MgO Sputtering in the AC-PDPs with Monte Carlo Methods

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Abstract

Sputtering yield of MgO film in the AC-PDPs has been calculated by Monte Carlo simulation of ion scattering. In the ion energy range less than 50 eV, the sputtering yield is 4×10^{-4} for Xe ions and it is between 0.1 and 0.01 for He, Ne, and Ar ions. The erosion rate is estimated about 25 Å per hour for Xe ions in an actual PDP plasma for sustain and full white mode.

Introduction

In the AC-PDPs, the MgO film provides protection from the discharge, lowers the discharge voltage and prolongs the device lifetime. Therefore long term stability of the AC-PDPs critically depends on the characteristics of the MgO films. However, the films are inevitably bombarded by ions, and their modification is the determining factor for their operational longevity. Previously, the erosion of the MgO films, the change in surface stoichiometry [1] has been suggested as the factors that influence the performance of PDPs. Even a several researchers execute the experiments in order to get the information of the erosion rate which is willingly expected to be about 0.1 Å per hour, so far exact data have not been reported yet.

In a high pressure of a few 100 Torr gas for the AC-PDP plasma, the incident ion energy into the MgO film is estimated as a few tens of electron volt[2] with the operating driving voltage above 200 eV. Unfortunately, the interactions of low energy(1-100 eV) ions with solid material surfaces have been little studied. This has been due partly to the difficulties of producing and controlling large fluxes of ions at selectable low energy. The usual techniques for creating high current beams at higher energies (typically keV) are much less useful in this low energy range.

In this study, the ion scattering in the MgO layer is calculated with Monte Carlo method. The sputtering yield and the erosion rate in an actual AC-PDP are calculated for understanding all impact-related phenomena involving the PDP plasma ions.

Monte Carlo Calculation

The present study specifically addresses the phenomena occurring under what is called low-energy ion bombardment, i.e. where nuclear stopping dominates more or less over electronic stopping. There are so many Monte Carlo (MC) simulation programs of ion scattering in solid. In this study, we will describe the MC program whose essential features are already introduced by many authors [3-6].

The main procedures in Monte Carlo calculations are how to decide the step length, between collisions, the new direction of motion after each collision, and how to estimate the nuclear energy loss at the collision center and the electronic energy loss dissipated along the step length. The mean free path between collisions is given with the number of target atoms per unit volume. The differential nuclear scattering cross-section is based on the LSS theory [7] and the universal scattering function has been evaluated numerically by Lindhard et al. [8] and can be also be represented by an approximation formula fitted by Kalbitzer and Oetzmann [9]. For the electronic energy loss in the low energy regime, we use the continuous slowing down approximation of the LSS theory [8].

The surface binding energy has a significant influence upon the total sputtering yields of the low energy sputtered atoms. Basically, the incident ions and the recoil atoms are followed throughout their slowing-down process until their energy falls below a predetermined energy; usually 5 eV is used for the incident ion, and the surface binding energy is used for the knock-on atoms. As an input for the surface binding energy, we have generally used the heat of sublimation which amounts to about 5 eV for fcc structures [10].

Results and Discussion

Ion trajectories in the MgO films are shown in Fig. 1 with the incident energy 20, 50, 100, 200 (eV) for He(a), Ne(b), Ar(c), Xe(d) ions, respectively. In each figures 50 incident gas ions and the recoil target atoms of Mg and O are included in the trajectories. As the incident energy is increased, the scattering spreads more wide, while the scattering area is smaller for heavier incident particle. For He ions, the scattering area is about 10 Å for 20 eV,

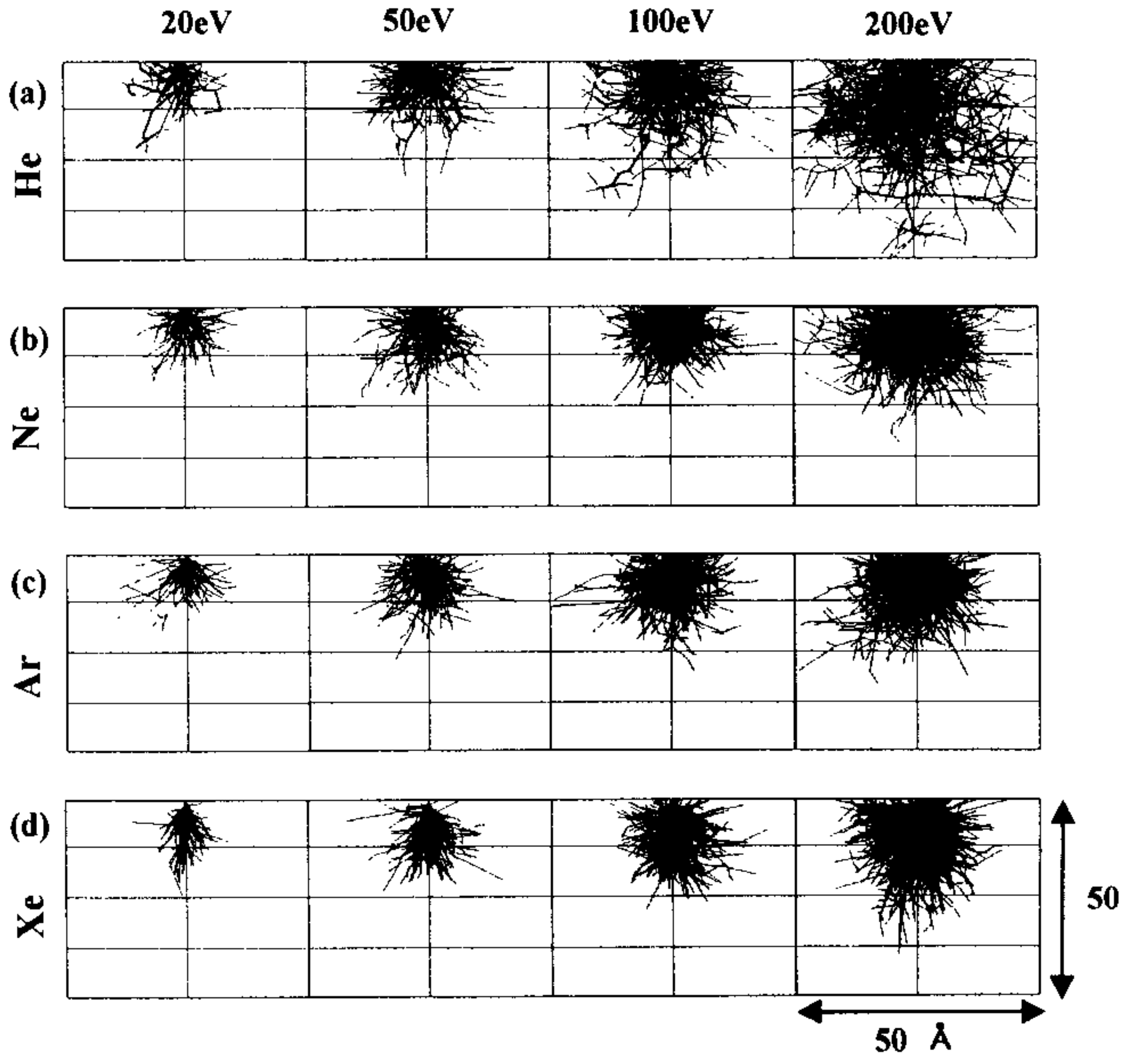

Fig. 1. Particle trajectories in the MgO films with the incident ion as He(a), Ne(b), Ar(c), Xe(d) and the incident energy 20, 50, 100, 200(eV).

25Å for 100 eV, and it spreads within 50Å for 200 eV. For the heavier particles of Xe ions, they scatter more deeply than laterally since the heavy particle goes generally forward rather than backward. The penetration depth is about 10Å for 20 eV and 25Å for 200 eV. In the figure we verify the ion scattering range is about a few 10Å on the MgO films having about 5000Å depth layer

In Fig. 2 the sputtering yield Y is represented for He, Ne, Ar, Xe ions. Total sputtering yield is in (a) and each MgO atoms are in (b) and (c), respectively. The yields of Mg (b) and O (c) are nearly same value so that the total yield (a) is two times the yield of each one. Contrary to high enough energy range of keV, the yield for heavier ion is smaller than that for lighter ions. Specially, in the ion energy range of a few 10 eV for the gas of high pressure in an actual AC-PDP, the sputtering yield is slightly decreased as the incident energy increases. These trends are unusual in the general results for a high energy ion sputtering [10], while we have report these phenomena recently to the other paper [11] where the surface binding energy effect has been verified to be important roles in a low energy ion scattering. However, the sputtering yield for Xe ions is much less than the other ions. In the AC-PDP ion energy range of a few 10 eV, the sputtering yield is about 4 x 10^{-4} for Xe ions and the yield for the other gas ions are about 100 times larger than that of Xe.

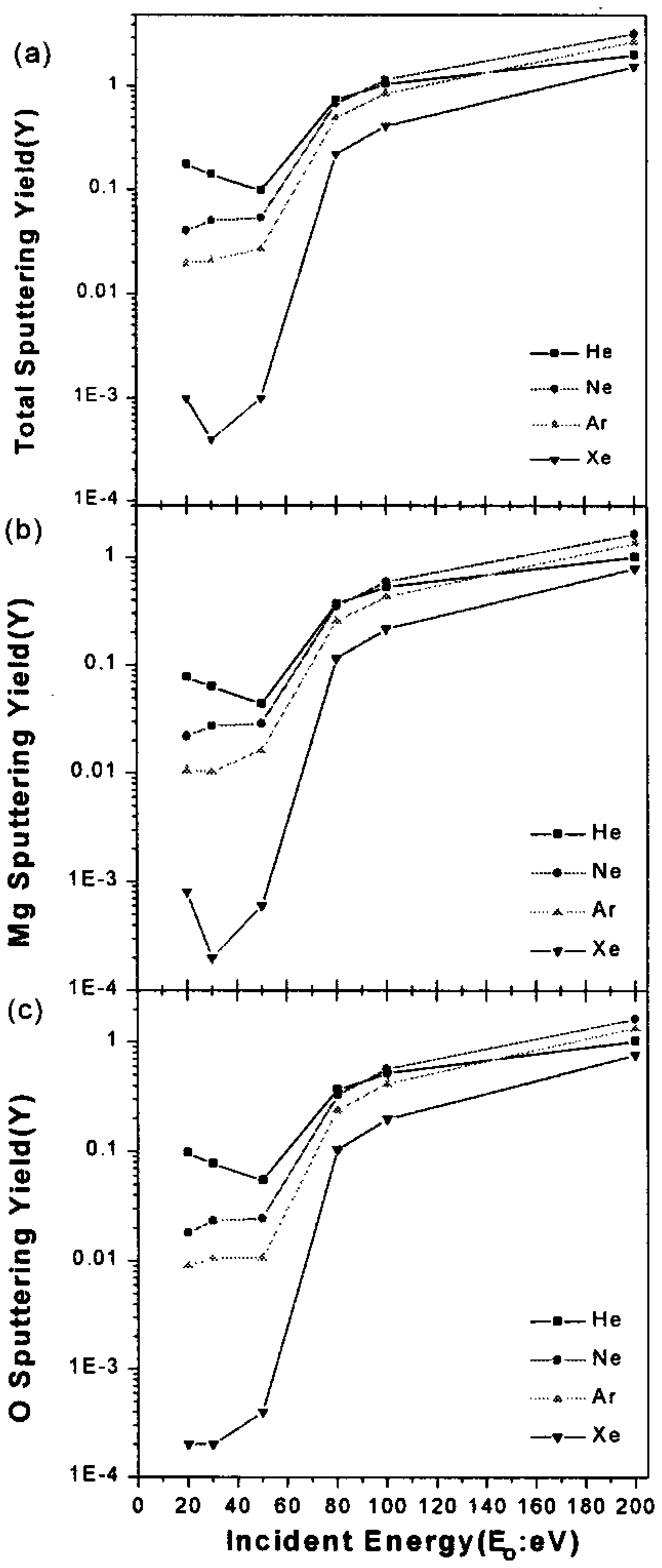

Fig. 2. Sputtering yield of (a) Total(Mg+O), (b) Mg, and (c) O versus incident energy E_0(eV) for He, Ne, Ar, Xe ions.

In order to calculating the erosion rate of MgO layer with the sputtering yield, we consider the parameters in an actual AC-PDP such as the peak current about 50 μA, the effective current driven time 0.1 μsec, the pulse duration time 6 μsec, and the area of the electrode surface 200 x 300 (μm x μm) covered with MgO whose density is 3.56 g/cm^3. Considering only the sustain and a full white with these parameters and the total number of ions arriving at the MgO surface per second is 4.16 x 10^{13}, we obtain the erosion rate h=58500 Y (A/hr). With Y=4 x 10^{-4} for a low energy Xe ion, we have the erosion rate about 25 Å/hour.

Conclusion

The sputtering yield and the erosion rate of the MgO films in the AC-PDPs have been calculated analytically. In an actual PDP using the Xe mixture gases of high pressure above 100 Torr, the sputtering yield is below 10^{-3} for Xe ions and between 0.1 and 0.01 for the gas ions of He, Ne, and Ar in the energy range less than 50 eV in the AC-PDPs. With the sputtering yield 4 x 10^{-4} for Xe ion dominant environment, the erosion rate has been calculated about 25 Å/hour. While the sputtering yields of He, Ne, and Ar ions are larger about 100 times than Xe ions.

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