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A Comparison of Simulation Characteristics of VacCAD and VacTran as Vacuum Simulator

Hyung-Taek Kim

Professor, Department of Advanced Materials Engineering
Incheon National University, Incheon, Korea
e-mail : kim95118@inu.ac.kr

Abstract

In this study, we compared the VacCAD and VacTran, commercial vacuum simulators, to investigate the simulation applicability and efficiency as vacuum simulation software. It was verified on reliability and simplicity of simulation modelling, and characteristics of the pump combinations, pumping down curves, and employed vacuum materials. First, usability of simulation schematics was estimated through the modeling tools and the overall simulation characteristics of each simulator were compared to evaluate the applicability in practice. Simulation reliability of each simulator was also probed by comparing the pumping performance characteristics of commercial high vacuum system models. In addition, the degree of tolerances on both simulators was also evaluated through pumping down analysis considering outgassing effect due to chamber material variations. The higher effectiveness and expediency of VacCAD than VacTran has been presented, and it was also expected that the utilization of VacTan in vacuum applications to be increased due to the higher availability of modelling variations.

Keywords: *Vacuum simulator, VacCAD, VacTran, Simulation Characteristics, Vacuum system*

1. INTRODUCTION

Since the semiconductor recession began, high advances and yield in semiconductor process are needed to overcome the recession. And cutting edges in high-vacuum technology and facilities are essential for the better performance in semiconductor fabrications. Modern vacuum systems in high-tech. process require highly developed components operating within exacting parameters, especially at the high or ultra-high end of the vacuum spectrums [1,2]. In such circumstances, the vacuum components employed need to be precisely matched. Commercial vacuum simulators are designed to aid the vacuum engineer in the modeling of vacuum systems and the execution of laborious vacuum calculations, enabling rapid predictions of vacuum system operational performance and design alternatives. Therefore, practical application of vacuum simulators was required for the optimum design of vacuum system. Effective utilizations of vacuum simulator expected to improve yield and reduce manufacturing costs through the optimum design and process standardization [3]. In this study, the characteristics of commercial vacuum simulators, VacCAD and VacTran were compared to prove the efficiency of simulations. Features of design modellings and simulation tools of both simulators were investigated. And the overall features of VacSim(Multi) , the first commercial vacuum simulator package, was

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Corresponding Author: kim95118@inu.ac.kr
Tel:+82-32-835-8274 , Fax :+82-32-835-0778
Professor, Department of Advanced Materials Engineering, Incheon National University, Korea

also introduced as reference [8]. VacSim(Multi) simulates a multiple gas model. This was a major improvement over previous entry versions of VacSim, which only modeled a single gas (effectively air). VacSim(Multi) simulates pump down and pressure cycling in the high and ultra-high vacuum regimes using any combination of the five available working gases : Air, Hydrogen, Helium, Argon, Water and one user defined gas (Generic). Utilized VacCAD (ver. 1.0) is the further development of the vacuum engineering software VacMaster (ver. 2.0) which was widely used by the world vacuum community. VacTran (ver. 3.0) was designed to ease the process of modelling a vacuum system. It was developed to solve common, real problems in vacuum industry. Industrial vacuum engineers have used VacTran worldwide for over twenty five years [1,7]. For reliable comparison, modelling characteristics of the same system variables in each simulator were estimated. In each modelling, the pumping down times to ultimate pressures of suggested modelling variables were compared by the variations of chamber shapes and dimensions. Effects of chamber volumes on modelling system by probed two simulators were analyzed to verify the feasibilities of VacTran, VacCAD as vacuum simulators. For reliable comparison, simulation characteristics of the same variable in each modelling was estimated. In each simulation, three main variables (chamber dimension, conductance interface, pump combination) were chosen based on the effects on performance of vacuum system. For decreasing the tolerance of simulation characteristics, outgassing effect in chamber volume and the combined pumping speed were also considered. But, the high vacuum components such as mass flow controller, throttle gate valve were not counted in this simulations. The main goal of study was to measure the practicality and general availability of introduced commercial vacuum simulation software, so the effects analysis of dynamic factors on the simulation's interpretation were not applied. In each modelling, the pumping characteristics to ultimate pressures of suggested modelling were also compared by the variations of chamber materials which provided by simulator itself. And, comparisons in effects of conductance variations with length and diameter in exhaust line showed the more dependable performance of VacTran than that of VacCAD. Through this work, the feasibility of commercial vacuum simulator, VacCAD and VacTran, were proposed and it was expected that applications of vacuum simulators could be increased in the fields of high-tech. vacuum applications.

2. SIMULATION

2.1. Modelling of commercial vacuum simulator

2.1.1. VacSim$^{(Multi)}$

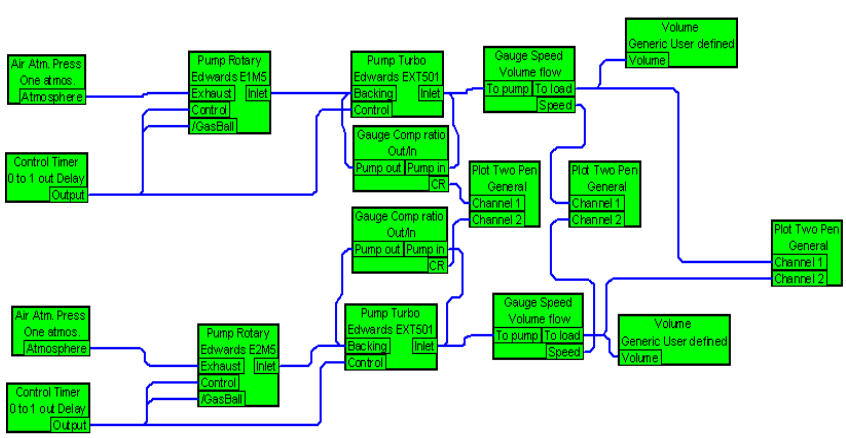
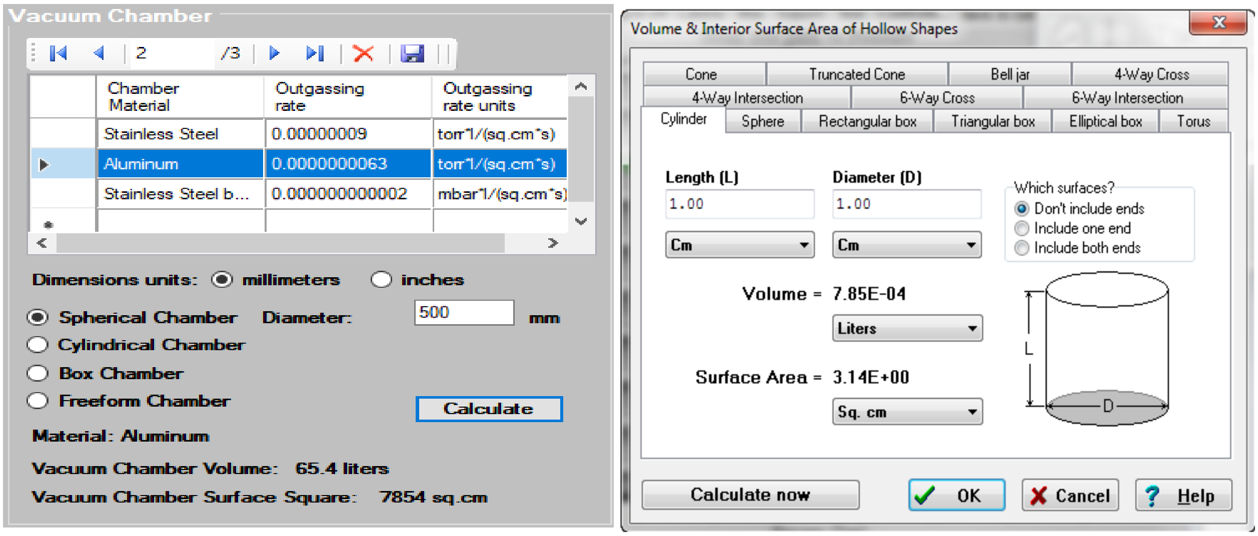


Figure 1. Modelling schematics by VacSim$^{(multi)}$

Figure 1 showed the system modeling tools of VacSim(Multi). The main VacSim(Multi) drawing window and associated interface allows the user to draw a connected set of items representing vacuum system components [5,8]. Each component is associated with a mathematical model describing its general behavior and a set of parameters which specify the detailed behavior. By changing the component parts and re-simulating, the influence of design changes on pumping characteristics and ultimate pressures were obtained. VacSim(Multi) simulator allowed a design best-suited to particular requirements considerably faster and with less cost than the build-it-and-test-it approach. But, although the modelling was intuitive, it is difficult to analyze the characteristics of each employed pump separately. And when comparing the overall performance of modelling system through variables, it is also hard to estimate the specific effects as an independent sub-system because common components such as valves are shared in simulations.

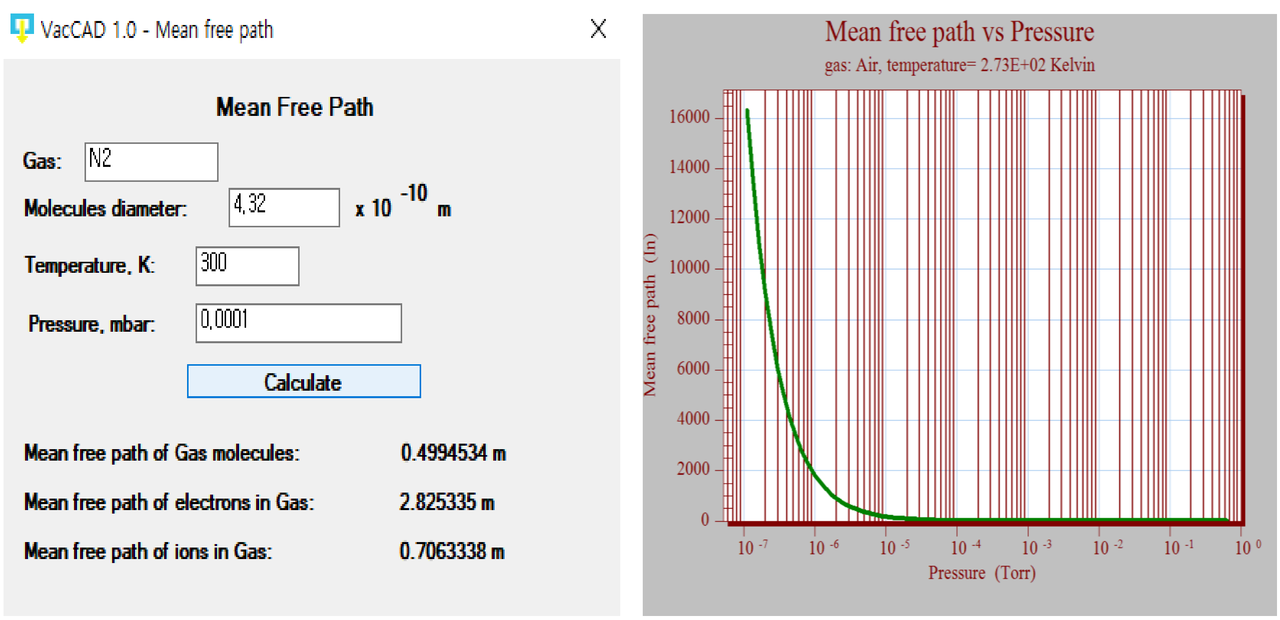
2.1.2. VacCAD and VacTran

User friendly main window tools of VacCAD and VacTran is showed on Figure 2. Vacuum chamber panel is illustrated how to model the materials and dimensions (volume, surface area) of vacuum chamber. Each panel was enabled to simulate certain design variables for modelling. If variables were chosen among panels, calculated dimension data are shown right below the panel. With setting up of all the specific system variables, when a button clicked from 'off' to 'rough' or 'high vacuum', the simulation results illustrated as a form of curved graph at the bottom side [7]. In addition, simulation analysis of mean free path could be achieved both as curves and text data so that more specific result could be obtained (Fig. 3). Also, more sophisticated factors like mass flow and throttle gate valve could have been added but those were not concerned in this simulation. However, more design variables such as conductance dimension could be added to each control panel of pump, hose, valve. Chamber panels also allowed the setting of outgassing rate of selected chamber materials. This minimized the tolerance between the performance curves of simulation and real system. Figure 2 represented that the volume of chamber is automatically calculated by selecting the shape of chamber and setting the diameter and height. The chamber control window of VacTran also contains a menu and tool bar for displaying text and graphs, and floating palettes for inserting conductance and gas load elements into models [8]. The main graph and the main text window are permanently visible. These are used in almost all modellings of VacTran for displaying calculated data from design factors. Each time a curve is generated, VacTran also displayed it in the main graph window. Basic goal of vacuum system for high tech. process is to remove an initial gas volume from a vacuum vessel, faster than new gas enters, to achieve a target pressure in a required time period. The other goal is to remove gas from a vacuum vessel at a rate equal to the rate it enters, maintaining an operating pressure that is acceptable to the vacuum process. Once the basic phenomena that affect vacuum systems, and the governing equations that help predict performance were understood, vacuum system design could be looked fairly reasonable. It was observed that VacCAD and VacTran had been designed to mathematically simulate these situations, forming the basis of vacuum pumping systems. The minimum system model of both VacCAD and VacTran had a vessel, a pump, and a conductance path between the pump and the vessel [9]. The basic flow diagram of this concept is fairly structured in VacCAD and VacTran as modelling modules.



(a) (b)

Figure 2. Modelling of vacuum chamber of (a) VacCAD and (b) VacTran



(a) (b)

Figure 3. Simulation of mean free path (a) text data in VacCAD and (b) graphic in VacTran

2.2. Simulation Characteristics

Pump combination were modeled and simulated for the estimation of general availability of each simulator. There was a constraint to estimate the feasibility of the both simulators by comparing the pumping speed of the modelled pumps simultaneously. Therefore, this comparison based on the separate estimation of each composed pumps in pumping combinations. Pumping modelling consisted of TMP and rotary pump combination.

Table 1. Pumping speed of pump models by VacCAD and VacTran [liter/min]

Rough pump / High pump	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 modelled pump combinations. In VacCAD simulation, the pumping speed was selected with the manufacturer's database provided by VacCAD pump panel. Therefore, the pumping speed of each modelled pump was shown as a graph, indicating automatically which pump is most efficient to reach the ultimate pressure in particular vacuum ranges. Figure 4 showed the pumping speed of rough and high vacuum pump in VacCAD curve. Resulted simulation curve estimated which pump had the fastest pumping speed, and therefore which pump combination is the most efficient. Difference of pumping time at 1E-2 $[mbar]$ was about 100 [s] which means 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.

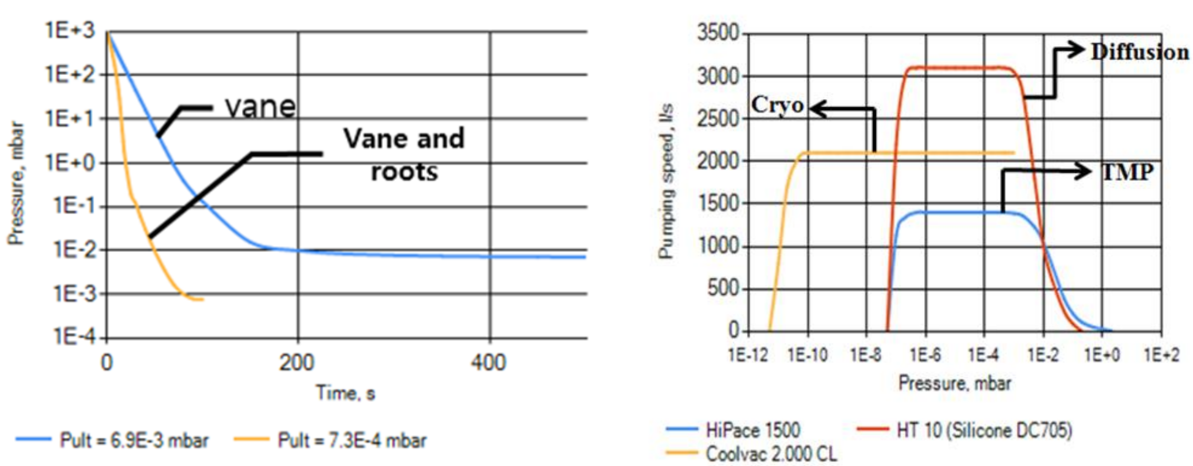


Figure 4. Simulation characteristics of VacCAD modelling

Performance characteristics between TMP, cryo-pump, diffusion pump and ion pump showed the pumping speed of diffusion pump in 1E-3 to 1E-7[$mbar$] range was as fast as twice that of the TMP. So, selection of diffusion pump instead of a TMP in this range could have reduced the time as much as twice to reach the ultimate pressure of 1E-7[$mbar$]. Below 1E-7[$mbar$], it was most efficient to use the cryo-pump because the ultimate pressure of cryo-pump was about 1E-4 [*mbar*] lower than diffusion pump. However, pumping speed of cryo-pump significantly slowed down at the below of 1E-10[$mbar$].

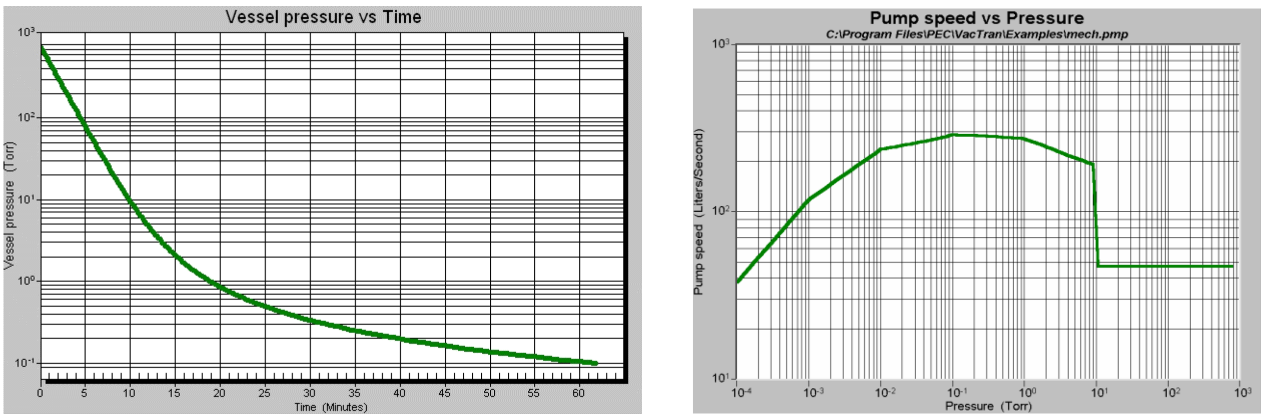


Figure 5. Simulation Characteristics of VacTran modelling

Figure 5 represented the simulations curve of pumping down time of chamber and pumping speed of modelled pumps with VacTran respectively. For better accuracy and higher utilization of the simulation results, the modelled pump combinations were same as VacCAD simulation. The VacCAD simulation showed the better accurate analysis concerning pumping down characteristics than that of VacTran. Figure 6 showed calculated high vacuum pumping curves and pumping control panel of VacCAD. Pressure down in the chamber was plotted as pumping time dependencies. Time is a linear scale from 0 to a top limit set automatically. Pressure, mbar is a logarithmic scale set by default from 1*[mbar]* to set automatically lower limit in control panel. Pch represented the calculated final pressure in chamber and Pin means the simulated pressure at high vacuum pump inlet flange.

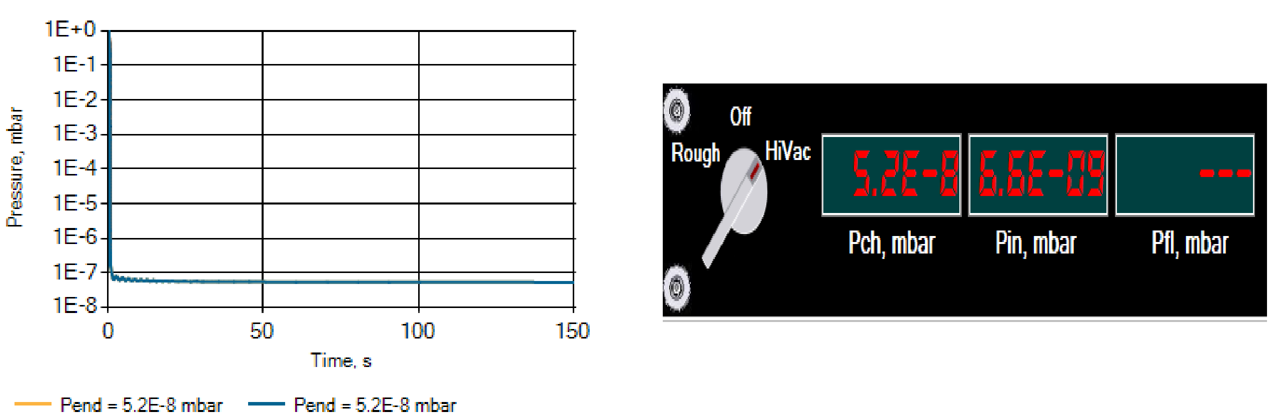


Figure 6. Pumping down curve of chamber and pumping control panel of VacCAD

3. CONCLUSION

In this study, the commercial vacuum simulators were introduced and the simulation characteristics were analyzed to investigate the effectiveness and reliability as a vacuum simulator. In general, all probed simulators had very friendly interface enabling the user to do productive simulation in a few minutes. Concerning to the simulation coherence, each simulator had some constraints and limitations but overall applicability in vacuum simulation was acceptable. Optimum simulation results after numerous repetitive simulations of VacCAD and VacTran were illustrated in the figures and tables. The modelling platform provided by each simulator were directly employed and simulated separately for the reliable analysis. In simulation modeling, system variables such as pump combination, dimensions of each simulator were fixed to demonstrate the comparative characteristics of simulation. Based on the simplicity of modeling tools, the VacCAD showed more excellence in user friendly interface regarding modelling schematics and parameter settings. Simulation characteristics of VacTran in pump combination provided the higher degree of applicability in real vacuum system. VacTran had the fairly extended variable database especially on the conductance and permeation, outgassing factors. It resulted in a significant complexity in system modelling and difficulties to analyze the simulation results accurately. And, VacTran characteristics of pumping curve indicated that simulation results could be more effectively predicted after a longer period of pumping time than that of VacCAD. In other word, VacTran had an advantage in the simulation of complex and relatively long period of vacuum process. VacCAD could be recommended to simulate the laboratory scale vacuum system. These comparisons of simulation behavior have created a high degree of reliability and utility of vacuum simulators. As the applications of vacuum technology become larger and more important particularly in semiconductor industry, more fore-studies based on the results of this work are expected to be conducted. Therefore, the possibility of utilization of major commercial vacuum simulators which were widely used by the vacuum community was verified.

Acknowledgement

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References

[1] VacTran Operation Manual (window version 3), www.vactran.com
[2] Vacuum Science World, www.vacuumscienceworld.com
[3] Hata David. Introduction of vacuum technology. Prentice Hall; 2012
[4] J.M. Lafferty. Foundations of vacuum science and technology. John Wiley and Sons; 1998
[5] Yoshimura Nagamitsu. Vacuum technology practice for scientific instruments. Springer; 2015
[6] Vacuum Technology Software, Professional Engineering Computations, 2016
[7] VacCAD(1.0) Operation Manual
[8] Technology Sources Ltd., User's Guide of VacSim[Multi] Simulator (manual), 2001.
[9] Vacuum Engineering & Simulation Software, VECOR, www.vecorus.com