Numerical Study on the Air-Cushion Glass Transportation Unit for LCD Panels

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ABSTRACT

Non-contact transportation system using air cushion for the manufacturing of large-sized LCD panels was considered. Flow characteristics between air pad and glass plate was analyzed using computational fluid dynamics method to obtain optimized air pad configurations. Effects of the design variables such as hole arrays from which gas is injected, gas-feeding method into the gas supplying channels, and horizontal and vertical pitches of clusters of holes were studied. Optimized air pad unit gave evenly distributed pressure contour on the glass surface and well-suspended levitation height in the experiment.

Key Words : Air cushion, LCD panel, Non-contact transportation, Glass plates

1. INTRODUCTION

Vertical sputtering system is a key part of the equipment for manufacturing liquid crystal display (LCD) panels. Market sharing of electronic goods using LCD such as television is highly dependent on the development of large size LCD panels. During the sputtering process for LCD panels, glass plates are transported from chamber to chamber to deposit chemical species on the surfaces. Design of the non-contacting transportation system is the most problematic to manufacturing the equipment for LCD. Researches on the new method such as utilizing combination of air bearing and electrostatic force [1] and near field acoustic levitation [2] have been reported recently.

Two types, compressed air and fan type, are usually used methods using air for levitation for transportation in semiconductor equipment. High levitation without compressor work is possible using high-speed fan but space for installation is the limitation to the most equipment. Furthermore, it can not be used in vacuum chamber that is common in semiconductor processes. Air bearing type using gas jet through small holes is another commonly used method because it can be applied to both atmospheric and vacuum conditions. Easy control for the glass levitation height and manufacturing work for simple channels are another merits of air bearing method.

Design variables of an air bearing system using gas jets are the types of holes, hole size, and hole array pitches in horizontal and vertical directions. Shape and size of the suction slots are also important. Minimization of the surface scratch and damage of the glasses, gas consumption rate, and stability of the floating glass plate are the object functions of an air pad design.

To develop new non-contact transportation system for large, thin glass plate, air pad unit was considered in this study. Effect of gas injection hole configurations, pitch distances in horizontal (x) and vertical (y) directions and gas supplying method was numerically analyzed. The ultimate objective is to obtain the design parameters for the 7^{th} generation LCD panel size but the 5^{th} generation LCD panel size was considered first to get insights of the effects of the design variables.

2. ANALYSIS

The gas, supplied by air pad unit, for levitation of

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glass plate is injected through small holes and flowed out through suction slots between the lines of holes. The force needed for levitating glass plate is able to obtain from the pressure distribution on the surface of glass plate. Therefore, it is a fluid mechanics problem to find flow characteristics of the gas between air pad and glass plate in engineering point of view.

Fig. 1 shows the geometrical configuration of the transportation unit. Repeatedly arrayed gas supplying pads and suction pads form an air pad unit. The numbers and shape of holes and suction slot are different from the real pad unit because the figure is simplified.

Several assumptions were made to simplify the problem. The gas flow was assumed a steady, laminar flow. Reynolds number based on the dynamic viscosity of air at room temperature, 1.33×10^{-5} m^2/s, inlet velocity of 5 m/s, and levitation height of 2 mm is about 700, which is lower than the critical Reynolds number of 1000. Deformation of the glass was not considered so the glass plate was assumed to be completely flat. Thirdly, the inlet velocity from each hole was considered uniform and the same for all the clusters of holes. This assumption will be discussed later in the discussion section. Temperature changes of the gas and glass plate were considered negligible so the gas properties were assumed to be constant during the transportation.

Continuity and momentum equations for x, y and z-directions were the governing equations for the gas flow between air pad and glass plate. Inlet velocity was calculated from the hole area, number and total

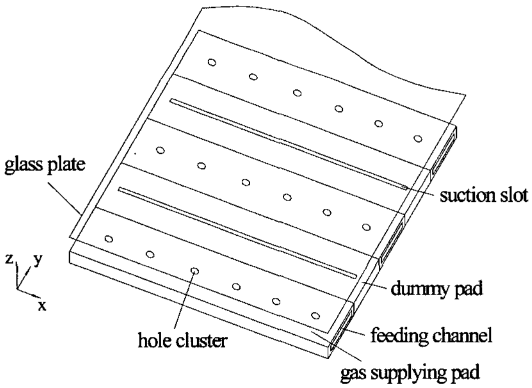

Fig. 1. Schematic diagram of an air-pad for non-contacting transportation unit.

flow rate. Let the normal direction of the air pad be z-direction, boundary condition at hole was

$$V_x = V_y = 0,\ V_z = V_{in} \quad (1)$$

A constant pressure was assumed at the suction slots and side edges. One-quarter region was considered in the calculation due to the symmetrical shape. The commercial computational fluid dynamics software, FLUENT [3] was used for all computations.

3. RESULTS AND DISCUSSIONS

3.1. Validation of the numerical method

To certify the appropriation of the computational method, a wafer transportation system using air cushion was chosen. Fig. 2 shows the grid system of the bottom surface of the 300mm wafer. Fig. 3 shows the calculated floating height according to the flow rates. The levitation height was determined from the balance between the weight of the wafer and the force by gas jet impingement given as

$$F = \int_A p\, dA \quad (2)$$

Measured levitation height was 0.4mm at 33.2 lpm whereas the simulation gave the height of 0.6 mm. Non-uniformity of the inlet velocity was thought to be the main reason for the difference. The difference between the simulation and experimental result was not important if the simulation results showed consistency.

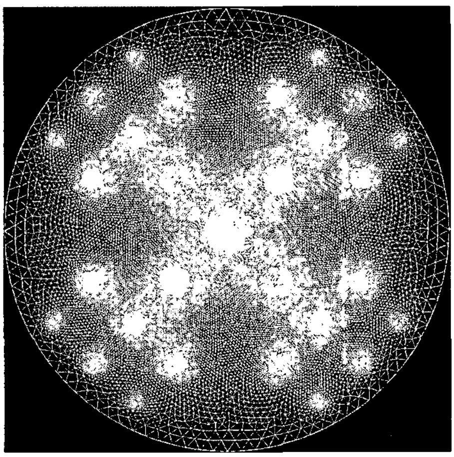

Fig. 2. Grid system for the 300 mm wafer transportation problem.

We have simulated for several times and obtained consistent results. Another glass plate levitation problem from the SMC (Sintered Metal Company) was also examined. The simulation results gave similar results to the above wafer problem. So despite of the difference, the computational method seemed to be applicable because the purpose of the simulations was not the levitation height itself but the effect of the air pad configurations.

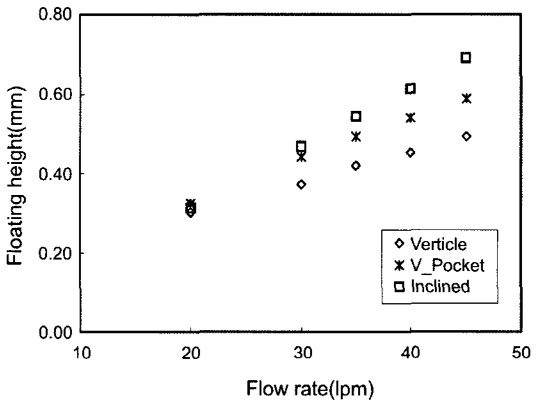

Fig. 3. Calculated floating height of the wafer according to the flow rate.

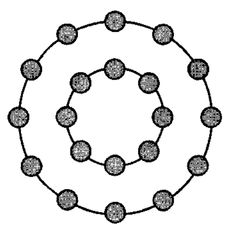

Fig. 4. Example of a cluster composed of twenty small holes.

3.2. Inlet velocity through holes

The size of the glass plate for the 5th generation LCD panel is set to 1100 mm×1250 mm×0.7 mm. The minimum levitation height was assumed to be 2 mm in the computations. Gas feeding method to the supplying pad was considered before the flow characteristic study between the glass and pad to satisfy the third assumption. One line of hole clusters, that is, one supply pad was considered in the calculations. We have examined the effect of hole numbers at each cluster. Fig. 4 shows an example of the cluster having twenty

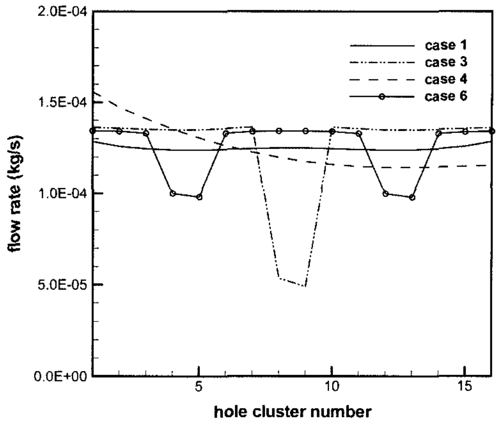

Fig. 5. Flow rate variations from each cluster according to the gas feeding method.

small holes. Twenty holes at one cluster gave almost the same flow rate throughout the cluster numbers.

Fig. 5 shows the flow rate gush out from each cluster of holes. The gas was fed from both of the inlets of the feeding channel shown in Fig. 1 and the channel was closed at the midsection in the x direction in the test case 1. The gas feeding hose was positioned at the bottom center of the feeding channel in the test case 3. The gas was supplied to the left inlet (x=0) in the case 4 and to the bottom part between the cluster 4 and 5, and 12 and 13 in case 6. The gas flow rate from the clusters of holes for the case 1 showed almost the same values through out the hole cluster numbers. By using the gas supplying method of the case 1, the third assumption was satisfied.

3.3. Vertical and Horizontal Pitches

To obtain the force for levitation of the glass plate, sufficient injection velocity of a gas had to be maintained. Pressure concentration on the plate just above the inlet holes is inevitable due to the high inlet velocity. Study on the hole-cluster pitches is important to get evenly distributed pressure variation and therefore to avoid damage or deformation of the plates. Fig. 6 shows the variations of flow rate and velocity according to the horizontal pitch of the cluster. Each cluster had twenty holes of 2 mm diameter. Flow rate is the summation of all clusters for the entire region of the plate. Pitch distance of 60~70 mm seems to be good because pressure concentration can be avoided at

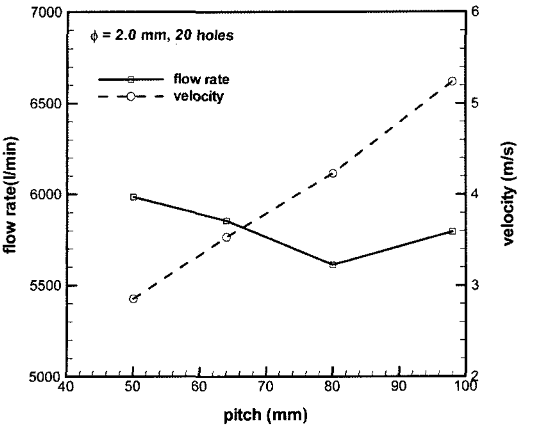

Fig. 6. Flow rate and velocity from the holes with variation of the horizontal pitch of the clusters.

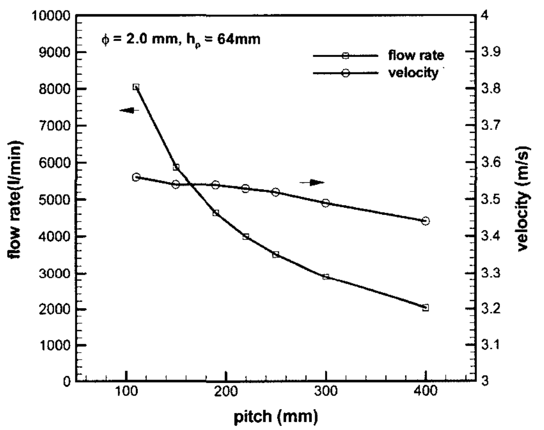

Fig. 7. Flow rate and velocity from the holes with variation of the vertical pitch of the hole clusters.

moderate flow rates. Flow rate, or consumption of gas, is low at long pitch distance but the injection velocity is high at a long pitch distance and vice versa.

Fig. 7 is the same results for the vertical pitch of the clusters with the fixed horizontal pitch of 64 mm. Narrow distance, smaller than 100 mm, between cluster lines in vertical direction (y-direction) was not good due to the large gas consumption. Velocity and flow rate diminished gradually with the pitch distance after 140 mm. Long pitch distance greater than 200 mm is recommended if other design variables are allowable.

Fig. 8 shows the pressure distribution on the glass plate surface. Pitch distances in x and y direction as well as the hole configurations determined from the computational results were used to the air pad unit.

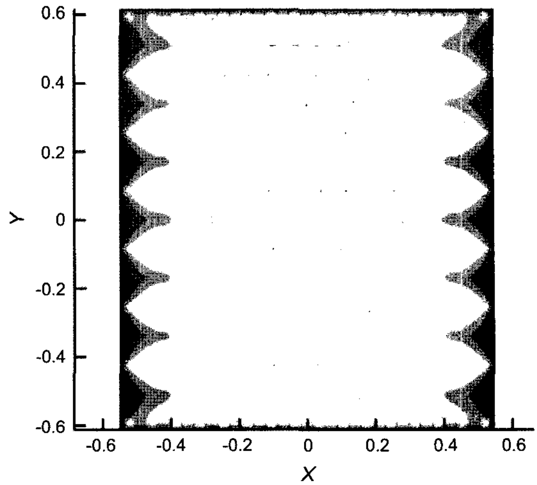

Fig. 8. Pressure contours on the bottom surface of the glass plate for the optimized air pad.

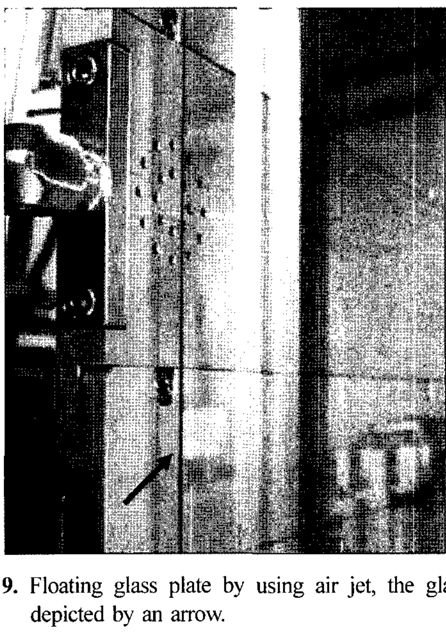

Fig. 9. Floating glass plate by using air jet, the glass is depicted by an arrow.

Horizontal and vertical pitches were about 70 mm and 160 mm, respectively. The contour map shows evenly distributed pressure distributions. We have made a test set and observed that a glass plate has been well suspended by the gas injection shown in the Fig. 9.

4. CONCLUSION

The air pad unit for the non-contacting transportation of a glass plate was considered in this study. The hole cluster configurations, including diameter and number of holes, horizontal and vertical pitches of the hole-clusters were determined from the analyses of the fluid flow between the air pad and glass plate. Gas feeding from the both end of the feeding channel with a blockage at the center of the channel gave almost uniform injection velocity from the holes. Pitch distance of 60~70 mm and greater than 200 mm for horizontal and vertical direction were the resulting values from the analysis. We could get well-distributed pressure contour map from the optimized air-pad system and confirmed the glass plate levitation from the test set experiments.

The air-pad system has also to be used under the vacuum in which the deposition would take place. We are now analyzing the gas injection in a vacuum chamber. Once the effects of the design variables are known, the 7^{th} generation LCD panel size will be studied.

ACKNOWLEDGEMENT

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3. FLUENT is a product of Fluent Inc., 10, Cavendish Court, Lebanon, NH, USA.