Anode Layer Linear Ion Source for Roll-to-Roll Process from 300 mm to 1550 mm

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1. Introduction

Roll-to-roll (RTR) process requires a linear surface treatment source in various processes such as pre-treatment, etching, and deposition. For high speed and large width processes the linear source should have superior characteristics that can be applied to 100~300 m/mim process and large width treatment up to 2 m. Several linear surface treatment sources have been proposed to the RTR process. For example, a dual magnetron sputtering (DMS) plasma enhanced chemical vapor deposition (PECVD) and a linear deposition source using a magnetic layer linear ion source have been introduced recently [1,2]. These sources showed outstanding performances for deposition methods. In pre-treatment and etching parts a RF plasma source, a glow discharge and a linear ion source have been used widely. Especially the linear ion source has been applied to the surface pretreatments from polymer to steel. There are two types of the linear ion source, a magnetic layer and an anode layer ion source. The magnetic layer source is convenient to generate plasma with low energy electrons for PECVD applications as mention above. In contrast, the anode layer linear ion source (ALIS) can emit high energy ion beams uniformly up to 2 m. The robust structure and reliable ion beam extraction are other attractive characteristics of the ALIS in RTR process.

Actually there are many application parts of the ALIS in RTR processes. Nevertheless several problems are issued in the practical field of ALIS applications. The problems are a substrate contamination by cathode erosion, an ion beam focusing, the enhancement of ion beam current density for the high speed RTR process. To enhance the ALIS performance and solve the problem, numerous methods have been adapted to the ALIS. For example, General Plasma Inc. (GPi) has developed a point pole anode layer source (PPALS), which uses a point pole cathode to focus ion beams and to reduce the contamination [2]. However, unfortunately, there is no clear description about an ion focusing and an electron trapping in the ALIS. Though we can use the ALIS well in many applications, clear descriptions about the ALIS discharge are required to invent extraordinary ALIS for a high speed RTR process.

Before 3 years ago, Korea institute of materials science (KIMS) has researched about the ALIS. Also we designed KIMS identified ALIS to realize the high speed RTR process, which requires the dynamic etching rate of 3000 nm-m/min at steel substrates. To increase the etching rate with stable ion beam extractions, we developed the ALIS by using a computer simulation and an experimental research. Particle-in-cell (PIC) method was used to calculate the plasma behaviors in the ALIS [3,4]. And an ion beam current was measured by using multi array Faraday cups. In this work, we summarized out recent researches and the direction of further works.

2. Anode Layer Linear Ion Source

The concept of ALIS has been invented in 1950's for a satellite thruster, called as a closed drift ion source. In ALIS, a magnetron is used to make a closed drift of electron by using ExB fields between an anode and a cathode. Thus, the discharge mechanism is similar to a conventional magnetron sputtering discharge except the mechanism of ion acceleration. The ALIS uses special acceleration region called as an "anode layer". There is an abnormally strong electric field region called as anode layer near an anode surface due to high electron temperature [5]. Most ions are accelerated in the anode layer. Thus, several factors to determine the generation of anode layer such as cathode geometry, magnetic field structure, distance between anode and cathode are should be considered when we design the ALIS.

We considered an anode layer and an ion extraction by using a PIC method [3]. The PIC method is useful to observe an ion trajectory, beam diversion, and ion energy distribution theoretically as shown in Fig 1. Especially the formation of anode layer can be observed in this simulation work [4]. The abnormally strong electric field is observed at anode surface as shown in Fig. 2. From this simulation work, we designed KIMS identified ALIS, which cathode structure and electrode gap are optimized for high flux ion beam extraction at high discharge voltage up to 5 kV. Note that the resistance for a high voltage breakdown in ALIS is important to generate stable high energy ion beams up to 1.5 keV.

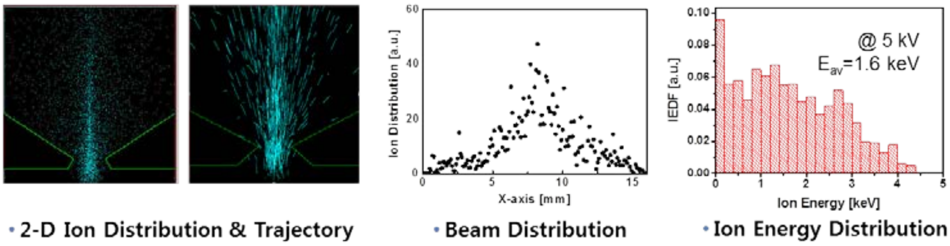

Fig. 1 PIC simulation results for ALIS analysis

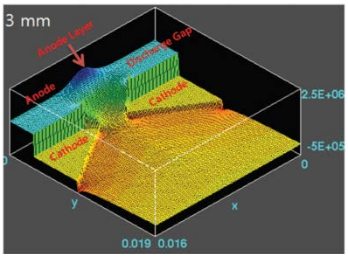

Fig. 2 Y-axis electric field intensity in ALIS. (pressure: Ar 1 mTorr, discharge voltage 3 kV)

Figure 3 compares the status of ALIS as a standard of Si etching rate. We have tested several commercial products of 300~400 mm-ALIS and KIMS ALIS in our vacuum system. The common test conditions are Si substrate, distance 100 mm, ion beam angle 60˚, Ar flow 30 sccm, and pressure 1.3 mTorr. And the presented etching rate in Fig.3 is the maximum value at each optimized condition near the common condition. Technical issue is how to increase a discharge voltage for enhancing an etching rate by an energetic ion acceleration without a cathode erosion. Because of a breakdown and an abnormal discharge at high voltage above 4 kV, many ALIS could not increase an etching rate continuously. In KIMS ALIS, the body has been designed to sustain a high voltage breakdown up to 5 kV. Thus the etching rate can be increased up to 12 nm/min. The static etching rate is calculated by the maximum etching depth at a bell shape etching profile as shown in Fig. 4.

Also the cathode erosion effect on the contamination was negligible. And the discharge transition from collimated beam to diffused beam is not occurred easily at large Ar flow. Note that the wide process window of the collimated beam is important when we use the ALIS in an ion beam assisted deposition. Because the operating pressure of magnetron sputtering is higher than that of the collimated beam ALIS normally, it could be difficult to find the process windows of co-working process of magnetron sputtering and ALIS with collimated beam mode.

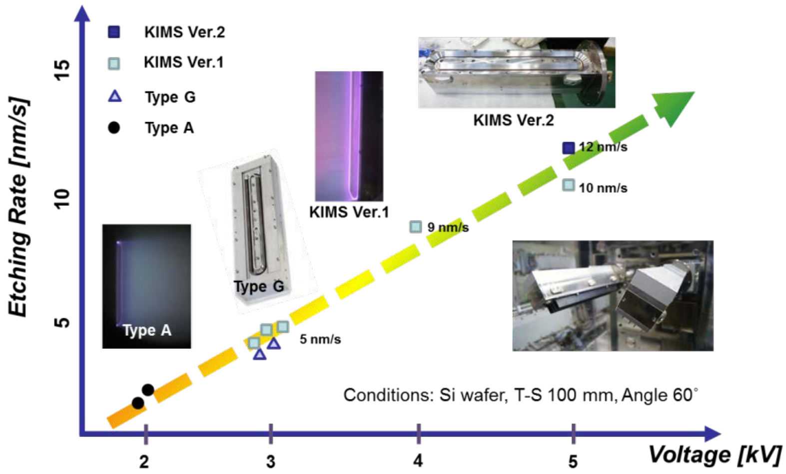

Fig. 3 The status of several ALIS for etching process

KIMS ALIS showed uniform treatment ability as shown in Fig. 5. The ion beam current distribution was measured by multi array Faraday cups. For example, 300 mm- KIMS ALIS showed the ion beam current uniformity of 4.5~5 % from 1 to 3 kV. The uniformity at 5 kV could be similar because Si etching rate is similar at whole positions except both edges. The uniform ion beam extraction is available by an uniform gas injection method. In previous ALIS there are many gas injection methods such as multilayer gas slits, and complex gas injection system. In KIMS ALIS special and simple gas injection method is adapted and its gas distribution ability is applicable to large width ALIS up to 1550 mm.

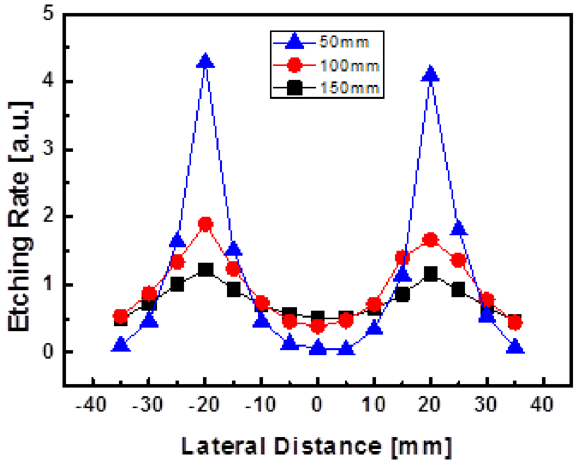

Fig. 4 Etching profiles at various distances between ALIS and substrate.

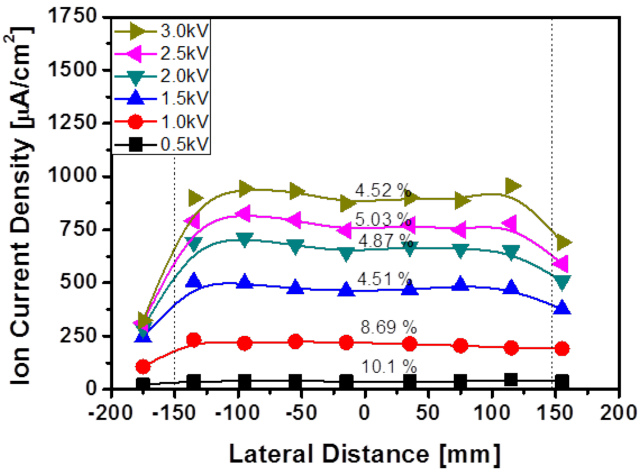

Fig. 5. Ion beam current uniformity of KIMS ALIS

3. ALIS Applications

ALIS has been used to various applications in KIMS. One is a surface pre-treatment process in RTR systems. When a substrate is a steel sheet 1.5 keV Ar ion beam is used to etch the native oxide at the steel sheet surface. When a substrate is a polymer 50~100 eV Ar and O_2 ion beam treatment is used to clean and activate a polymer substrate. Figure 6 showed the steel sheet pre-treatment process. Ar ion beams etched both sides of a moving steel sheet. Bright emissions by an ion beam sputtering is observed at the steel surface. At present 10 ALISs are required to realize 100 m/min RTR steel sheet etching process.

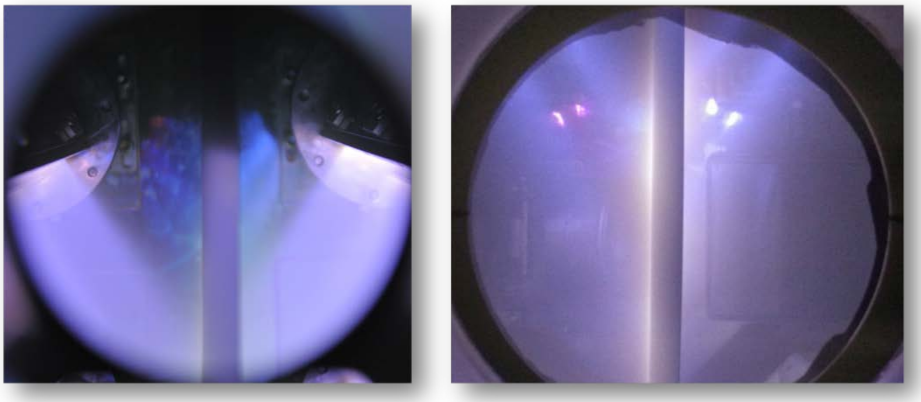

Fig. 6. Steel sheet surface treatment process. Source(left) and treated surface (right)

Another application is a deposition part. Diamond like carbon coating is one of the deposition applications. DLC coatings are used to protection and lubrication layers on metal and polymer substrates. The DLC films have high hardness 45~50 GPa, low friction coefficient 0.2 at dry lubrication and 0.04 at oil lubrication, and high adhesion strength up to 50 N.

4. Concluding Remark

We developed a high performance ALIS with the highest etching rate and tried to understand ALIS discharge by using a PIC simulation. Also it was confirmed that the ALIS can be used to wide applications from etching to deposition. Based on the promising possibility, 1550 mm width ALIS is developing nowadays. In further work, the technical issues to realize high speed and uniform large width ALIS will be discussed.

Reference

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