

A study on Applicability of VacCAD Simulator

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Abstract

In this study, we compared the VacCAD and VacSim^(Multi), commercial vacuum simulators, to verify the advantages of VacCAD's efficiency. It was emphasized on immediacy and simplicity of simulation modelling, and characteristics of the pump combinations, pumping down curves, and vacuum materials. First, usability of simulation mechanism was estimated through the modeling schematics and obtained simulation results of each employed simulator were compared to evaluate the applicability in practice. Simulation reliability of each simulator was also probed by comparing the pumping characteristics of commercially available high vacuum systems. In addition, the degree of tolerances on VacCAD was also investigated through pumping down analysis considering outgassing effect due to chamber material variations. The higher effectiveness and expediency of VacCAD than VacSim^(Multi) has been presented, and it was expected that the utilization of VacCAD in vacuum applications to be increased.

Keywords: Applicability, Vacuum simulator, VacCAD(1.0), VacSim^(Multi), Vacuum simulation, Vacuum system

1. Introduction

Since the semiconductor recession began, high advances and yield in semiconductor process are needed to overcome the recession [1,2]. And cutting edges in high-vacuum technology and facilities are essential for the better performance in semiconductor fabrications. Therefore, practical applications of vacuum simulators are required for the optimum design of high-vacuum system [3]. Effective utilizations of vacuum simulator expected to improve yield and reduce manufacturing costs through the optimum design and process standardization. Thus, for selection and utilization of effective vacuum simulators, we compared the Vacsim^(Multi) and VacCAD simulators and demonstrated the advantages in the effectiveness of VacCAD simulator. Through this work, feasibility and application of VacCAD as a vacuum simulator were proposed, and it was expected that VacCAD could be used in vacuum research and industry thereafter. In this study, the characteristics of commercial vacuum simulators, VacCAD and VacSim^(Multi) were compared to prove the

efficiency of VacCAD. Features of design mechanisms and representations in simulation result of two simulators were investigated. For reliable comparison, system modeling of the same variable in each simulator was estimated. For each simulator, three comparing points (interface, simulation of pump combination, simulation of chamber materials) were chosen for their importance of vacuum simulators. For a sophisticated analyzing, the simulation considered outgassing effect and compared not a single pump speed but the combined pump speed.

If there's no additional mention, fixed variables [stainless steel, aluminium-65.4 liter (volume of chamber)-vane pump- 50 and 500 [mm] with roughing hose's diameter, length - 90° elbow standard radius for bend – HiPace 1500(TMP)] are used for this simulation [4]. Also high vacuum components, mass flow controller, throttle gate valve were not considered in this simulation. The main goal of this study was to measure the practicality and general availability of VacCAD through estimation of each simulator, so an accurate analysis of the simulation's interpretation was not considered.

2. Simulation

2.1. Mechanism of simulation modeling

2.1.1. VacSim^(Multi)

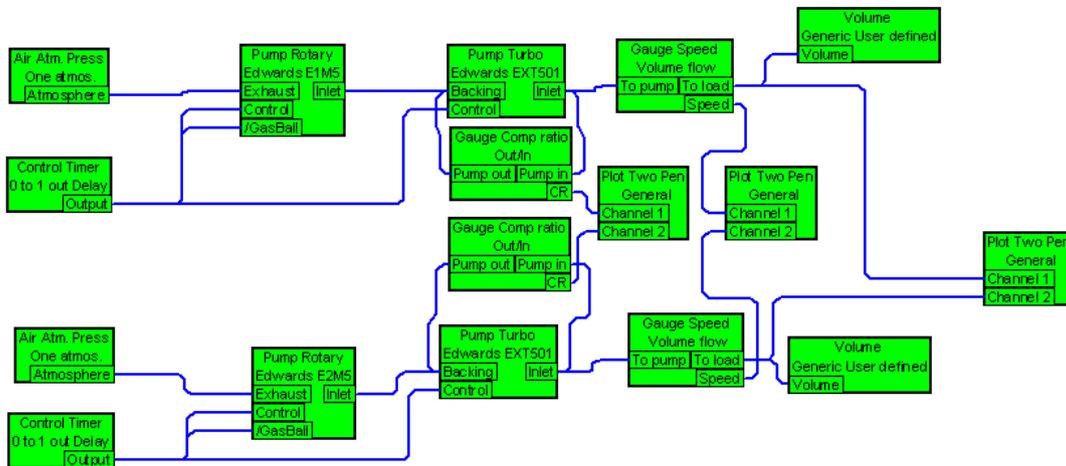


Figure 1. Modeling schematics by VacSim^(multi)

Figure 1 is a system modeling method of VacSim^(Multi). Users model a system by directly modifying green boxes. Although modelling is intuitive, it is difficult to understand a system at a glance [6]. In addition, it is difficult to identify the characteristics of each pump used for modeling and to change variables. And when comparing characteristics of a vacuum system through variables, it is difficult to compare as an independent system because common elements are shared.

2.1.2. VacCAD

Each panel was enabled to simulate certain vacuum conditions for users. If factors were chosen among panels, chosen data are shown right below the panel [5]. With setting up of all the specific vacuum conditions, when a user clicked a button at the left-bottom side from 'off' to 'rough' or 'high vacuum', the simulation data would be illustrated as a form of curved graph on a picture at the right-bottom side. In addition, outcomes

could be achieved both as curves and text data so that more specific result could be obtained. Also, many parameters like mass flow and throttle gate valve could have been added but those were not concerned in this simulation. However, extra factors could be added to each control panel. Therefore, high usability and practicality of VacCAD as simulator was proved. Chamber panels allow users to set the outgassing rate of materials and chamber materials. This minimizes system errors and allows user to set them to their desired units. In addition, the volume of the chamber is automatically calculated by selecting the shape of the chamber and setting the diameter and height.

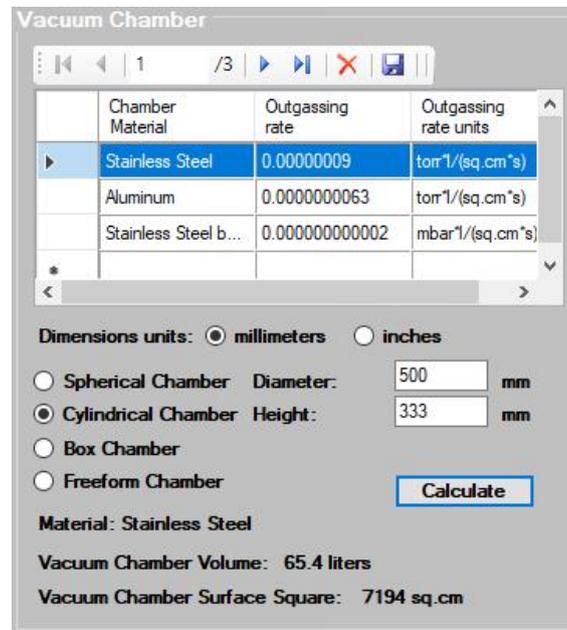


Figure 2. Modelling schematics of VacCAD

2.2 Simulation of pump combination

Pump combination were modeled and simulated for estimation of utility and general availability of each simulator. There was a blind spot to estimate the feasibility of the two simulators by comparing the pumping speed of the composite pump. Therefore, this comparison focused on comparing complex pumps and handiness of users. Combined pump consists of TMP and rotary pump.

Table 1. Pumping speed of each pumping models by VacSim^(Multi) [liter/min]

	E2M175	E2M275	E2M40	E2M80
EXT501	485.714	486.952	422.85	463.143
STP2001	95.9048	123.048	51.62	64.2667
STP400	139.45	185.714	143.662	141.37

Table 1 summarizes the pumping speed of combined pumps simulated with VacSim^(Multi). In case of Vacsim^(Multi), user should arrange the pumping speed of pumps and select the pump appropriate for situation. However, in the case of VacCAD, the pumping speed of each pump shows a graph, indicating automatically which pump is most efficient for user to use in which vacuum. Figure 3 is a comparison graph of pumping speed of a rough pump using VacCAD. Figure 4 shows a graph of pumping speed of high vacuum pumps. These two graphs allow the user to estimate which pump has the fastest pumping speed, and therefore which pump combination is the most efficient.

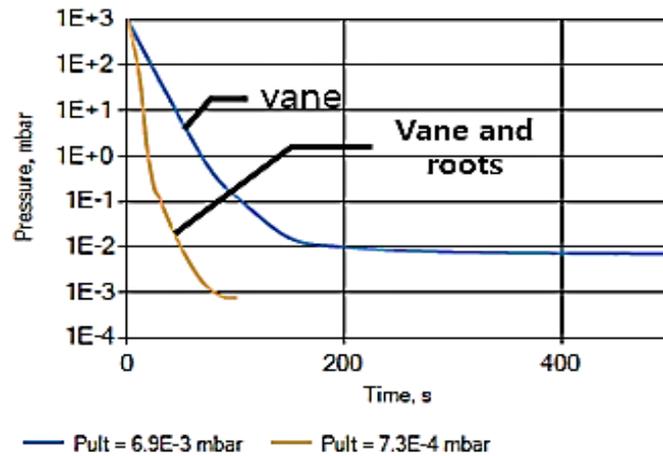


Figure 3. Pumping characteristic of selected roughing pumps by VacCAD

As illustrated in Figure 3, the difference of pumping time at $1E-2$ [mbar] was about 100 [sec] which mean that roots with vane pump performed more efficiently. The difference became so large below $1E-2$ [mbar] that vane with roots pump had to be considered in that pressure range. And next, it was simulated to compare performance between TMP, cryo-pump, diffusion pump and ion pump.

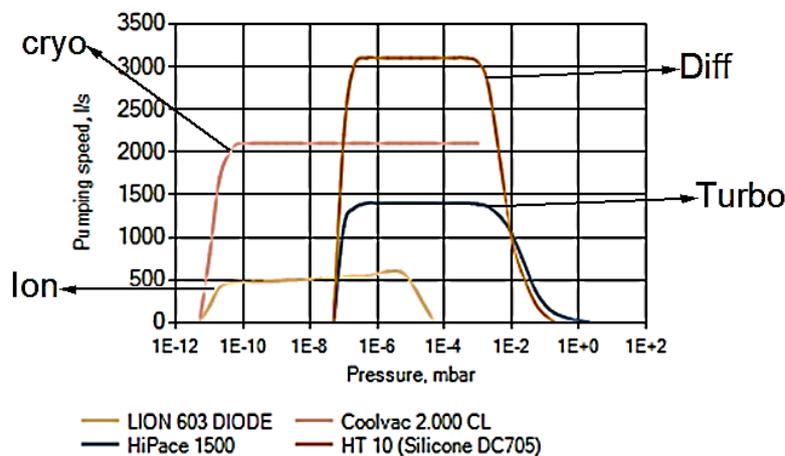


Figure 4. Comparison graph of pumping speed by VacCAD

In Figure 4, the Hipace1500, Coolvac 2000, HT 10 and LION 603 diode represented TMP, cryo- pump, diffusion pump and ion pump. Pumping speed of diffusion pump in $1\text{E}-3$ to $1\text{E}-7$ [mbar] range was as fast as twice from that of the TMP. So, using a diffusion pump instead of a TMP in this pressure range could have reduced the time as much as twice to reach the target pressure of $1\text{E}-7$ [mbar]. Below $1\text{E}-7$ [mbar], it was most efficient to use the cryo-pump because as showed in Fig.4, ultimate pressure of cryo-pump was about $1\text{E}-4$ [mbar] lower than diffusion pump. However, pumping speed of cryo-pump significantly slowed down at the below approximately of $1\text{E}-10$ [mbar].

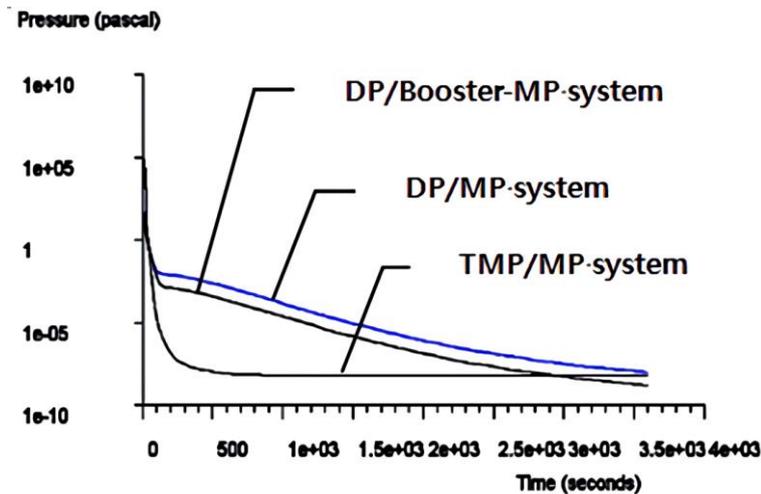


Figure 5. Pumping speed of three different systems by VacSim^(Multi)

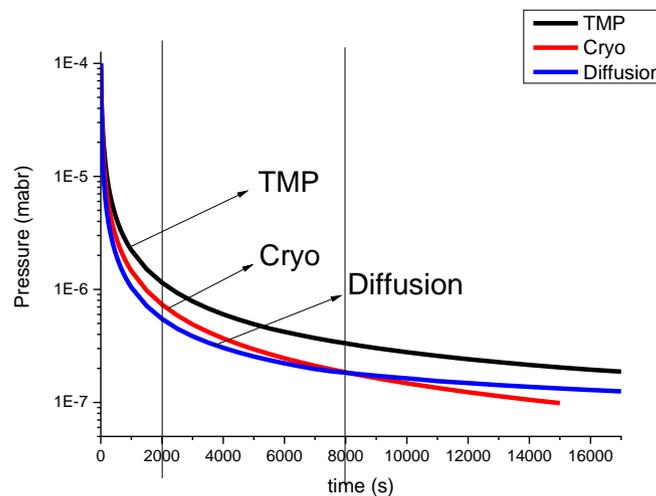


Figure 6. Pumping speed of high vacuum pumps by VacCAD

Figure 5 and figure 6 showed the simulations of pumping speed of high vacuum pumps with VacSim^(Multi) and VacCAD respectively. The pumps used in the two graphs were different, but sufficient for the purpose of comparing the accuracy and utilization of the simulation results. First, the accuracy of VacCAD has improved noticeably compared to VacSim^(Multi). In addition, the performance difference between the two simulators is shown in the simulation results about 4000 seconds later. In the case of VacSim^(Multi), the expression was expressed up to about 4000 seconds, even though it was not clear from 0 to 200 seconds,

from 2500 to 3000 seconds. However, in the case of VacCAD, the expression of pumping speed up to 16000 [sec] is clear and showed the difference in pumping speed between each pump.

2.3 Simulation of chamber material variables

One of important factors in the evaluation of vacuum systems is the outgassing effect. Therefore, this study focused on the outgassing effects by vacuum materials. For universal assessment, aluminum and stainless steel and copper which are commercialized as chamber material, were adopted. When aluminum, stainless and copper were adopted as chamber materials, obtained simulation curves of each simulator were evaluated when the outgassing rate was simulated.

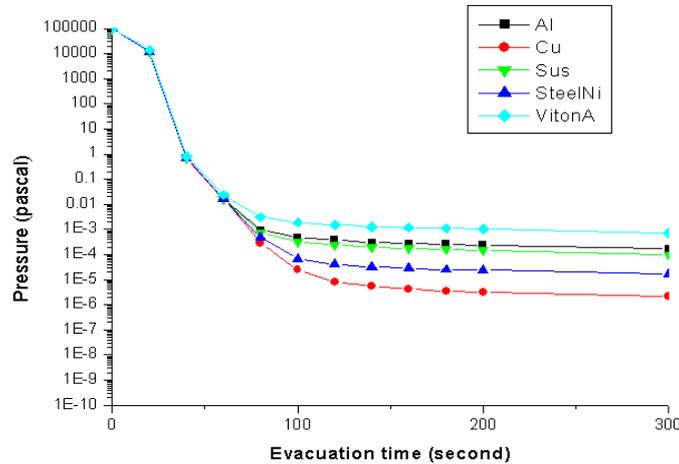


Figure 7. Outgassing characteristics of vacuum materials TMP-MP system by VacSim^(multi)

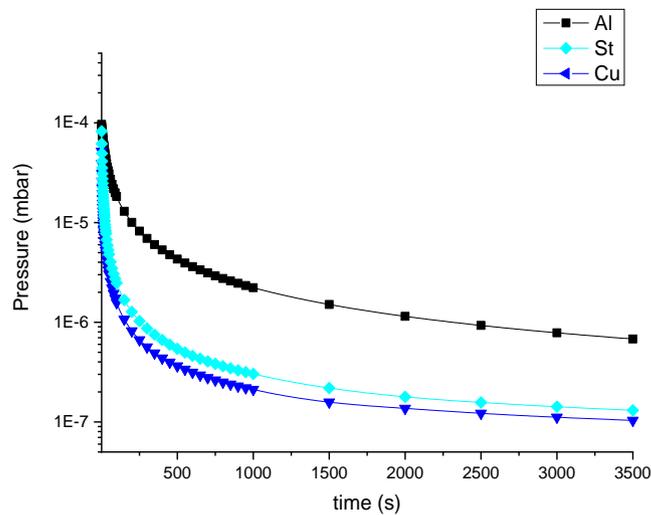


Figure 8. Pumping characteristics of stainless steel, aluminum and copper by VacCAD

Figure 7 showed the outgassing rate of five substances expressed through VacSim^(Multi) and interpreted the graph by concentrating on the black, blue and red lines. Figure 8 is the outgassing rate of aluminum, stainless steel and copper obtained by VacCAD. For Figure 7, only the results of are shown in a short time from 0 to 300 seconds. However, for Figure8, the result is about 10 times more time than 0 to 3500 seconds. In addition, for VacSim^(Multi), the expression of the outgassing rate for a period of 0 to 100 seconds is not clear. However,

in the case of VacCAD, it is possible to enlarge the curve data within the program to clearly see the results during that time period. In addition, it is able to inspect that result of VacCAD is accurate in the continuous expression of the outgassing rate slope compared to VacSim^(Multi).

3. Conclusion

The two simulators were compared through three comparison points to investigate the effectiveness and general availability of the VacCAD compared to VacSim^(Multi). The contents of existing VacSim^(Multi) and VacCAD related papers were quoted and simulated separately for proper estimation. In modeling system, three important factors were used to demonstrate the effectiveness of VacCAD. Through assessment of modeling method, the vacuum system schematics and parameter setting have proved the excellence of VacCAD in user convenience. Simulation of pump combination increased the degree of applicability of simulation results, showed the pumping speed of VacCAD and verifying the ease of pump setup. In addition, pumping speed and outgassing rate graphs confirmed that results can be predicted after a longer period of time and more accurate and detailed results can be predicted, and the performance improvement of the simulator itself has been argued. These comparisons have created a high degree of reliability for high generality and utility of VacCAD. With application of vacuum technology growing and important especially in the semiconductor industry, the need for reliable simulators is expected to be increased. Therefore, the purpose of this work as effectiveness and general availability of VacCAD for simulation of vacuum systems were demonstrated. It is expected that the feasibility and applicability of VacCAD as vacuum simulator increased in the future.

Acknowledgement

This work was supported by the Incheon National University Intra-Research Grant in 2018.

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