A System for Predicting the Area Selective Deposition of Titanium: Plasma State Diagnostics Using Electrical Simulation

The selective deposition of thin films in specific areas is crucial for achieving the desired size and low resistance of semiconductors. Due to differences in chemistry between molecule/surface and molecule/vapor interactions, thin films are selectively deposited on pre-patterned substrates. Although simulations have been used to predict Ti film thickness using plasma simulation and surface reaction models, the effect of selective deposition on the pattern was not studied. In this study, an electrical simulation was used to predict the selectivity of the area selective deposition process on the patterned wafer.

To identify the main factors affecting selectivity, we reviewed the plasma temperature and density. Plasma density can be indirectly inferred from the output current of the matcher. Another factor that influences selectivity is plasma temperature, specifically the electron temperature [eV]. The sheath voltage is proportional to the electron temperature. Therefore, we established an electric simulation system (Fig. 1) to estimate the sheath voltage. The CCP consists of an RF generator, a matcher, and a chamber. We identified the matcher parameters (C_{tune}/C_{load}/L) using the maximum power transmission theory, assuming that the chamber was $Z_{chamber}$(Fig 2). The model was verified using MATLAB and the sheath voltage was derived using the matcher and bottom currents. The simulations and evaluations of pressure/RF power/impedance were performed. The validity of the electrical model was confirmed by comparing the simulation and the experimental current.

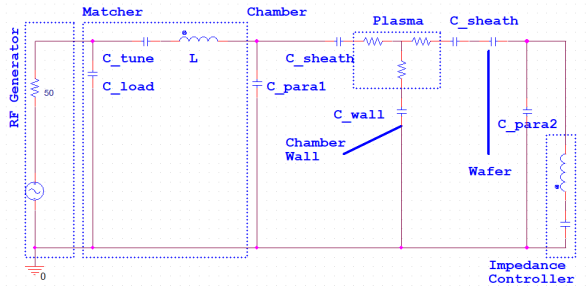

Figure 1. Equivalent electrical model.

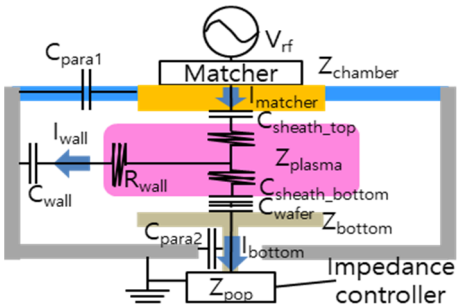

Figure 2. Modeling the process chamber

To verify the simulation, Ti deposition experiments were conducted on Si/SiO wafers under 7 conditions (Table1). The simulation results for sheath voltage and the experimental results for deposition rate showed a correlation of 0.77, and the Si/SiO selectivity showed a correlation of 0.92(Fig 3).

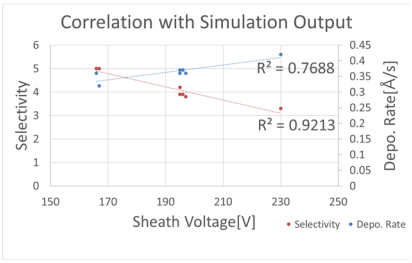

Figure 3. Correlation between selectivity and sheath voltage; the depo. rate and sheath voltage (blue)

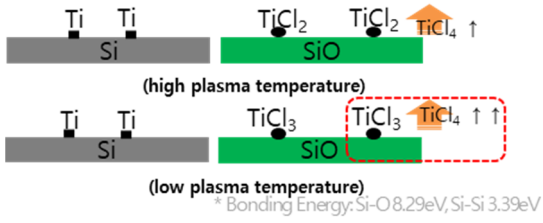

Figure 4. Area Selective Ti Modeling

Through the correlation result, it was derived as the following conclusion. The correlation results between sheath voltage and the area selective deposition explains the difference in the activation energy of the Si/SiO surfaces: The Si-Si bonding energy is 3.39 eV and the Si-O bonding energy is 8.29eV (Fig 4). Since there are regions where the plasma temperature is active on Si and inert on SiO, they are selectively deposited. Therefore, a sheath voltage simulation can be used to predict the selectivity. With further development, this simulation can be applied to other deposition equipment that uses plasma, and trends in process results for other process parameters that are sensitive to plasma temperature can be inferred.

Table 1. The coefficient result between experiment and simulation.

Condition				Experiment Result				Simulation		
	Press.	Power	Z_{pop}	$I_{matcher}$	I_{bottom}	D/R	Selectivity	$I_{matcher}$	I_{bottom}	Sheath Vol
	Torr	W	Ohm	Arms	Arms	Å/s		Arms	Arms	V
1	5	300	70	1.51	0.435	0.42	3.3	1.78	0.39	230
2	5	200	70	1.3	0.276	0.36	3.8	1.53	0.31	197
3	6	200	70	1.32	0.256	0.37	4.2	1.50	0.30	195
4	6	150	70	1.22	0.147	0.32	5	1.34	0.25	167
5	9	200	70	1.45	0.181	0.36	5	1.43	0.35	166
6	5	200	60	1.32	0.268	0.37	3.9	1.53	0.28	196
7	5	200	55	1.32	0.263	0.36	3.9	1.52	0.28	195
coefficient of determination (R^2)						0.77	0.92	0.70	0.66	