Another Look at TCAD--Challenges of the 1990's

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Introduction

I am pleased to present this overview paper at the tenth anniversary of this conference. I believe VPAD has been a very effective forum for discussion of TCAD and will continue to be so in the future. As we look at accomplishments over the last decade, I believe that progress has been steady and impressive. However, in my talk today I would like to offer some words of encouragement that we not become complacent in our efforts and take another look at our goals for the decade of the '90s.

When I was on sabbatical in Japan during 1988-89, I had the pleasure to visit the scenic and historic Amanohashidate on the Japan Sea near Kyoto. Myth has it that the god and goddess Izanagi and Izanami descended to earth on the "floating bridge to heaven" at this spot. To visualize the bridge linking heaven and earth one has to "take another look" at the scene by inverting the image (looking upside down between your legs). I would offer that to take another look at TCAD for the 1990's we need to consider more deeply several new perspectives on the landscape. The three perspectives I would like to discuss are: nano-scale device physics, mega-scale computation and application-driven interfaces.

Application-Driven Interfaces

I will begin here since this perspective has the closest analogy to my opening story about Amanohashidate. I believe that the perspective of technologists and circuit designers is fundamentally different and that in order to fully exploit the potential of TCAD in the 1990's we must understand these differences. For the circuit designer it is a world of higher-level logic and device objects which ultimately are translated into layout--electrical data is coupled both at the layout and device levels. Figure 1 shows both the circuit design and technologist views. I believe the audience is well aware of the technologist's perspective, it is intense in its physical orientation with electrical parameters being the highest level of abstraction. In order to recognize and adapt to the needs of circuit designers, several perspectives must change: layout-based input must be used more effectively [1], support of complex tasks such as gridding must be automated [2], curve-tracer style access to I-V data must be efficient [3] and better interfaces to circuit analysis must be supported [4]. Progress is being made in each of these areas but taken as a whole, we are still far from an integrated system that circuit designers can easily and safely use. Yet to realize the full potential of ICs in the ASIC era and to overcome the difficulties such as sub-micron design rules, we need to "take another look" at application-oriented TCAD.

A second application that increasingly drives TCAD is the need to achieve manufacturability of sub-micron technologies. Here the issues have a broader context than for the application of circuit design--we need to consider a range of physical models and heterogenous uses of the tools. The new perspectives for manufacturing include: equipment modeling [5], process flow representation [6] and statistical design [7] to name only a few. The problems of achieving simplicity of use and efficiency in computation are even more severe for the manufacturing than in the application circuit design world.

Nano-Scale Physics

The example of equipment modeling provides one excellent example of the growing need for nano-scale physical modeling. In addition to problems of modeling temperature, gas flow and discharge conditions [8], the problems of surface kinetic modeling are indeed complex [9]. The use of Monte Carlo techniques for simulation of both ion bombardment and polymer deposition effects that occur during trench etching are becoming essential tools in understanding surface kinetics [10]. Other examples of the increasing need for better microscopic models in understanding process technology dependences abound--ion implantation, diffusion, oxidation and epitaxy are all approaching atomic scale limits of control and resolution. Instruments such as the scanning tunneling microscope are becoming engineering tools.

At the device level we have already begun to shift our perspective, the analysis of non-thermal equilibrium effects is an ongoing topic of deep fundamental concern. The conclusions from Professor Engl's panel at VPAD '90, "Work in Progress", is likely to apply for some time to come. Despite progress in both Monte Carlo [11][12] and energy transport modeling [13][14], we are still uncovering as many new questions as answering old ones. I will leave further discussion of this theme to this year's Rump Session. Nonetheless, this theme of nano-scale physics is key to the mission of TCAD for the '90s.

Mega-Scale Computation

The need for more computation, including finer resolution (nano-scale) for physical models, drives the appetite for TCAD in an era of high-performance computing (HPC). There are several approaches to HPC and it is far too early to choose winners. The two computational models that represent extremes of the field are SIMD (single instruction, multiple data) and MIMD (multiple instruction, multiple data) architectures. The range of problems that need to be addressed using HPC for TCAD include: atomic scale modeling, Monte Carlo and statistical analysis as well as the solution of partial differential equations (PDEs). It appears that the fine-grain nature of the SIMD approach may have advantages for atomic-scale models [15] whereas MIMD has clear advantages for unstructured grid used in solving PDEs [16]. Both MC and statistical analysis are inherently parallel tasks and both SIMD and MIMD architectures are expected to be suitable. Of course the dream of present generation electronic work-station (EWS) users is that networked EWS systems can also be used. Here the rate-limiting step will be communication (and synchronization) overhead--network "wire length" is not as uniform as it is for computer back-planes. The landscape of computer technology is changing rapidly. The last decade has witnessed the shift from mini- to mini-super- and now "personal" super-computers. This decade will see the emergence of multi-processor and networked super-processor systems and their entry into the mainstream of TCAD applications, as well as other HPC tasks.

Conclusions

Taking another look at TCAD requires new perspective and definition of the tools needed to solve the pressing problems posed by applications. Application-drivers such as circuit design and manufacturing require major shifts in interfaces and software integration. The role of nano-scale physics is growing as we move deeper into the sub-micron regime. Finally, new computational strategies are essential to meet the growing appetite for analysis required both in mega-scale PDE problem solving and in addressing the problems of nano-scale physics. In this talk the above themes will be put in the context of work over the past decade as well as previews of the work to come.

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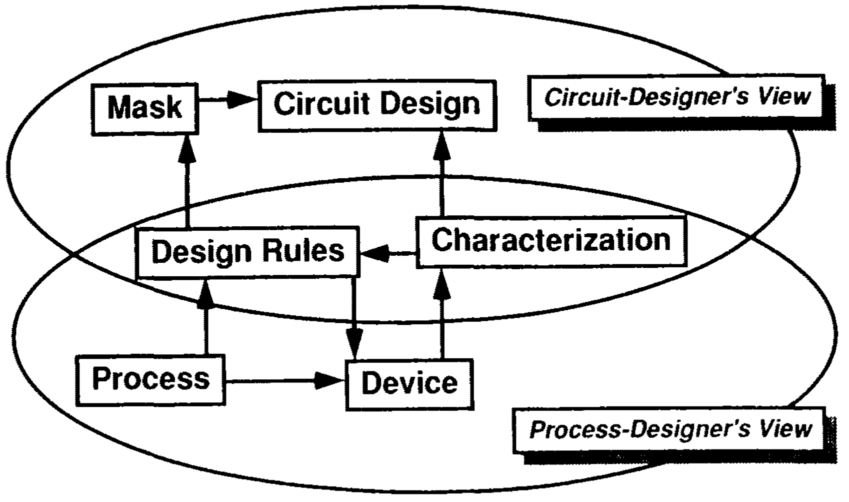

Figure 1 Circuit and Process Designer's Views of TCAD