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External and Internal Instability in the Medium Having Electron Typ Conductivity

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Abstract:*External and internal instabilities have been theoretically studied under electron type conductive conditions located in the external stable electic and magnetic fields. The frequencies of the waves formed under internal and external instability were calculated. Analytical expression of the electric field was calculated using the theoretically calculated impedance.*
Keywords: *wave, oscillation, instability, impedance, electric field*

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I. Introduction

If the electric charge in the environment is spreaded uniformly, then the medium is balanced with respect to the load distribution. Any external effect can disturb the load distribution and the system can be transformed from equilibrium into non-equilibrium state. When the system is in non-equilibrium state, the electric charges are not spreaded uniformly. In case if the system is in the state close to thermodynamic equilibrium, the state of macroscopic system is uniformly with respect to the coordinate. The medium can be strongly apart from the balanced state. This state can be caused by the impact of external electric or magnetic fields. As far as the state is far from the balanced, the distribution of electric field (including magnetic field) within the medium became uneven, and the new internal parts with the intensities smaller than the electric field intensity and the fields with comperatively higher intensities are formed. These fields are called electric domains (or electric and magnetic domains) [1]. The domains can be of static or dynamic types. In the medium where domains are present, the dependance of current strength from electric field (electric or magnetic fields) is non-linear. Electromagnetic oscillations can be formed and intensified in such environment, and that is in non-equilibrium state. The unbalanced state that forms in different solid bodies dramatically changes the physical properties of the environment. The domain unbalanced state is strongly dependent on the value of the energy spectrum of charge carriers in the environment as well as on the capture (recombination) and release (generation) of the carriers by impurity atoms. It is clear that the value of the external electric field (external electric and magnetic fields) is an important factor in the formation of the non-equilibrium state. The non-equilibrium states created in the external electric and magnetic media are caused through various mechanisms occurred in metals, semi-conductors and dielectrics. In case, there is electric field of moving charge carriers in the environment and their velocity $U_d = \mu E_o$ (U_d – drift speed, μ – walking, E_0 – electrik field intensity), is higher than the sound waves velocity (s) in the environment ($U_d \geq S$), then the electric field is called strong, otherwise ($U_d \leq S$) the electric field is called weak. After the middle of the last century (XIX), physical properties of various metals and semiconductors began to be studied both in practice and in theory.

As a rule, it has been proven that when the moving domains are formed, oscillation occurs in electric circuit. Such oscillations mean the appearance of a domain on one side of the sample and its loss on the other side. If the time of formation and disappearance of domains is smaller than the time of passing the domains through sample, the period of the current is measured by the time of passing the domains through the medium and $T=L/U_d$ (L – the length of sample). Figure 1 shows a constant current from the consistent combined sample to R resistance [2].

The constant current is broken when the voltage – E is increased that causes oscillation in the circuit. The period of this oscillation proportionates with the sample length – L. Violation of the constant current regime causes breakage and leap in the volt-amperage characteristics. In1964, the english scientist Hann in GaAs semi-conductor component with $L \approx 0{,}1$ cm length, under the external electric field $E_0 \approx 3 \cdot 10^3$V/cm observed oscillations with $5 \cdot 10^8 \div 5 \cdot 10^9$ hers frequency. This is called Hers effect [2]. One kilohers oscillations with $L \approx 1$cm, $E_0 \approx 10$V/cm values were observed in electron type Ge semi-conductor [2-5].

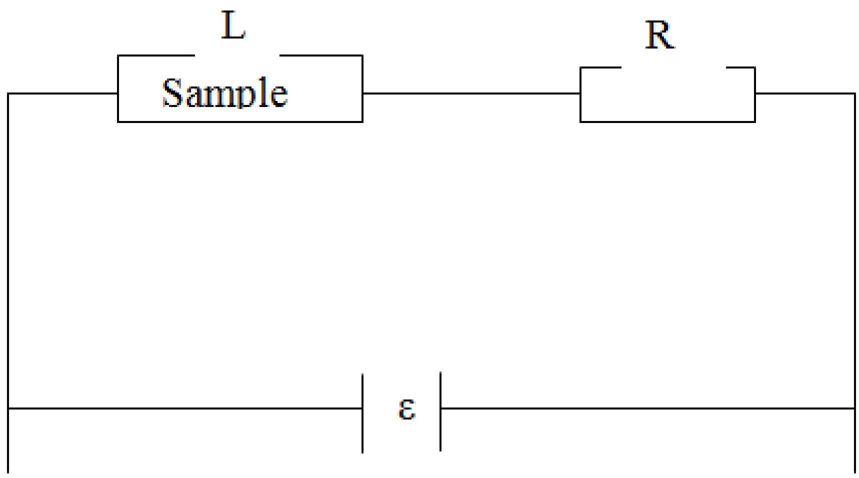

Figure1.

Observation of current oscillations shows that the domains created in the medium are mobile. The actions of the domains depend heavily on the type of the sample and the connection to the circuit (the new boundary conditions). Depending on the ohmic and non-ohmic character of the connection of the sample to the circuit, i.e its injection character, the frequencies of the occured current oscillations are different. If spontaneous oscillations are spread within the sample, but are not oscillating in the outer circuit (i.e. the current is constant), such state is called instability[3]. If the oscillation in the sample causes current oscillation, such instability is called external instability. For the first time, internal and external instability were theoretically studied in the case of impurity semiconductors [3-5]. In this theoretical work, we will analyse the mechanism of formation of the internal and external instabilities in the electron conductive medium (in metals and semiconductors) under the electric and magnetic fields' effect together with the frequencies of both the occured oscillations and the directions of inside waves.

Internal instability: When there are external electric and magnetic fields, the current intensity in an electron conductive medium is as follows:

$$\vec{j} = \sigma(E_0, H_0)\vec{E} - \sigma_1(E_0, H)\left[\vec{E}\vec{h}\right] + \sigma_2(E_0, H_0)\vec{h}\left[\vec{E}\vec{h}\right] + D\vec{\nabla}\rho - \quad (1)$$

where, E_0 - constant external electric field,
H_0 - constant external magnetic field,
-ohmic conductivity,
$\sigma_1(E_0, H_0)en_0\mu_1(E_0, H_0)$-Holl's conductivity, $\sigma_2(E_0, H)en_0\mu_2(E_0, H_0)$- focusing conductivity, $D = \frac{T_{ef}}{e}\mu(E_0, H_0)$ ohmic diffusion coefficient, $D_1(E_0, H_0) = \frac{T_{ef}}{e}\mu_1(E_0, H_0)$ Holl's diffusion coefficient, $D_2 = \frac{T_{ef}}{e}\mu_2(E_0, H_0)$ focusing diffusion coefficient, T_{ef} - electronic temperature in a powerful electric field, $\rho_0 = en_0$, n_0 - electron concentration in equilibrium state.

$\vec{l}$-single vector in the magnetic field. Frequencies of oscillations in internal instability

$$\frac{\partial \rho}{\partial t} + div\vec{j} = 0$$

$$divE = \frac{4\pi\rho}{\varepsilon} \quad (2)$$

$$\frac{\partial H}{\partial t} = -crot\vec{E},$$

should be find joint solution of system equations (2). The waves formed inside the crystall can be distributed to various directions with respect to changing electric field $(E^{'})$, i.e. $\vec{k}$-wave vector and $\vec{E^{'}}$ electric field can form different angles. If $\vec{k} \parallel \vec{E^{'}}$, such waves are called longitudinal waves. First let's examine the instability of longitudinal waves. If variables in equation system (2):

$$(E^{'}, H^{'}, n^{'}) \sim e^{i(\vec{k}\vec{r} - \omega t)}, \qquad (3)$$

is assumed as monochromatic wave, than

$$\frac{\partial \vec{H^{'}}}{\partial t} = -c\,rot\vec{H^{'}} = -ci\left[\vec{k}\vec{E^{'}}\right] = \mathbf{0}\text{ , that is } H^{'} = \text{const} \qquad (4)$$

Longitudinal waves are formed only due to the changing electric field. Taking into account (3) and (4) conditions and lining equation system (2) with the following terms

$\vec{E} = \vec{E}_0 + \vec{E}^{'}$, $\quad n = n_0 + n^{'}$, $\quad \vec{H} = \vec{H}_0$ we can obtain the dispersion equation as below:

$$\omega + i\frac{4\pi\sigma_0}{\varepsilon} + i\frac{8\pi\sigma_0 E_0}{k}(\vec{k}\vec{E}_0)\frac{1}{\mu_0}\frac{d\mu}{d(E_0^2)} - \mu_0(\vec{k}\vec{E}_0) + i\frac{4\pi\sigma_{1_0} H}{\varepsilon k}(\vec{k}\vec{n})sin\alpha +$$

$$+i\frac{8\pi\sigma_{1_0}}{\varepsilon k}E_0^2 H\frac{1}{\mu_{1_0}}\frac{d\mu_1}{d(E_0^2)}sin\alpha\left(\vec{k}\vec{n}\right) - \mu_{1_0}E_0 H sin\alpha\left(\vec{k}\vec{n}\right) + i\frac{4\pi\sigma_{2_0}}{\varepsilon k}H\left(\vec{k}\vec{H}\right) +$$

$$+i\frac{4\pi\sigma_{2_0}}{\varepsilon k}HE_0^2\frac{1}{\mu_{2_0}}\frac{d\mu_2}{d(E_0^2)}cos\beta\left(\vec{k}\vec{H}\right) - \mu_{2_0}E_0 H cos\beta\left(\vec{k}\vec{H}\right) + iDk^2 +$$

$$+in^{'}\vec{k}\left(\vec{k}\vec{H}\right)D_1 + iD_2 n^{'}\left(\vec{k}\vec{H}\right)^2 = 0,$$

(5)

In dispersion equation (5) $n^{'} = -\frac{\varepsilon}{4\pi e}\left(\vec{k}\vec{E^{'}}\right)$, $\vec{n}$- single vector.

$(E^{'}\hat{\ }H_0) = \alpha, (E_0\hat{\ }H_0) = \beta$

When we examine $\vec{k} \parallel \vec{E}_0$, $\vec{E}_0 \perp \vec{H}_0$, $\vec{k} \parallel \vec{H}_0$ directions in (5) we get the following expression:

$$\omega = \mu_0 k E_0 - i\frac{4\pi\sigma_0}{\varepsilon}\left[\frac{2E_0^2}{\mu_0}\frac{d\mu}{d(E_0^2)}\right], \qquad (6)$$

It can be seen from this, when

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Condition is fulfilled, the wave with $\omega_0 = \mu_0 k E_0$ frequency is instable.

If we write $\omega = \mu_0 k E_0 + i\gamma = \omega_0 + i\gamma$ expression in $(E', n') \sim e^{i(\vec{k}\vec{r} - \omega t)}$ a harmonic oscillation with accelarating amplitude like e^{nt} is obtained in form of $(E', n') \sim e^{n\cos(\mu_0 k E_0 t + \theta)}$. Negative expression of means that the mobility of electrons due to the $eE_0 l$ energy derived from the external electric field (l-the length of free path of electrons) decreases. The electrons having great energy create weak conductivity, but the electrons having little energy create strong conductivity. From equation (5) $\vec{k} \| \vec{E}_0, \vec{k} \perp \vec{E}_0, \quad \vec{k} \| \vec{n}, \quad \vec{E}_0 \perp \vec{H}$,

$$\omega = \mu_{2_0} E_0 H - i\frac{4\pi\sigma_0}{\varepsilon}\left[1 + \frac{2E_0^2}{\mu_0}\frac{d\mu}{d(E_0^2)} + \frac{\mu_{2_0} H^2}{\mu_0} + \frac{1}{\mu_0}\frac{E_0^2 d\mu_2}{d(E_0^2)}\right] i - Dk^2 - k^2 D_2 H^2, \quad (7)$$

If we write $\omega_0 + i\gamma$, from (7) the instability condition of a wave with $\mu_{2_0} E_0 H_0$ frequency again requires the decrease of mobility by the influence of the external electric field. Let's now assume that the wave vector is not in the K $^{\rightarrow}$, (H $^{\rightarrow}$, E $^{\rightarrow}$) flatness and is directed as follows. The dispersion equation (5) geometry will be as follows:

$$\omega = +i\frac{4\pi\sigma_0}{\varepsilon} + i\frac{8\pi\sigma_0}{\varepsilon}E_0^2\frac{1}{\mu_0}\frac{d\mu}{d(E_0^2)}\sin\theta\sin\varphi - \mu_0 \vec{k}\vec{E}_0 \sin\theta\sin\varphi +$$

$$+i\frac{4\pi\sigma_{1_0} H}{\varepsilon}\sin(90-\theta) + i\frac{8\pi\sigma_{1_0}}{\varepsilon}E_0^2 H\frac{1}{\mu_{1_0}}\frac{d\mu_1}{d(E_0^2)}\cos\theta - \mu_{1_0} E_0 H\cos\theta +$$

$$+i\frac{4\pi\sigma_{2_0}}{\varepsilon}H^2\cos(90-\theta)\cos(90-\theta) = 0$$

$$\omega = \omega_0 + i\gamma, \omega_0 = \mu_0 k E_0 \sin\theta\sin\varphi + \mu_{1_0} E_0 H k\cos\theta$$

$$\gamma = -\frac{4\pi\sigma_0}{\varepsilon}\left[1 + \frac{\mu_{1_0} H}{\mu_{1_0}}\sin(90-\theta) + \frac{\mu_{2_0} H^2}{\mu_{2_0}}\cos(90-\theta)\cos(90-\theta) + \right.$$
$$\left. + \frac{2E_0^2}{\mu_0}\frac{d\mu}{d(E_0^2)}\sin\theta\sin\varphi + \frac{2E_0^2}{\mu_0}\frac{d\mu_1}{d(E_0^2)}H\cos\theta\right], \quad (8)$$

(8) expression can be simplified in $\theta = \frac{\pi}{4}, \varphi = \frac{\pi}{4}$ values, then

$$\omega_0 = \frac{1}{2}\mu_0 k E_0 + \frac{1}{\sqrt{2}}\mu_{1_0} E_0 H k,$$

$$\gamma = -\frac{4\pi\sigma_{1_0}}{\varepsilon}\left[1 + \frac{1}{\sqrt{2}}\frac{\mu_{1_0} H}{\mu_{1_0}} + \frac{1}{2}\frac{\mu_{2_0} H^2}{\mu_{2_0}} + \left(\frac{E_0^2 d\mu}{d(E_0^2)} + \frac{1}{\mu_0}\frac{E_0^2 d\mu_1}{d(E_0^2)}\frac{H}{\sqrt{2}}\right)\right], \quad (9)$$

It is seen from expressions (9), the Hall mobility plays important role in the formed instability waves.

The fluctuating current should be taken into account at high frequencies, then the full current is as follows:

$$\vec{j} = \frac{\varepsilon}{4\pi}\frac{\partial \vec{E}}{\partial t} + \sigma\left(\vec{E},\vec{H}\right)\vec{E} - \sigma_1\left(\vec{E},\vec{H}\right)\left[\vec{E}\vec{h}\right] + \sigma_2\left(\vec{E},\vec{H}\right)\left[\vec{E}\vec{h}\right]\vec{h} + D\nabla\rho -$$
$$-\mathbf{D_1}\left[\vec{\nabla}\rho\vec{h}\right] + \mathbf{D}_2\vec{h}\left(\vec{\nabla}\rho\vec{h}\right), \qquad \frac{\partial n}{\partial t} + divj = 0 \tag{10}$$
$$div\vec{E} = 4\pi\rho'; \qquad \vec{H}' = 0$$

Taking into account (3) monochromatic condition, we obtain the following equation from (10) equation system:

$$\frac{\mathbf{d^2E_x'}}{\mathbf{dx^2}} + \frac{\mathbf{U_0\gamma + U_1\gamma_1}}{\mathbf{D\gamma + D_1\gamma_1}}\frac{\mathbf{dE_x'}}{\mathbf{dx}} + \frac{\boldsymbol{\sigma_{1_0}\gamma_1(1+\varphi_1) + \gamma(\sigma_0\varphi - \Omega)}}{\mathbf{D\gamma + D_1\gamma_1}}\mathbf{E_x'} = \frac{\gamma}{\mathbf{D\gamma + D_1\gamma_1}}\mathbf{J_x'}, \tag{11}$$

Here

$$\Omega = \frac{i\omega\varepsilon}{4\pi} - \sigma_0, \qquad \sigma_0 = \mathbf{en_0\mu_0}; \ \ \boldsymbol{\varepsilon}\mathbf{D_1k_y^2} - 4\boldsymbol{\pi\sigma_{1_0}} + i\boldsymbol{\varepsilon}\mathbf{U_0}$$
$$\sigma_{1_0} = \mathbf{en_0\mu_{1_0}}; \quad \mathbf{k_y} = \frac{\mathbf{2\pi}}{\mathbf{L_y}}m; \quad m = 0, \pm 1, \pm 2, \pm \ldots\ldots\ldots$$

The measure of the crystal on L_y axis. $\mathbf{J_x'} = 0$ in case of the internal instability and equation (11) is expressed as:

$$y^2 - \frac{4\pi}{\varepsilon^2}\left[1 + \frac{\varepsilon^2\mu_1\mathbf{k_y}}{4\pi\mu_0\mathbf{k_x}} + i\frac{\boldsymbol{\varepsilon}\mathbf{D}}{\mathbf{U_0}}\left(\mathbf{k_x} + \frac{\mathbf{k_y^2}}{\mathbf{k_x}}\right)\right]y + \frac{i\boldsymbol{\sigma_{1_0}}}{\mathbf{k_yU_0}}(2 + \varphi_1 - \varphi) = 0$$

here $$y = \frac{\omega}{\mathbf{k_yU_0}}; \ \ \varphi = \frac{E_0^2}{\mu}\frac{d\boldsymbol{\mu_0}}{d(E_0^2)}; \ \ \varphi_1 = \frac{E_0^2}{\boldsymbol{\mu_{1_0}}}\frac{d\boldsymbol{\mu_{1_0}}}{d(E_0^2)} \tag{12}$$

in strong magnetic field $\frac{\mu_0\mathbf{H}}{c} \gg 1$ [5]

$$D = \frac{T_{ef}}{e}\mu, \qquad D_1 = \frac{T_{ef}}{e}\mu_1, \qquad T_{ef} = \frac{T}{3}\left(\frac{c\mathbf{E_0}}{SH}\right)^2$$

expressions are taken into consideration, T_{ef} - effective temperature of electrons, T- the temperature of crystal lattice, c- the speed of light spreading in the space.

If to take into account $\mu = \alpha\left(\frac{c}{H}\right)^2 \cdot \frac{1}{\mu_0}, \quad \mu_1 = \sqrt{2}\frac{c}{H}, \quad \mu_2 = b\mu_0, \quad \mathbf{a} \approx \mathbf{b} \approx 1$ [6] expressions in (12) equation, the solution of this equation will be as follows:

$$y_{1,2} = \frac{2\pi}{\varepsilon^2}(\alpha + i\beta) \pm \frac{2\pi\alpha}{\varepsilon^2}\sqrt{1 - i\delta}, \tag{13}$$

here $$\alpha = \frac{\varepsilon\mu_0\mathbf{H}}{2\sqrt{2}c}, \qquad \beta = 2\pi\varepsilon\frac{T}{e\mathbf{E_0}\mathbf{L_x}}\left(1 + \frac{L_x^2}{L_y^2}\right)$$

$$\delta = \sqrt{2}\frac{\mu_0\mathbf{H}}{c}\cdot\frac{1}{2\pi}\frac{\mathbf{en_0}L_x^2}{L_y\mathbf{E_0}}(2 + \varphi_1 - \varphi), \qquad \delta \ll 1$$ və $\alpha \ll 2$

$$y_1 = \frac{4\pi\alpha}{\varepsilon^2} + i\frac{2\pi}{\varepsilon^2}\beta; \quad y_2 = 0 + i\frac{2\pi}{\varepsilon^2}\beta \qquad (14)$$

If to write (14) as $\omega_1 = \left(\frac{4\pi\alpha}{\varepsilon^2} + i\frac{\beta}{\alpha}\right)\cdot k_y U_0, \qquad \omega_1 = i\,\frac{2\pi\alpha}{\varepsilon^2}\,\beta k_y U_0$ it is seen from $(E^{'}, n^{'}) \sim e^{i(kx-\omega t)}$ expression, the waves formed with ω_2 are aperiodic, i.e. like $(E^{'}, n^{'}) \sim e^{\frac{2\pi}{\varepsilon^2}\beta k_y U_0 t}$. The wave formed with ω_1 frequency is a harmonic oscillation as

$$(E^{'}, n^{'}) \sim e^{-\frac{4\pi}{\varepsilon^2}k_y U_0 t} \cdot e^{\frac{4\pi}{\varepsilon^2}\beta t U_y U_0 t} = A_0 e^{\frac{4\pi}{\varepsilon^2}\beta t k_y U_0} \cos\left(\frac{4\pi\alpha}{\varepsilon^2}k_y U_0 t + \theta\right)$$

and the amplitude of oscillation is increasing like $A = A_0 e^{\frac{4\pi}{\varepsilon^2}\beta t k_y U_0}$, that is the system is in non-equilibrium state.

In this case, the system is radiated with $\omega_0 = \frac{4\pi}{\varepsilon^2}\alpha k_y U_0$, (15)

frequency and transforms to energy source.

External instability. Impedance instability: It is necessary to calculate the impedance of the medium to investigate the current oscillation in the external circuit. If the sample is supplied with slightly varied tension

$$\delta V(t) = \int_{-\infty}^{+\infty} \delta V(\omega) e^{-i\omega t} d\omega$$

Then it changes the current in the system to $J^{'}$, i.e.

$$Z(\omega)\delta J(\omega) = \delta V(\omega) \qquad (17)$$

here $Z(\omega) -$ impedance according to ω frequency. The following three issues is interesting during impedance calculation:

1) If the real part of impedance is $Jm\omega = 0$ with $Rez(\omega) < 0$ designation the sample works as amplifier;
2) Zeros of impedance;
3) Finding the impedance poles.

Here we will explore the mark of the real part of the impedance. ΔV tension changes as below:

$$\delta v(t) = \int_0^L \delta E(x,t) dx, \qquad (18)$$

L- the size of the sample. $E(x,t) = E^{'}(x,t)$ quantity from (11) equation should be calculated through the boundary conditions. Oscillation frequency is a real quantity when there is external instability. (11) is an integral-differential equation. So, its complete solution is possible when the electric field variables in the ends of the sample $E^{'}(0,t)$ and $E^{'}(L,t)$ are known. In fact, the contractual terms of border may also be subject to fluctuation. Therefore, it is possible to write different terms on the electric field in the borders and compare the calculated values with the experimental results.

Electric field distribution in the borders may be uniform, that is:

$$E^{'}(0,t) = E^{'}(L,t) = 0, \qquad (19)$$

If periodicity occurs during fluctuations in the borders, then

$$E^{'}(0,t) = E^{'}(L,t) = 0, \qquad \rho^{'}(0,t) = \rho^{'}(L,t) = 0, \qquad (20)$$

If the concentrations of charge carriers in the borders are given, based on the Puasson equation we can write

$$\frac{\partial E'}{\partial x}\Big|_{x=0,x=L} = 0 \qquad (21)$$

(19-20-21) expressions

(22)

Special cases of the condition (22), (19-20-21) and (22) conditions have to be studied theoretically, but separately. We will calculate the impedance under the periodicity condition, i.e. [2]

$$E'(x,\omega) = A_0 J' + \sum_q A_q e^{ikx} \qquad (23)$$

here, **compilation of the equation when** $q - E'(x,\omega)$ is fulfilled, k- the vector of the wave spreading in the sample under instability condition. In order to calculate the impedance of the sample, we write (11) as following:

$$\left[\frac{d^2}{dx^2} + \alpha_1 \frac{d}{dx} + \alpha_2\right] E_x' = \beta J_x', \qquad (24)$$

We need to find a complex wave vector k_x from solution of (24) equation. Since (24) equation is quadratic according to k_x, complete solution of (24) is as following:

$$E'(x,t) = c_1 e^{ik_1 x} + c_2 e^{ik_2 x} \frac{\beta}{\alpha_2} J_x, \qquad (25)$$

If integrate $\delta v = \int_0^L E'(x,t)\,dx$ [7] taking into account (23) periodicity condition and the fact that $\delta V = Z(\omega) J'$ we obtain

$$Z(\omega) = \frac{\delta V}{J'}\frac{\beta}{\alpha_2}, \qquad (26)$$

$$\frac{c_1}{ik_1}\int_0^{L_x} e^{ik_1 x} d(ik_1 x) = \frac{c_1}{ik_1}\left(e^{ik_1 L_x} - 1\right) = \frac{c_1}{ik_1}(\cos k_1 L_x + \sin k_1 L_x - 1) = 0$$

then (26) expression will be as:

$$Z = Z_0 \frac{\gamma}{\frac{\mu_{10}}{\mathbf{k}}(1+\varphi_1)\gamma_1 + \gamma\left(\varphi - \frac{\Omega}{\sigma_0}\right)}; \quad Z_0 = \frac{L_x}{\sigma_0},$$

(27)

If the real and imaginary parts of the equation (27) are segregated

$$\left.\begin{aligned} Re\frac{Z(\omega)}{Z_0} &= \frac{\gamma_0\theta_1 - \varepsilon U_{10}k_y\theta_2}{\theta_1^2+\theta_2^2} \\ Jm\frac{Z(\omega)}{Z_0} &= -+\frac{\gamma_0\theta_2 + \varepsilon U_{10}k_y\theta_1}{\theta_1^2+\theta_2^2} \end{aligned}\right\} \quad (28)$$

here,

$$\theta_1 = \frac{\mu_{10}}{\mu_0}(1+\varphi_1)\Omega_1 + \gamma_0(\varphi+1) - \frac{\varepsilon^2\omega U_{10}k_y}{4\pi\sigma_0}; \quad \Omega_1 = \varepsilon D_1 k_y^2 - 4\pi\sigma_{10}$$

$$\theta_2 = \varepsilon k_y U_{10}(\varphi_1 - \varphi) - \frac{\omega\gamma_0\varepsilon}{4\pi\sigma_0}; \quad \gamma_0 = \varepsilon D k_y^2 - 4\pi\sigma_0$$

It is seen from (28) that the determination of the signs of real and imaginary parts of the impedance is impossible. Therfore, $Re\frac{Z(\omega)}{Z_0}$ və $Jm\frac{Z(\omega)}{Z_0}$ signs and the values of both electric field (E_0) and magnetic field (H) observed during experiments will be taken into account. It is seen from expression (28) that the L_y measure is of great importance. If write $k_y = \frac{2\pi}{L_y}$; $L_y^2 = \frac{\pi\varepsilon T_{eff}}{e^2 n_0}$ in (28) equation [8],

$$\left.\begin{aligned} Re\frac{Z(\omega)}{Z_0} &= \frac{(\varphi-\varphi_1)}{\left(\frac{\varepsilon\omega}{4\pi\sigma_0}\right)^2 + (\varphi_1-\varphi)^2}; \\ Jm\frac{Z(\omega)}{Z_0} &= \frac{\left(\frac{\omega\varepsilon}{4\pi\sigma_0}\right)\varepsilon}{\left(\frac{\varepsilon\omega}{4\pi\sigma_0}\right)^2 + (\varphi_1-\varphi)^2} \end{aligned}\right\}, \quad (29)$$

It is known from (29), that $Jm\frac{Z(\omega)}{Z_0}$ <0. It means, that in the sample, the capacity nature creates $R_{capacity} = -\frac{1}{\omega C}$ (C- electrical capacity) tension. Minus sign of equation $R_e\frac{Z(\omega)}{Z_0}$ (i.e energy radiation of crystal) is dependent on the signs of φ and φ_1 expressions. If μ and μ_1 decrease in accordance with the increase of the electric field mobility, then will be $|\varphi| > |\varphi_1|$. If $\varphi > 0, \varphi_1 > 0$ then $\varphi_1 > \varphi$, $\varphi < 0$, $\varphi_1 > 0$ and $\varphi > \varphi_1$, $\varphi = \varphi_1$ when the impedance passes through zero.

Thus, at minus sign of $R_e\frac{Z(\omega)}{Z_0}$ expression from $-R_e Z(\omega)\frac{R}{Z_0}$ =0 [8] equation we calculate the frequency of radiation energy.

$$\omega^2 = \left(\frac{4\pi\sigma_0}{\varepsilon}\right)^2 (\varphi - \varphi_1(1))\,(Z_1 0/R - \varphi + \varphi_1 1) \quad (30)$$

It is seen from (30) expression, that we can obtain radiations with different frequency through changing the resistance R connected to the circuit (within ω^2>0 condition). E' and n' values, which are changing inside the sample are fluctuated depending on time as shown in Figure below.

Figure 2.

Amplitude A [9], is increasing under $A \sim e^{\gamma t}$ γ>0 condition, but this increase stabilizes when the reduction of charge carriers' mobility depending on the electrical field is stopped. As the energy obtained from the external electric field insrease, the electrons are less involved in conductivity. This mechanism starts with the value of frequency during the impedance instability determined by expression (30), on the condition that U_d>S.

II. Conclusion

Based on the results, it was established that instable electromagnetic waves are created in n-type conductive media due to perpendicular orientation of the external electric and magnetic fields. The frequencies of these waves were calculated under μH>c value of the magnetic field. It was revealed that the radiation frequencies change depending on the directions of the waves spreaded inside the sample. It is possible to achieve the necessary frequency in such samples. If the waves inside the sample spread over the width, i.e. the theoretical researches are complicated when $\left[\vec{k} \perp \vec{H'}\right]$ differs from zero, but this is important.

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