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# Effect of Different Plasma Parameters on Plasma Energy by means of Velocity Shear Instability

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**ABSTRACT**

*Application of plasma energy is in spot light of many industrial applications such as plasma welding, plasma cutting, ignition delay, nontraditional machining process etc. This paper present effect of different parameters: magnetic field, homogenous DC electric field, density gradient on plasma energy. Numerical investigation with the help of mathematical formulation and computer technique on plasma energy is systemically investigated by using blend of plasma parameters. It was found that the effect of electric field, magnetic field, temperature anisotropy, shear scale length, density gradient etc influences significantly the plasma energy. With the help of above study one can use plasma energy for dissimilar industrial applications by selecting appropriate plasma parameters.*

**Key words:** Plasma, plasma energy, Effecting parameters, Velocity Shear Instability, computational method.

## INTRODUCTION

The plasma generation by a coaxial plasma puff-gun using a double Langmuir probe and spectrometer has been studied by has been discussed regarding details plasma parameters like charge voltage of the energy-storage capacitors of the gun ranges from 1.5 to 4.0 KV**,** the plasma electron temperature from 10 to 20 eV, the kinetic energy from 45 to 310 eV and the density from $5\times10^{13}$ to $7\times10^{14}$ per $cm^{3.}$ An approximate solution has been obtained under the assumption of the snowplow model, and the comparison of the predictions of the theory with our experimental results indicates general qualitative agreement [1].

Sigmund's model described the low and high energy regions, however, it breaks down at low energy suggesting that, there is no single equation to describe the whole energy region. Sigmund's maximum values of Ei,max, Sy,max are (288.03, 31.59), (154.46, 21.51), (59.83, 13.04), (21.09, 7.24), (40.88, 7.73) for Xe+/Ag, Kr+/Ag, Ar+/Ag, Ne+/Ag and Ar+/Cu, respectively. Schwarz and Helms applied their theoretical equation to match the available experimental data for the noble gas ions bombarding Ag and Cu. Their theoretical data are worthy accuracy to the Sigmund theory but, the (Ei,max, Sy,max) values are not included in their curves. Biersack and Eckstein's maximum values of (Ei,max, Sy,max) are (100, 6.98), (30, 3.352), (3, 0.184) for Xe+/Ni, Ar+/Ni and He+/Ni, respectively, whereas Yamamura's maximum values of Ei,max, Sy,max are (400, 33.5), (300, 11.55), (50, 4.75), (1.5, 0.163) for Xe+/Ag , Xe+/Ni, Ar+/Ni and He+/Ni, respectively. According to the present model, the maximum values of (Ei,max, Sy,max) are (392.5, 52.5), (120.4, 8.74), (87.3, 6.95), (3, 0.172) for Xe+/Ag, Xe+/Ni, Ar+/Ni, He+/Ni combinations, respectively [2].

If the potential difference $U$ has a value corresponding to voltage applied usually within the electrical discharge machining (for example, $U$=70 V), one can notice that the depth of electron's penetration is insignificantly small ($\delta=1.381\times10^{-9}$ cm). But if the potential difference is $U$=5000÷200000 V, then the depth of electron's penetration in the surface layer of the metallic workpiece is much more ($\delta=7.05\times10^{-8}\div1.128\times10^{-2}$ cm). After the penetration of the electrons through the layer of depth δ, the electron's energy is dissipated and as a consequence the temperature of workpiece material increases up to the vaporizing and melting temperatures, so that the micro-explosions are produced and the small quantities of the workpiece material are ejected and the small craters are generated [3].

**Objective:** The energy of plasma species is important factor. The magnitude of plasma energy decides the application such as, micromachining, plasma etching, welding etc. The motive of this article is to compute plasma energy and effect of argon plasma parameters.

**Model & Methodology:** In this article plasma is generated by using argon gas and applying the D.C electric field, magnetic field. The direction of electric/magnetic field and generation of plasma with velocity shears instability is described in detail by Tyagi et.al [4, 5]. The plasma of argon gas is ionized, therefore velocity and trajectory is influenced by electric/magnetic field. The velocity of ions is calculated with the help of real frequency of the waves. Than energy of the argon plasma is calculated by using equations 1, 2, 3. Generation of velocity shear instability is described in detail in Tyagi et al [5].

The real frequency of waves is found out by relation-

$$\text{Real frequency of waves} = \frac{b_1}{2a_1} \qquad (1)$$

$$v_i = \text{Group Velocity of ions/waves} = \frac{b_1}{2a_1}\times\frac{\Omega_i}{K_{\parallel}} \qquad (2)$$

$$a_1 = a_2\left(\frac{\Omega_i}{k_{\parallel}\alpha_{\parallel}}\right)^2,\ b_1 = \frac{\Omega_i}{k_{\parallel}\alpha_{\parallel}}b_2 - \frac{2k_{\perp}\Delta'}{k_{\parallel}^2\alpha_{\parallel i}^2}a_2\Omega_i$$

$$b_2 = \frac{\Gamma_n(\mu_i)k_{\perp}}{2k_{\parallel}}\varepsilon_n\rho_i\frac{\alpha_{\perp i}}{\alpha_{\parallel i}} - \frac{\Gamma_n(\mu_i)k_{\perp}}{2k_{\parallel}} - \frac{\Gamma_n(\mu_i)k_{\perp}n\Omega_i}{2k_{\parallel}^2\alpha_{\parallel i}}$$

$$a_2 = \frac{\eta_e}{\eta_i}\frac{T_{\perp i}}{T_{\parallel i}} + \frac{T_{\perp i}}{T_{\parallel i}} - \Gamma_n(\mu_i)\frac{T_{\perp i}}{T_{\parallel i}}$$

$$\eta_i = 1 - \frac{\overline{E_i'(x)}}{4\Omega_i^2},\ \eta_e = 1 - \frac{\overline{E'_e(x)}}{4\Omega_e^2},\ \overline{\omega}' = \overline{\omega} - n\Omega_i$$

$$E(x) = E_0\left(1 - \frac{x^2}{a^2}\right),\ \overline{E}(x) = \frac{e_s E(x)}{m_s},\ E(x) = E_0\left(1 - \frac{x^2}{a^2}\right)$$

$$\Omega_s = \frac{e_s B_0}{m_s},\ \alpha_{\perp s} = \left(\frac{2k_B T_{\perp s}}{m_s}\right)^{1/2},\quad \alpha_{\parallel s} = \left(\frac{2k_B T_{\parallel s}}{m_s}\right)^{1/2}$$

$$\xi = \frac{\overline{\omega} - (n+p)\Omega_s - k_{\perp}\Delta'}{k_{\parallel}\alpha_{\parallel s}},\ \Delta' = \frac{\partial\Delta}{\partial t},\ \Delta = \frac{\overline{E}(x)t}{\Omega_s}\left[1 + \frac{E''(x)}{E(x)}.\frac{1}{4}\left(\frac{v_{\perp}}{\Omega_s}\right)^2 \ldots\ldots\ldots\ldots\right]$$

$$A_s = \frac{1}{\Omega_s}\frac{\delta v_{oz}(x)}{\delta x},\ \varepsilon_n = \frac{\delta \ln n_0(x)}{\delta x},\ A_T = \frac{\alpha_{\perp s}^2}{\alpha_{\parallel s}^2} - 1,\ \overline{\omega} = \omega - k_{\parallel}v_{oz}(x)$$

$$\Gamma_n(\mu_s) = \exp(-\mu_s) I_n(\mu_s), \ \mu_s = \frac{k_\perp^2 \rho_i^2}{2}$$

$$\left(\frac{E_{th}}{E_i}\right)^{\frac{1}{\Omega}} = \frac{2}{3}\left(\frac{1.2^2 - (0.8\beta)^2 E_i^{1.3}}{0.8 - (0.75\beta^2)E_i^{0.8} - \left(\frac{1}{\Omega}\right)(1.2 + (0.8\beta)E_i^{0.67})}\right) \quad (3)$$

$$E_i = \frac{m_i v_i^2}{2} = eV \quad (4)$$

## RESULTS AND DISCUSSION

Numerical investigation with aid of the mathematical formulation and computer technique by using the experimental data has been performed on the basis of the equations equations (1), (2). The generated plasma contains the argon gas ions. The plasma parameters are selected by [6].

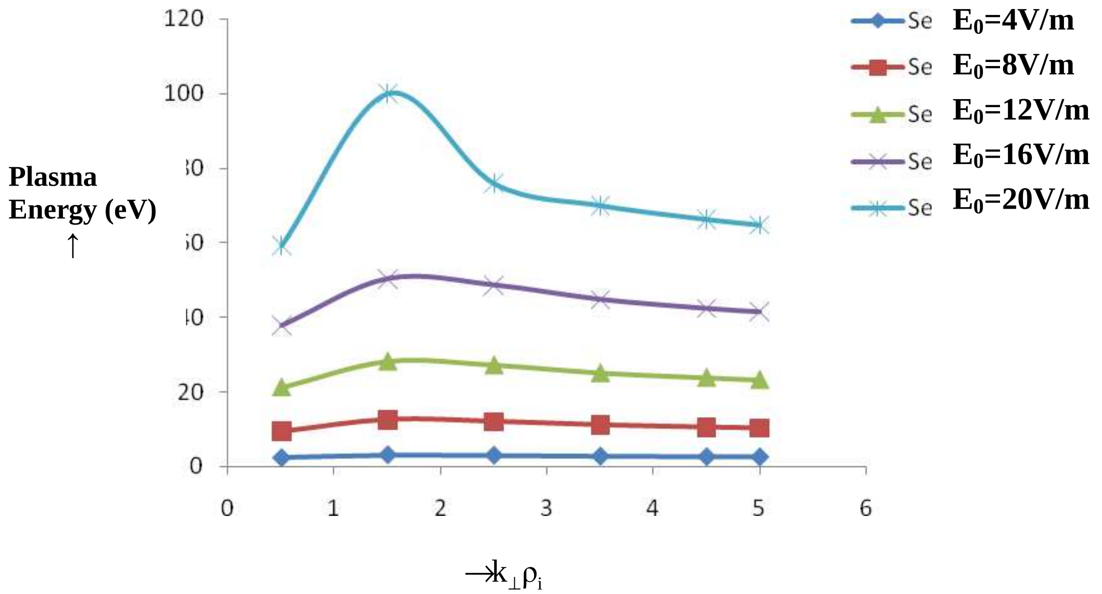


**Fig.1.Variation of energy of plasma (eV) verses $k_\perp \rho_i$ for different values of DC electric field ($E_0$) x and other parameters are $A_i$ =0.5, $T_e/T_i$ =2, $\theta_1 = 88.5^0$, $A_T$ =1.5, $\varepsilon_n\rho_i$=0.0, $B_0$=0.16T**

Figure 1 shows the variation of plasma energy (eV) versus $k_\perp \rho_i$ for different values of homogeneous D.C electric field with other fixed parameters listed in figure caption. The plasma energy increases with increasing the value of homogeneous D.C electric field. The maximum value of plasma energy is 100 eV when the value of homogeneous D.C electric field is 20 V and the minimum value is 2.37 eV for 4V with other fixed parameters listed in the figure caption.

Figure 2 shows the variation of plasma energy (eV) versus $k_\perp \rho_i$ for different values of the magnetic field (T) with other fixed parameters listed in figure caption, the value of plasma energy increases with decreasing the value of magnetic field. The maximum value of plasma energy is 28.4 eV when the value of magnetic field is 0.16T and the minimum value is 13.5 eV for 0.19 T with other fixed parameters listed in the figure caption.

Figure 3 shows the variation of plasma energy (eV) versus $k_{\perp}\rho_i$ for different values of the density gradient, the value of surface roughness decreases with increasing of the density gradient. The maximum value of plasma energy is 23 eV when the value of density gradient is 0.2 and the minimum value is 13.9 eV for 0.6 density gradient with other fixed parameters listed in the figure caption.

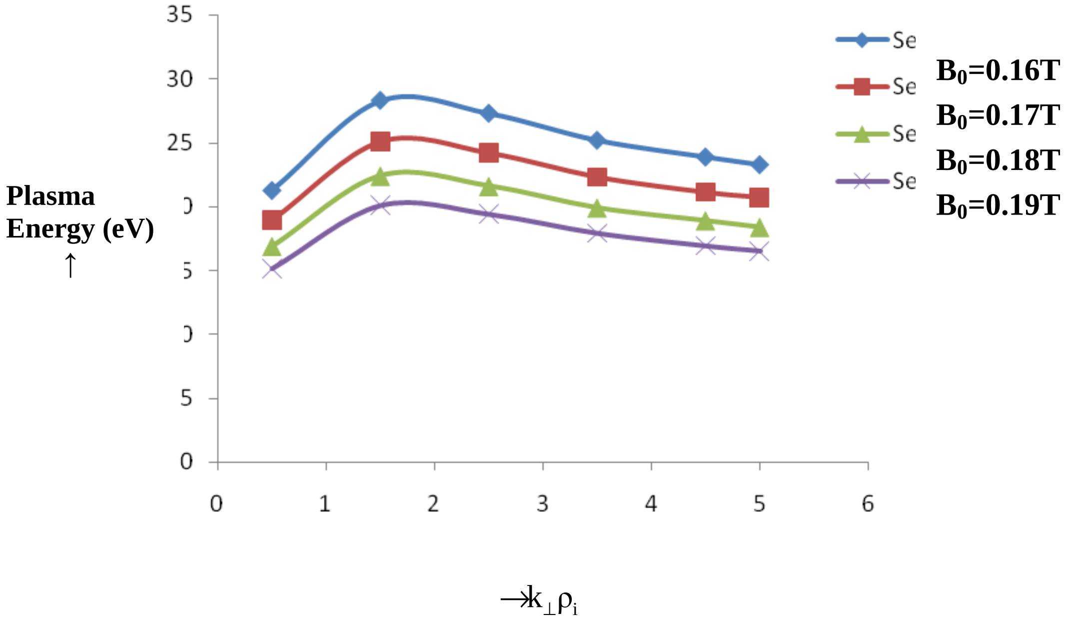


**Fig.2.Variation of energy of plasma (eV) verses $k_{\perp}\rho_i$ for different values of $B_0$ x and other parameters are $A_i$ =0.5, $T_e/T_i$ =2, $E_0$=12 V/m, $\theta_1 = 88.5^0$ , $A_T$ =1.5, $\varepsilon_n\rho_i$=0.0**

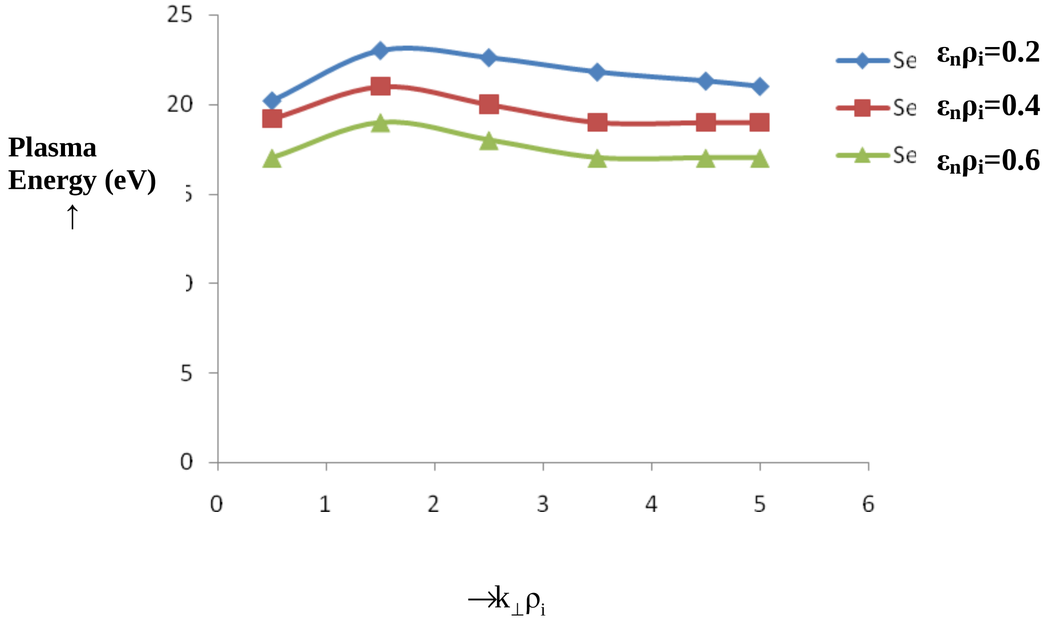


**Fig.3.Variation of energy of plasma (eV) versus $k_{\perp}\rho_i$ for different values of density gradient ($\varepsilon_n$ $\rho_i$) x/a and other parameters are $A_i$ =0.5, $T_e/T_i$ =2, $E_0$=12 V/m, $\theta_1 = 88.5^0$ , $A_T$ =1.5, $\varepsilon_n\rho_i$=0.2, $B_0$=0.16T.**

## CONCLUSION

This paper describes the mathematical model for plasma energy. In the framework given model for plasma, the ion velocity is obtained, and hence the ion kinetic energy is obtained. The dependences of plasma energy versus $k_{\perp}\rho_i$ for the different parameters of the plasma model (magnitudes of electric and magnetic fields, density gradient etc.) is calculated and graphically represented. The analysis executed here shows the flexibility of using the magnetic field, electric field and density gradient and other parameters for control of the plasma energy. The significance of the paper is that its result will be useful to find out plasma energy for specific application for different purpose.

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