Reflectivity of Metal: Platinum

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Introduction

Platinum is an important metal in the scientific industry. The reason for this are based on some of the characteristics of this metal which include platinum being a soft, silvery-white, and dense with a strong shine. Platinum is also a malleable and ductile metal with a high melting point. Another beneficial property of this metal is that it does not oxidize in air. In the scientific field, platinum is used as a catalyst for chemical reactions, help create strong magnets, various lab equipment, resistant wires, and electrodes sealed in glass. However, the most notable properties that affect the reflectivity of this metal include that the metal is malleable and is lustrous. [4] Some periodic facts for this element include; its atomic number of 78, atomic symbol Pt, atomic weight of 195.1, and its density of 21.45 g per cubic cm.

Method

Many of the parameters for platinum were hard to find online, however, the easiest one to find was the Hall coefficient R_H [3]. Knowing this coefficient will give the electron density,

$$R_H = \frac{1}{N_e * e}. \tag{1}$$

Where e is the charge of an electron and N_e is the charge density. Rearranging equation (1) so that we can solve for electron density the equation becomes,

$$N_e = \frac{1}{R_H * e}. \tag{2}$$

The Hall coefficient for platinum is $7.1 * 10^{-9} \frac{m^3}{C}$. Entering this value into the equation and the value into equation (2)

$$N_e = \frac{1}{7.1 * 10^{-9} * \frac{m^3}{C} * 1.6 * 10^{-19} C}. \tag{3}$$

the value of charge density for platinum becomes $N_e = 8.8 * 10^{28}/m^3$. Now that the value of charge density is know, the value for the mobility is found with the coefficient of resistivity for platinum $\rho = 1.06 * 10^-7$ [1]. Therefore, the mobility is given by

$$\mu = \frac{1}{\rho * N_e}. \tag{4}$$

If we plug the known values into equation (4)

$$\mu = \frac{1}{1.06 * 10^{-7}\Omega m * 8.8 * 10^{28}/m^3}. \tag{5}$$

equation (5) finds that the mobility of platinum is $\mu = 6.7 * 10^{-4}$. Since the charge density and mobility are known values now, the conductivity of platinum can be calculated by

$$\sigma = \mu * N_e * e. \tag{6}$$

The calculated value for conductivity becomes $\sigma = 9.4*10^6 S/m$. Checking the value online [1] relieves the same values as the one calculated to four significant figures, ensuring that all values so far are correctly calculated for platinum.

One of the last constants to be calculated for platinum is the dielectric permittivity constant ϵ. Based off the data online, the dielectric permittivity constant in a vacuum, ϵ_0, is $8.85 * 10^-12$. The relative dielectric permittivity constant for platinum, ϵ_r is 7. The dielectric permittivity for platinum is then calculated by [4]

$$\epsilon = \epsilon_0 * \epsilon_r. \tag{7}$$

Thus, the calculated value for $\epsilon = 6.2 * 10^{-11}$.

The final constant needed to model platinum is the mean free space constant τ. τ can be found by

$$\tau = \frac{\sigma * m}{e^2 * N_e} \tag{8}$$

where m is the mass of an electron. Entering some of the previous values found

$$\tau = \frac{9.4 * 10^6 S/m * 9.11 * 10^{-31} kg}{(1.6 * 10^{-19})^2 * 8.8 * 10^{28}/m^3}, \tag{9}$$

resulting in a value of $\tau = 3.8 * 10^-15 s$.

Results

The values calculated in the methods section are essential since they relate to properties of platinum. To simulate a good model, these values have to be within the same order of magnitude. Also, with the parameters set above the plasma frequency, index of refraction, and dielectric constant can all be accurately calculated. To be able to model the interesting properties of platinum the angular wavenumber (ω) and the plasma frequency (ω_p) need to be calculated. The angular wavenumber is calculated by

$$\omega = \frac{2 * \pi * c}{\lambda}, \tag{10}$$

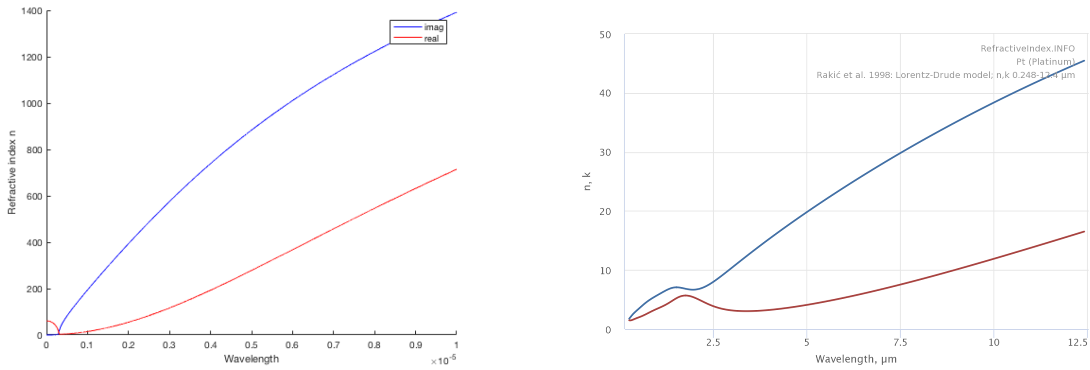
where c is the speed of light and λ is wavelength. In order to find the index of refraction one more variable needs to be found, the absorption (k). The equation for k is as follows

$$k = \omega(\mu * \epsilon)^{\frac{1}{2}} * \left(1 - \frac{\sigma}{\omega^2 * \epsilon * \tau}\right)^{\frac{1}{2}}. \tag{11}$$

When the values from equation (10) are plugged into equation (11) the model for the real part of the index of refraction and the imaginary part of the index of refraction. This is plotted against wavelength ranging from x-ray spectrum to the near IR spectrum. The index of refraction is calculated by

$$n = \frac{c * k}{\omega}, \tag{12}$$

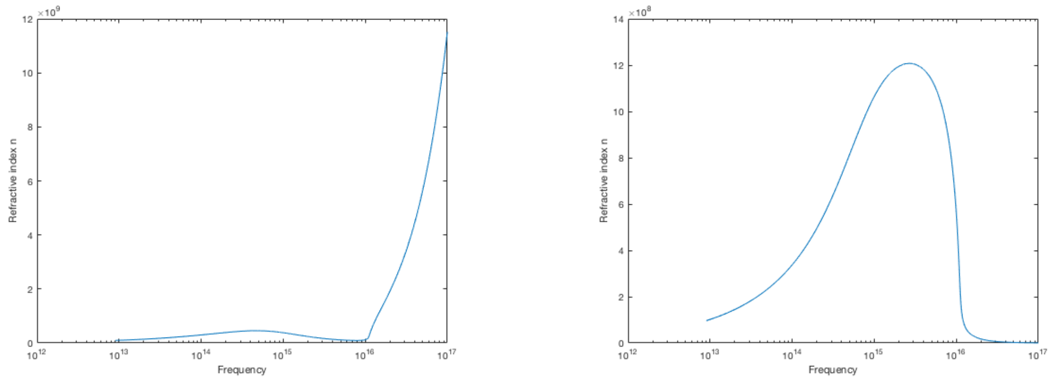
where k is is gave in equation (11), ω is gave in equation (10), and c is the speed of light. Calculating the index of refraction over the electromagnetic spectrum from near ultra violet spectrum to the near IR spectrum results in the figure below, figure (1a).



(a) Model with data (b) Online model

Figure 1: In (a) the blue line corresponds to the imaginary part on n

Figure (2) below represents the dispersion curves. The figure on the left show the real part of the dispersion curve while the figure on the right shows the imaginary part. Equation (11) was used to calculate the k values, this plot resembles the refractive index vs. frequency.

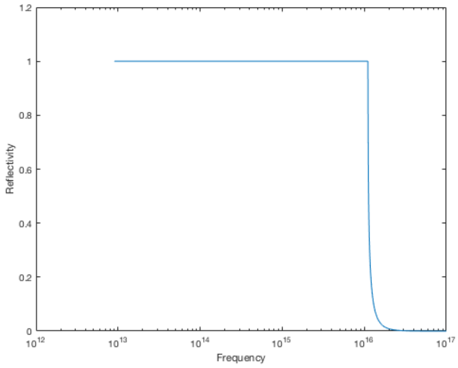


(a) Real (b) Imaginary

Figure 2: In (a) the line represented is the real part of k and in (b) the line is the imaginary part of k.

Figure (3) below represents the reflectivity of platinum. When the frequency is very small the light can not penetrate the material, thus all of the light is reflected off the material. As the frequency increases, there becomes a sudden spike in the material the significantly reduces the metals reflectivity. Once the frequency is high enough, there is no reflectivity and the metal absorbs all of the light. The equation for reflectivity is as follows,

$$\left| \frac{1 - (1 - \omega_p^2/\omega^2)^{1/2}}{1 + (1 - \omega_p^2/\omega)^{1/2}} \right|^2. \tag{13}$$



(a) Reflectivity

Figure 3: As the ω gets smaller the reflectivity increases. When ω is large there is no reflectivity on the metal.

Equation (13) represents how figure (3) was created. It can be computed that when ω is small there becomes a lot of reflectivity. But when ω becomes large there is no reflectivity.

Conclusion

Platinum is a shiny malleable metal. Based on the properties mentioned platinum becomes transparent with higher frequencies, meaning that it becomes transparent near the high ultra violet spectrum. Platinum is also a shiny metal with a high reflectivity.

References

[1] Dielectric Constants of Common Materials. `www.kabusa.com/Dilectric-Constants.pdf`.

[2] Electrical Resistivity and Conductivity. Wikipedia, Wikimedia Foundation, 17 Jan. 2018, `en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity`.

[3] Room Temperature Hall Coefficient and Resistivity for Selected Chemical Elements, `it.stlawu.edu/ koon/HallTable.html`.

[4] Says, Jayson Brown. Jayson Brown. Chemicool, `www.chemicool.com/elements/platinum.html`.


```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%    Timothy Holmes
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function platinum

h = 6.6*10^-34; %planck's constant J/s
hev = 4.13*10^-15; %planck's constant eV
e = 1.6*10^-19; %Charge of an electron C
m = 9.11 * 10^-31; %Mass of an electron kg C
c = 3*10^8; %speed of light
epsilon0 = 8.85*10^-12; %permittivity in a vacuum
```

```
epsilonp = epsilon0 * 7; %platinums permittivity
rho = 1.06*10^-7; %platinums resistivity
Rh = 0.23*10^-10; %platinums Hall's constant
Ne = 1/(Rh * e); %charge density
mu = 1/(rho * Ne * e); %mobility
sigma = (mu * Ne * e); %conductivity
tau = (sigma * m)/((e^2) * Ne); %mean free path
wp = sqrt(sigma/(epsilonp * tau)); %plasma frequency
lambda = linspace(1*10e-12,10*10^-10,100000); %wavelength
lam = (2.*pi)./lambda;
%E = hev.*(c./lambda);
%n = sqrt(1 - (wp^2./w.^2));
%mu0 = (4*pi)*10^-7; %H/m
%eff = 1 - (wp^2./w.^2);
%kdis = w.*sqrt(epsilon0*mu0).*sqrt((eff)/(1+eff));
%k1 = w*.sqrt(mu*epsilon)*.sqrt(eff)
%B0 = (m.*w)/m;
%wc = e/m *B0;
%dis = (Ne*(e)^2)./(m*(w.^2));
%Ne0 = (w.^2.*m.*epsilon)/(e^2);

w = linspace(9e+12, 1e+17,100000);
k = zeros(1,length(w));
n = k;
r = k;

for j = 1:length(w)

k(j) = w(j).*(sqrt(mu.*epsilonp).*sqrt((1 + ((sqrt(-1) .* sigma)./(w(j) .* epsilonp .* (

r(j) = abs(((1-sqrt(1-(wp^2/w(j)^2)))/(1+sqrt(1-(wp^2/w(j)^2)))))^2;

n(j) = (k(j).*c)./w(j);

dis(j) = (Ne*(e)^2)./(m*(w(j).^2));

end

%n = (c.*k)./w; %index of refraction

%r(w) = abs((1-sqrt((1-(wp).^2)./(w.^2)))./(1+sqrt((1-(wp).^2)./(w.^2)))).^2;

%rck = w.*sqrt(mu*epsilonp).*sqrt((1 - ((wp.^2.*tau.^2.*(1 - wc./w))./(1+(w - wc).^2.*ta


figure(1)
semilogx(w,real(k))
xlabel('Frequency')
ylabel('Refractive index n')

figure(2)
semilogx(w,imag(k))
xlabel('Frequency')
ylabel('Refractive index n')

figure(3)
```

```
semilogx(w,r)
xlabel('Frequency')
ylabel('Reflectivity')

figure(5)
plot(lambda,real(n),'r')
plot(lambda,imag(n),'b')


end
```