Mechanism of Striation in Plasma Display Panel Cell

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Abstract

The mechanism of striation in the coplanar- and matrix-type plasma display panel (PDP) cells has been studied using the particle-in-cell Monte-Carlo Collision (PIC-MCC) model. The striation formation is related to the ionization energy of neutral atoms and the well-like deformation of space potential by space charge distribution. Negative wall charge accumulation by electrons on the MgO surface of the anode region is also one of the key factors for the formation of striation. The clearness of the striation phenomenon in PIC-MCC code in comparison with fluid code can be explained by using non-local electron kinetic effect.

1. Introduction

Striation phenomenon in plasma discharge of a PDP cell has been well known by experimentally observation since the late 1990s [1, 2, 3, 4, 5]. This phenomenon has been observed in matrix-type as well as coplanar-type PDP cells and macro-size as well as micro-size PDP cells [4, 5]. Several characteristics of striation have been reported from these experiments. Striation is only observed in the anode region with the electrode covered by dielectric layer. Unlike the striation of other devices, PDP striation is stationary. The density humps of striation are isolated from each other. Also striations are dependent on pressure and gas composition. In case of positive column discharge, non-local electron kinetics is very important factor in forming striation [6]. Unfortunately, until now, there have been no satisfactory theoretical explanations for the mechanism of striation phenomenon in a PDP cell.

Numerical simulations are very useful tools for investigating the physics and observing diagnostics of plasma in a PDP cell, which has very small plasma discharge space. Using XOOPIC (2-dimensional self-consistent PIC-MCC code [7]), we already showed the striation phenomenon in coplanar-type PDP cell and tried to explain the mechanism for it [8]. We also observed the striation in matrix-type PDP cell [9]. However, it was not enough to explain the origin of striation phenomenon in a PDP cell. In this paper, we have tried to analyze PDP striation again using XOOPIC and explained successfully the self-consistent mechanism of it.

2. Simulation conditions

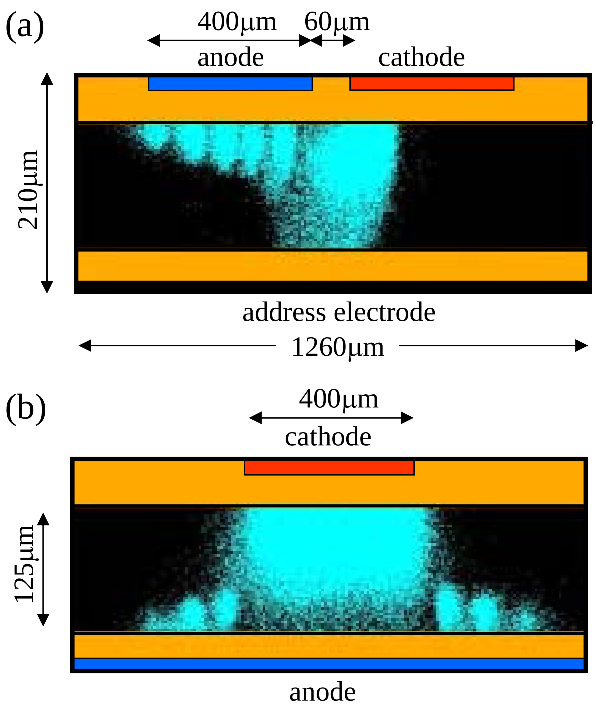

Figure 1 Striation phenomena in (a) coplanar-type and (b) matrix-type PDP cells

For 2-D kinetic simulation, we used typical coplanar-type and matrix-type PDP geometries with *x-y* plane as shown in Fig. 1(a) and (b). The thickness and relative dielectric constant of a dielectric layer

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were respectively 45µm, 12 and 40µm, 10 for each upper and lower dielectric. In this simulation, the thickness of MgO was ignored, and the characteristics of MgO were included in dielectric layers. The gas pressure was 500 Torr and the gas compositions were Ne 100% and Xe 10%-Ne. The secondary electron emission coefficients for Ne and Xe ions on upper dielectric layer were assumed to be 0.5 and 0.05, respectively. The applied voltages were 350V and 0V for the anode and the cathode, respectively. For the address electrode, a half of the value of voltage difference between the anode and the cathode was applied. As kinetic simulations need very long-time duration, we simulated it for only one pulse period.

3. Simulation results

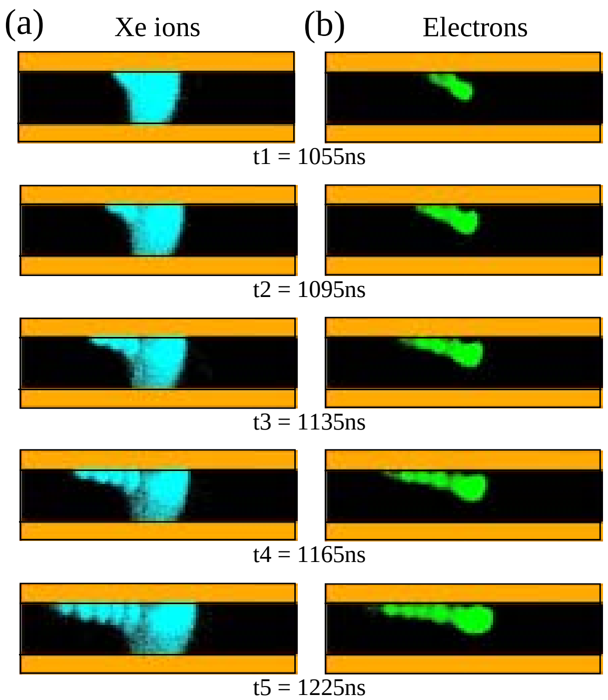

Figure 2 Time evolution and comparison of (a) Xe ion and (b) electron particle distributions in Ne-Xe 10% at 500Torr

Figure 1(a) and (b) show the spatial distributions of Xe ions in a coplanar-type PDP cell and Ne ions in a matrix-type PDP cell in PIC-MCC 2-D simulation. It shows the clear striation phenomena in the anode side. Figure 2 presents time evolution of the spatial distributions of Xe ions and electrons. Initially, a plasma bunch is created at inner edge of the anode region. As time goes on, another separated plasma bunches appear one by one along the dielectric surface from inside to outside of the anode. We also observed that the plasma bunch formed by Xe ions is created earlier than that formed by electrons. If negative wall charges by electrons are accumulated on dielectric surface in the anode region, only one plasma bunch is created at inner edge of the anode region. Discharge then can not be spread to outside of the anode region any more and striation phenomenon is not observed.

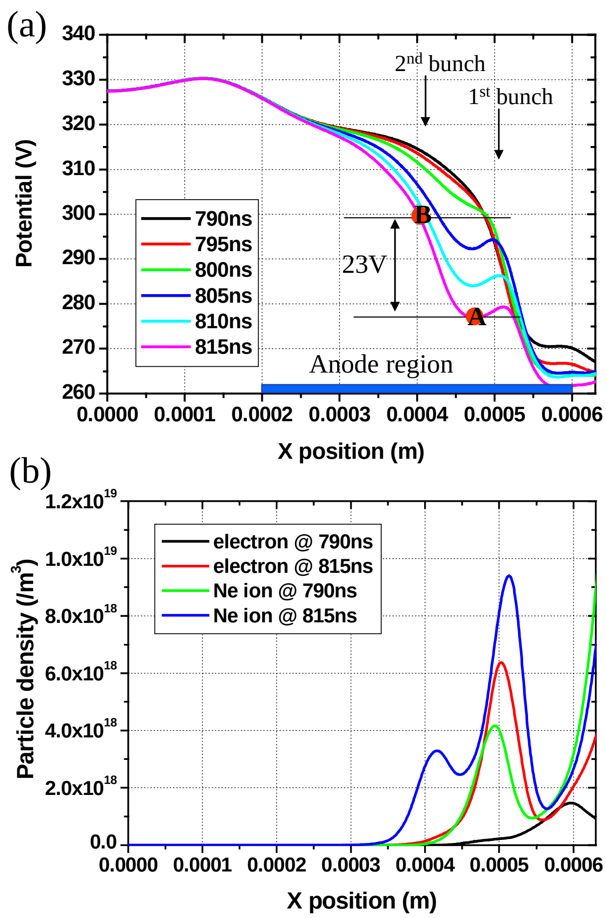

Figure 3 Time evolution of (a) potential and (b) charged particle distributions near the dielectric surface of the anode region in a coplanar-type PDP cell with pure Ne at 500 Torr.

The time evolution of potential distributions near the dielectric surface is shown in Fig. 3(a) in pure Ne gas at 500 Torr during short time period. The times 790ns and 815ns indicated in Fig. 3 correspond to the time when the 1st and the 2nd striation bunches are about to be created, respectively. Point A in Fig. 3(a) is the edge point of the 1st striation bunch. As time goes on, potential distributions of space are changed and point B becomes the central region of next (2nd) bunch. In this figure, potential difference between points A and B is about 23eV, which corresponds to ionization energy of Ne atoms (~22eV). From the comparison of the density distributions between Ne ions and electrons at the same instant of time, we can obtain that when the striation bunch is created, positive ions have much higher density than electrons as shown in Fig. 3(b).

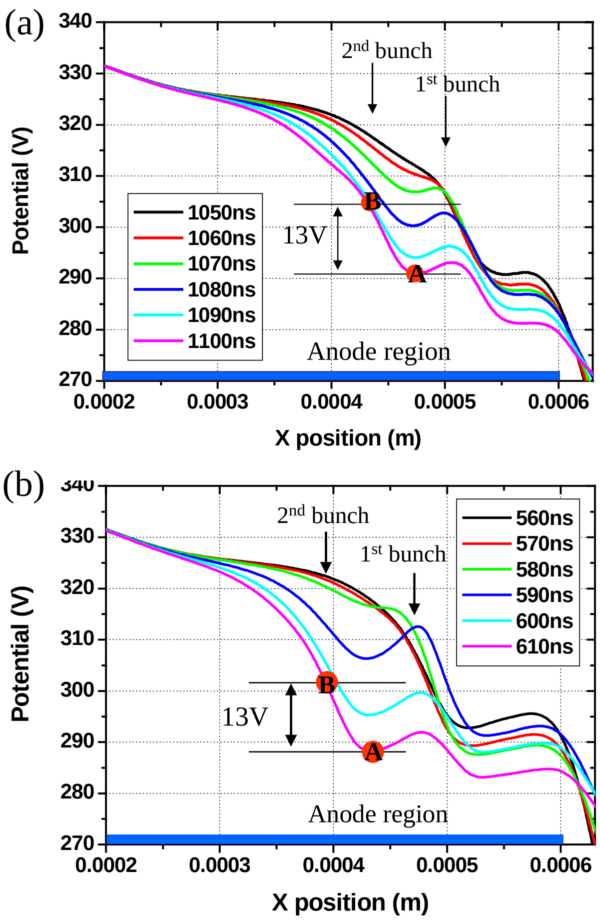

Figure 4 Time evolution of potential distributions near the dielectric surface of the anode region in a coplanar-type PDP cell with Xe 10%-Ne at (a) 500 Torr and (b) 200 Torr

In case of Xe-Ne mixture gas, potential difference between points A and B is different to that of pure Ne case. Figure 4 shows the time evolution of potential distributions with Ne-Xe 10% at different gas pressure (500 and 200 Torr). Both Figs. 4(a) and (b) show that potential difference is about 13eV in Xe-Ne mixture gas cases. This potential difference corresponds to the ionization energy of Xe ions.

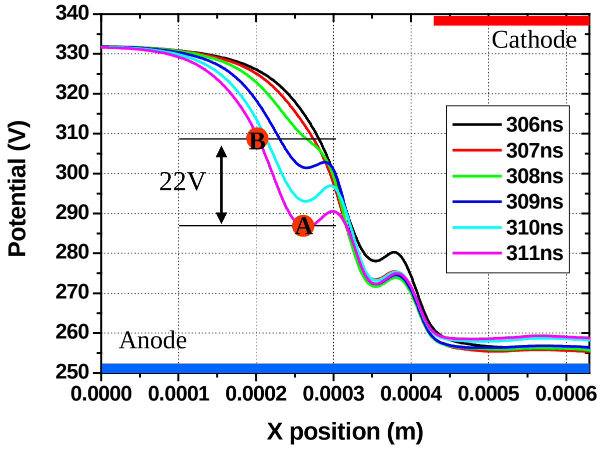

Figure 5 Time evolution of potential distributions near the dielectric surface of the anode region in a matrix-type PDP cell with pure Ne at 500 Torr

As shown in Fig. 1(b), by using 2-D PIC-MCC simulation, we can observe striation at the anode region of a matrix-type PDP cell similar to the experimental measurement. In simulation of matrix-type PDP cell, striation phenomenon can appear when there is an enough difference in electrode length between two sustain electrodes. After the main bunch is created between two sustain electrodes, several small plasma bunches appear near the dielectric surface of the anode region one by one from the location corresponding to the edge of the cathode. If the length of two sustain electrodes are same, only one main bunch between two electrodes is observed. Figure 5 shows the time evolution of potential distributions near the dielectric surface of the anode region. As the potential distribution is nearly symmetric along the y-axis at the central position in x-axis, only the potential distributions of left-hand side in a matrix-type PDP cell are shown. In this case, we used pure Ne gas and found that potential difference between points A and B is about 22V as was obtained in a coplanar-type PDP cell with pure Ne gas.

4. Discussion

From these simulation results, we can obtain several important characteristics to explain the striation mechanism in PDP system. In order to make the striations with several isolated plasma bunches, the negative wall charge by electrons on the dielectric surface of the anode region is required. Due to these wall charges, discharge can be spread to the outer side of the anode region. The formation of ion-rich region in the space near the dielectric surface induces the potential deformation like potential well. The bunch separation is related to the ionization energy of dominant positive charged particles. Combining these key factors, we can explain the occurrence of striation in matrix- and coplanar-type PDP cells as follows.

At the initial time of discharge, electrons are accelerated by strong electric field at the inner edge of the anode and make many ions due to the ionization process. Most of the electrons are pulled to the anode surface and accumulated with the reduction of wall potential. Therefore potential on the surface becomes lower than that in the space and electrons which move to the dielectric surface vertically should come back to the plasma bunch. However, some electrons can go to the dielectric surface, which have not been covered by electrons yet. The remaining ions make the ion-rich region in the space and it becomes the potential well, which pull electrons from bulk region. Most low energy electrons are trapped within this potential well. One striation bunch is created. As time goes on, potential well depth becomes shallow due to the increment in number of trapped electrons. Therefore electrons with low energy can escape the potential well (point A in Fig. 3, 4, and 5) and meet the strong electric potential of the anode which is uncovered by negative wall charges. During this movement, electrons get enough energy to ionize neutral atoms and make isolation of ions again at that position (point B in Fig. 3, 4, and 5). This forms another ion-rich region and it becomes a new striation bunch. These procedures are repeated and high density humps are created in the anode region one by one until negative wall charges cover whole dielectric surface of the anode region and screen the electric field from it. In case of matrix-type PDP cell, the same mechanism produces striation phenomenon.

In movement of low energy electrons escaped from potential well, the energy loss by elastic collisions is negligible. This non-local kinetics of electrons plays an important role in forming of the striation and electrons in the inter-striation regions have higher temperature than those in the striation regions. Even though a PDP cell has very high pressure, the electron mean energy is determined by the potential distributions, not by the reduced electric field. This is the reason why fluid simulation based on the local field approximation can not produce clear striation phenomenon as shown in Ref. [8].

5. Summary

The mechanism of striation phenomenon observed in matrix-type as well as coplanar-type PDP cells was successfully explained by using 2-D PIC-MCC simulation. Several isolated bunches with high plasma density in the anode region are generated by combined effect of accumulated negative wall charge on the dielectric surface and the deformation of space potential distributions by non-local kinetics of electrons. This mechanism can be applicable to other dielectric barrier discharges.

6. Acknowledgements

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