Design of Processing Chamber Based on the Flow Uniformity

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Abstract: Orthogonal experimental design and flow field simulation are applied to the mechanical design reasonably in this paper. Based on the flow uniformity, design of processing chamber is completed. The results show that, Spalart-Allmaras one-equation turbulence model is effective for the shear flow simulation of wall in processing chamber with a low Reynolds number; design of showerhead is critical, which directly affects the distribution of flow field inside, as well as the etching effect; the location of exhaust port under the chamber scarcely affect the distribution of wind speed nearby the substrate, so gas exhaust unit is designed in the view of mechanical, in order to make the whole processing chamber achieve the dual effect of beauty and utility.

1 Introduction

With the rapid development of IC industry, chips become more and more integrated, which requires IC equipment manufacturers continue to introduce new product, invent new technologies, test new models, as much as possible to shorten product development cycles. Meanwhile, IC equipment and processes involve in the multidisciplinary field of knowledge that can be able to quickly and easily accept, analyze and use by researchers during the product development process. For most domestic enterprises and universities within the PVD, CVD, PECVD almost have the single structural design, and the uneven thickness during the coating, etching, and ionization deposition leads to the longer production cycle and some other problems as well. In this article, referenced to a lot of patent [PKK08] [NNK11] [SB210] [FCCPW09] [Du03] [SKD03]and paper about simulation [SSOO02] [Lu10] [CZDW08]of flow field inside about PVD、CVD and

PECVD equipment, design of processing chamber is completed, in order to realize the flow uniformity inside of the chamber.

2 Dimension parameter design

In this paper, the total height of cylindrical processing chamber is 200mm. The height change of processing chamber is the change of the distance between the substrate and the showerhead. Using the lifting mechanism control the movements of the substrate achieves the height variation between the substrate and the showerhead. The distance between the substrate and the showerhead sets 30mm. Consideration the distance variation between the chamber superior wall and the showerhead, the design adjusts to the distance between the first showerhead, the chamber superior wall and the second showerhead by bolt. The diameter change of processing chamber is achieved by increasing the lining in the chamber. According to the production design needs, the diameter of the substrate required is greater than 300mm, the distance between the outer edge of the substrate and the chamber inner wall is 50mm., so the chamber the minimum diameter sets 460mm; the maximum diameter sets 660mm.

3 Dimension parameter design

1) Turbulence model

The criteria of Reynolds number $\mathrm{Re} = \rho VL / \mu$ determines the laminar or turbulent. The density of air is 1.225kg/m3, viscosity coefficient is 1.7894e-5kg/ms, and the characteristic length is 8mm. So when V≤4.24m/s, the flow is laminar. In order to make the gas mixture more uniform, the flow should be turbulent. Setting the V=5 m/s, that is to say, the flux is 15000sccm. Spalart-Allmaras turbulence model is selected at last.

2) Mesh generation

The mesh model is generated respectively in different parts, which are inlet part, showerhead and inside of the processing chamber. In order to simulate the shear flow of the low-speed gas better, twenty boundary layers must be established round the wall which is discrete by a smaller dimension; the structure mesh is generated in all parts; local mesh refinement is necessary in showerhead part. At last, the total number of grid is 2 million, which meets the discrete requirement.

3) Boundary conditions

Inlet boundary conditions: diameter of gas inlet is 8mm, defined velocity-inlet with speed of 5m/s;

Outlet boundary conditions: the gas exhaust unit is defined the pressure-outlet in order to reflect the real flow field inside the processing chamber;

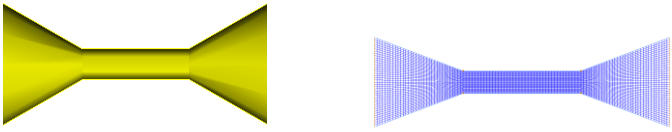
Wall boundary conditions: the shear friction between air and the wall of chamber when the air is flowing through it, so set the wall for no-slip wall boundary conditions.

4 Internal structure design

1) Showerhead design

Showerhead structure, which contains the structure of vent, the dimension, and the distribution, is a key factor. Design of showerhead is critical, which directly affects the distribution of flow field inside, as well as the etching effect.

There are two showerheads after the gas flow into the chamber. The first showerhead uses cylindrical holes. Holes on the second showerhead are shaped by tapered hole, cylindrical hole and the inverted tapered hole, of which the maximum diameter is 2mm, and the minimum diameter is 0.5mm. The specific structure is showed in Figure 1.



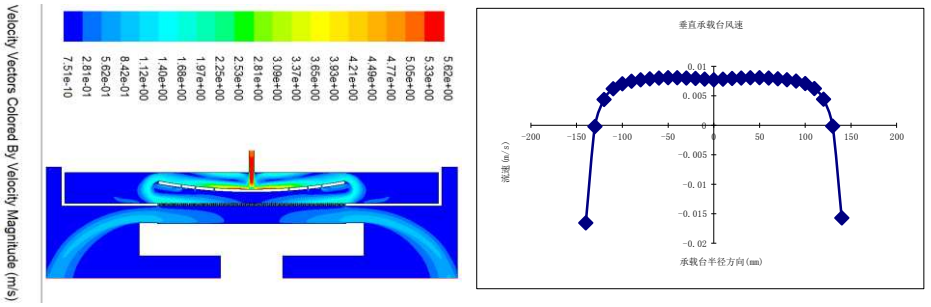
（a）Structure shape　　（b）mesh shape

Figure 1: Shape of hole on the second showerhead

After orthogonal experimental design and analysis of flow field simulation, the effective film range, the uniformity of flow near the substrate and the uniformity of flow near the showerhead of different objects are compared. Based on flow uniformity of design, the concave of the first showerhead faces the inlet. In the first showerhead, there are no holes in the center and three times holes distributed along the circumference. Radius of three times holes is 2.5mm, 1.5mm, 1.5mm respectively, as well as the distance between the holes center and the center of showerhead is 60mm, 90mm, 112.5mm respectively. Figure 2 shows velocity vector and the velocity distribution near substrate, simulated flow field inside of the processing chamber.

2) Gas exhaust unit design

The whole bottom is not completely the gas exhaust port. In order to keep the lifting mechanism which connects with the substrate work better and the air flows through the chamber quicker, the best setting place must be researched.

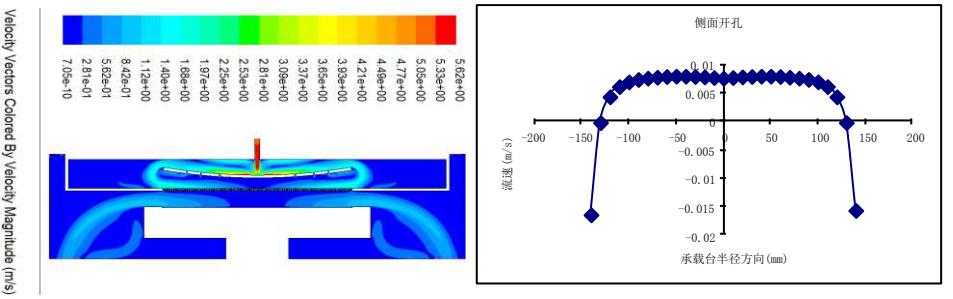


（a）Velocity vector （b）Velocity distribution near substrate

Figure 2: Flow field characteristics of processing chamber

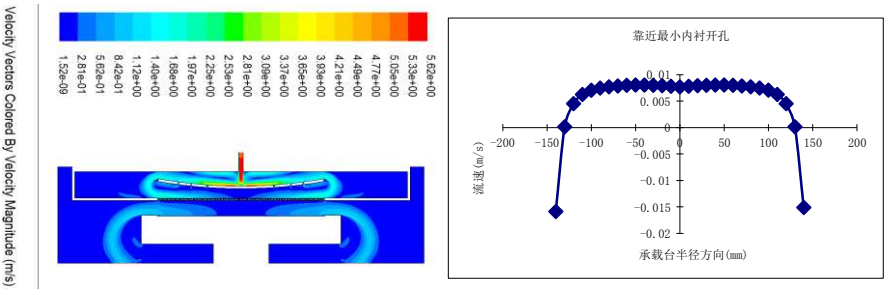
Figure 2 shows, after the design of showerhead, the effective film region is ± 90mm, in which velocity relative error is less than 5%.

On the bottom, there are three places to set the exhaust port. The first place project is near the side, close to the processing chamber wall; the second is near the minimum lining, between the minimum lining and substrate; the third is in the middle, close to the lifting mechanism. The diameter of the exhaust port is 50mm, and simulation results are shown in Figure 3 to Figure 5.



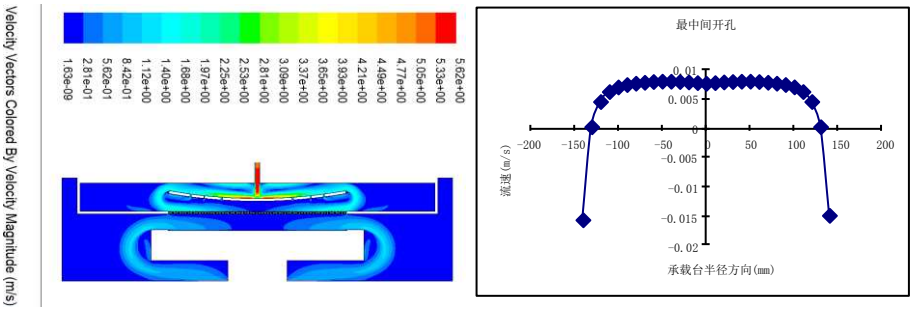
（a）velocity vector （b）velocity distribution near substrate

Figure 3 Flow field characteristics of processing chamber in project 1



（a）velocity vector （b）velocity distribution near substrate

Figure 4: Flow field characteristics of processing chamber in project 2



（a）velocity vector （b）velocity distribution near substrate

Figure 5: Flow field characteristics of processing chamber in project 3

The simulation results show, the location of exhaust port under the chamber scarcely affect the distribution of wind speed nearby the substrate, so three place projects are all well in principle. However, in Figure 3, diameter of the minimum lining is 460mm, and the first project will interfere its placement, so the first project is ruled out; in Figure 5, the flow field inside is very complex, and there will be a great vortex under the substrate. The lifting mechanism also greatly affects the gas exhaust, so the third project is ruled out; in Figure 4, when the port position is between the minimum lining and substrate, there is no interference among the lifting mechanism、the minimum lining and the gas exhaust, so the second project is the best.

5 Processing chamber structure

According to the research based on the flow uniformity, structure of processing chamber is designed in Figure 6. In figure 6, the lifting mechanism is used to complete the substrate's change in the height direction; linings are placed to achieve change in the diameter direction; showerhead is designed to achieve the airflow fully mixed, and ensure the flow uniformity near the substrate; gas exhaust unit is designed, without causing interference, to keep the chamber's flow balance.

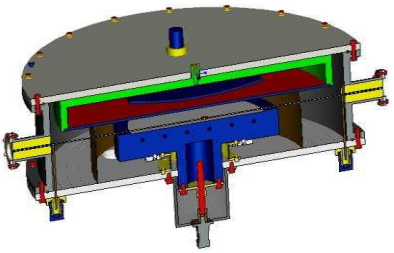


Figure 6: Structure of the processing chamber

6 Conclusions

The research shows that: Orthogonal experimental design and flow field simulation are applied to the mechanical design reasonably. Based on the flow uniformity, structure design of processing chamber is completed, greatly improving the efficiency and accuracy; Spalart-Allmaras one-equation turbulence model is effective for the shear flow simulation of wall in processing chamber with a low Reynolds number; Design of showerhead is critical, which directly affects the distribution of flow field inside, as well as the etching effect; the two showerheads make the gas mixture more uniform, and keep the flow uniformity nearby the substrate; the effective film region is ± 90mm, in which velocity relative error is less than 5%; The location of exhaust port under the chamber scarcely affect the distribution of wind speed nearby the substrate, so gas exhaust unit is designed in the view of mechanical, in order to make the whole processing chamber achieve the dual effect of beauty and utility.

Acknowledgments

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