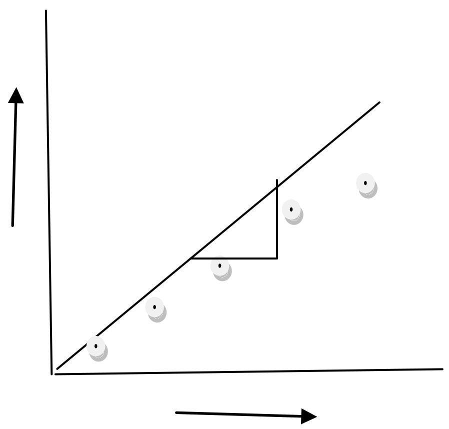
1. **Dimension**

Length of the specimen = L = 5m,
Diameter=D=0.5mm
Radius=D/2=r= 0.25mm
Cross sectional area= A = $\pi r^2 = 0.196 \times 10^{-6} m^2$
Density ρ = 8930Kg m^{-3}

Data:

NATURE OF GRAPH

Temp. ºC	**Temp. in K**	**Voltage (V)**	**Current (A)**	**Resistance** $R = \frac{V}{I}$
35	308	1.43	0.50	2.86
40	315	1.43	0.50	2.86
45	318	1.44	0.49	2.93
50	323	1.44	0.48	3.00
55	328	1.46	0.48	3.04
60	333	1.46	0.48	3.04
65	338	1.49	0.47	3.08
70	343	1.46	0.46	3.15
75	348	1.45	0.45	3.22
80	353	1.45	0.44	3.29
85	358	1.44	0.44	3.29



Slope= AB/BC
=0.001Ω/^{o}K

Mean=R=3.341Ω

<u>Caculation:</u>

1. ***Fermi energy*** $E_{F=}$ $1.36 \times 10^{-15} \sqrt{\frac{\rho A x slope}{L}}$

$$= 1.36 \times 10^{-15} \sqrt{\frac{8930 \times 0.196 \times 10^{-6} \times 0.001}{5}}$$

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$= 1.36\times10^{-15}\ x0.5916\times 10^{-6}$
$=0.9466x10^{-18}/1.6x10^{-19}$
$= 0.5916$
$= 5.916eV$

2. Fermi velocity $V_F = \sqrt{\frac{2E_F}{m}}$

$= \sqrt{\frac{2x09466x10^{-18}}{9.1x10^{-31}}}$

$=\sqrt{0.20804x10}x10^6$

$= 2.080\times 10^6$ m/s

3. Fermi temperature $T_F = \frac{E_F}{K}$

$=0.9466x10^{-19}/1.38x10^{-23} = 0.685\times 10^5$

$T_F = 6.85\times 10^4$ K

2. Dimension

Length of the specimen = L = 6m, ,
Diameter=D=0.8mm
Radius=D/2=r= 0.4mm
Cross sectional area= A = $\pi r^2 = 0.50272 \times10^{-6} m^2$
Density ρ = 8930Kg m^{-3}

Data

Temp. °C	**Temp. in K**	**Voltage (V)**	**Current (A)**	**Resistance** $R=\frac{V}{I}$
35	308	1.43	0.50	2.86
40	315	1.43	0.50	2.86
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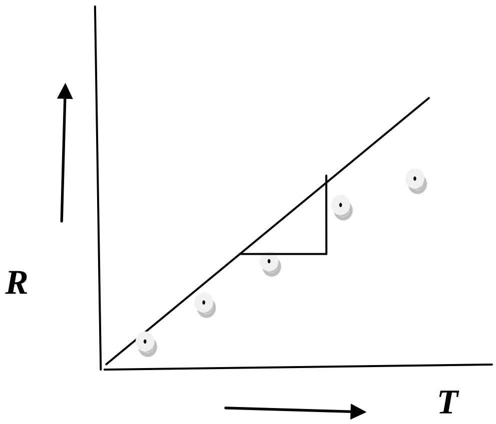
Nature of the graph



Calculation: ***Mean= R= 3.34*** **Ω**

1. ***Fermi energy*** $E_F = 1.36\times10^{-15}\sqrt{\frac{\rho A x slope}{L}}$

$= 1.36\times10^{-15}\sqrt{\frac{8930\times0.50272\times10^{-6}\times0.001}{6}}$

$= 1.36\times10^{-15}\ x0.8649941\times 10^{-6}$

$$= \frac{1.176391 \times 10^{-18}}{1.6 \times 10^{-19}}$$
$$= 0.7352$$
$$= 7.35\text{eV}.$$

2. Fermi velocity $V_F = \sqrt{\frac{2E_F}{m}}$

$$= \sqrt{\frac{2 \times 1.17639 \times 10^{-18}}{9.1 \times 10^{-31}}}$$
$$= \sqrt{0.2585 \times 10} \times 10^6$$
$$= 2.585 \times 10^6 \text{ m}$$

3. Fermi temperature $T_F = \frac{E_F}{K}$

$$= \frac{1.1763919 \times 10^{-19}}{1.38 \times 10^{-23}}$$
$$= 0.8524 \times 10^5$$
$$T_F = 8.52 \times 10^4 \text{ K}$$

3. Dimension

L = 8m, D=0.5mm, D/2=r= 0.25mm, *Density ρ* = 8930Kg m

Cross sectional area = A=πr^2 = 0.196375$\times 10^{-6}$m^2

Data

Temp. ºC	**Temp. in K**	**Voltage (V)**	**Current (A)**	**Resistance** R= $\frac{V}{I}$
35	308	1.43	0.50	2.86
40	315	1.43	0.50	2.86
45	318	1.44	0.49	2.93
50	323	1.44	0.48	3.00
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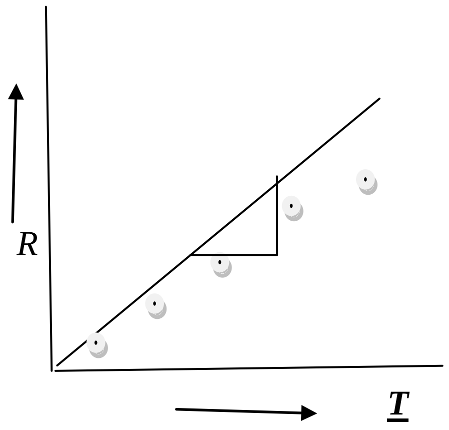

Calculations:

1.Fermi energy $E_{F} = 1.36 \times 10^{-15} \sqrt{\frac{\rho A \times slope}{L}}$

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$$= 1.36\times10^{-15}\sqrt{\frac{8930\times0.196375\times10^{-6}\times0.001}{8}}$$

$$= 1.36\times10^{-15}\ \mathrm{x}0.46819\times10^{-6}$$

$$=0.6367\mathrm{x}10^{-18}/1.38\mathrm{x}10^{-19}$$

$$= 0.4614$$

$$= 4.61\mathrm{eV}.$$

2. Fermi velocity $V_F=\sqrt{\frac{2E_F}{m}}$

$$= \sqrt{\frac{2x0.6367x10^{-18}}{9.1x10^{-31}}}$$

$$=\sqrt{0.13993x10}\mathrm{x}10^{6}$$

$$= 1.399\times10^{6}\ \mathrm{m}$$

3. Fermi temperature $T_F = \frac{E_F}{K}$

$$= 0.6367\mathrm{x}10^{-19}/1.38\mathrm{x}10^{-23}$$

$$= 0.4613\times10^{5}$$

$$T_F = 4.61\times10^{4}\ \mathrm{K}$$

4. Dimension

L = 10m,

D=0.5mm

D/2=r= 0.25mm

Cross sectional area =A= πr^2 = $0.196375\times10^{-6}\mathrm{m}^2$

Density ρ = 8930Kg m^{-3}

Data

Temp. °C	Temp. in K	Voltage (V)	Current (A)	Resistance $R=\frac{V}{I}$
35	308	1.43	0.50	2.86
40	315	1.43	0.50	2.86
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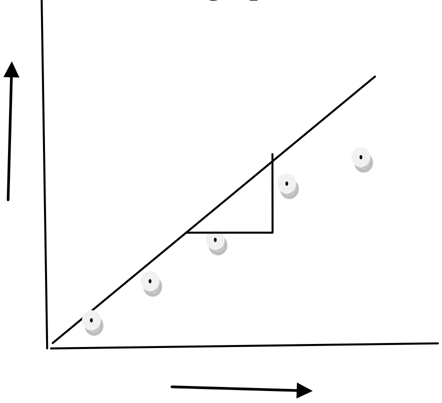
Nature of graph



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Calculations:

1.Fermi energy $E_{F=}$ $1.36\times10^{-15}\sqrt{\frac{\rho A x slope}{L}}$

$$= 1.36\times10^{-15}\sqrt{\frac{8930\times0.196375\times10^{-6}\times0.001}{10}}$$

$$= 1.36\times10^{-15} x0.4187\times 10^{-6}=0.5695182$$

$$= 0.5695182x10^{-18}/1.8x10^{-19}$$

$$= 0.4126$$

$$= 4.26eV.$$

2. Fermi velocity $V_F=\sqrt{\frac{2E_F}{m}}$

$$=\sqrt{\frac{2x0.5695152x10^{-18}}{9.1x10^{-31}}}$$

$$=\sqrt{0.1251688x10}\ x10^{6}$$

$$= 1.2516\times 10^{6}\ m/s$$

3. Fermi temperature $T_F = \frac{E_F}{K}$

$$= 0.5695182x10^{-19}/1.38x10^{-23}$$

$$= 0.4126\times 10^{5}$$

$$T_F = 4.12\times 10^{4}\ K$$

Comparison values

Metal	Parameters	Theatrical Value	Mean Experimental Value
Copper	E_F in (ev)	9.870eV	6.00eV
	V_F in (10^6 m/s)	1.57 (10^6 m/s)	1.76 (10^6 m/s)
	T_F in (10^4 K)	8.12 K (10^4 K)	8.05 K(10^4 K)

Results and Discussion

Fermi energy, temperature, and velocity are measurements carried out at room temperature. The resistance values are nearly constant for more number of readings. Thus resistance is directly proportional to temperature of the material.

Conclusion

Fermi Energy is an important concept in the study of insulators, conductors, and understanding material properties, and deeper study in many areas of science and more about the interactions of electrons, correlation between energy states. A number of measurements were performed on the sample to check the repeatability and observed the resistance value. All these parameters are dependents on materials, but not dimensions. It was also found that the measured values are precise (exact).

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