ASML Advances Computing Breakthroughs with Multiphysics Modeling

ASML reveals how multiphysics simulation is becoming crucial for the computer chip industry. The lessons they've learned are likely to be important to manufacturers everywhere.

by VALERIO MARRA

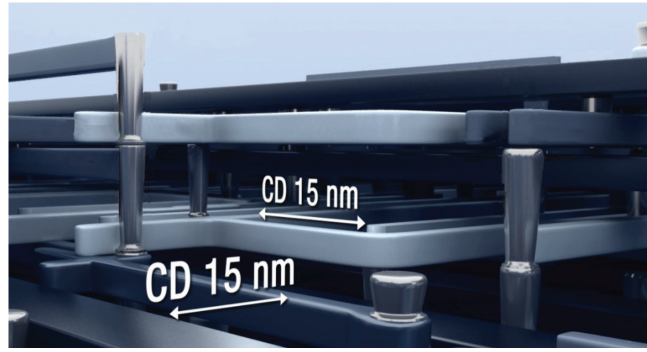

FIGURE 1. The critical dimensions inside a smartphone processor measures in nanometers. To put it in perspective, a human hair measures 5300 times larger than the critical dimensions in these chips.

It seems poetic that it takes complex simulations running on powerful computers to help design the machinery that will make the next generation of computers. Such is the case with ASML, the world's leading supplier of photolithography systems. ASML makes computer chips by optically exposing microchip blueprints to a light-sensitive photoresist layer on a silicon wafer.

ASML's customers include many of the top suppliers of computer chips. To stay competitive, they must help their customers keep up with Moore's law. What they are finding is that the newest generation of machinery aimed at maintaining that progress requires understanding a level of physics where many effects, such as fluid flow and solid mechanics, are inherently coupled.

Multiphysics simulation is a nonnegotiable tool for many industries that are moving toward building devices with micrometer and nanometer levels of precision.

⇨ OPPORTUNITIES AND CHALLENGES WITH EXTREME UV LIGHT

Creating higher performance chips means cramming more transistors into a given unit area. Physical features are getting smaller (Figure 1), which poses challenges to the manufacturing process, and are sensitive to minute environmental changes. The accuracy has greatly improved from previous generations of systems. The latest photolithography machines (Figure 2) exploit extreme ultraviolet (EUV) light, which has a wavelength of 13.5 nm, to etch features. "There is a direct linear relation between the wavelength of the light that is used and the size of the components — the critical dimensions — that are projected on the microchip," explained Fred Huizinga, group leader for mechanical analysis. "We are talking about nanometer-scale features with exceptionally small tolerances."

The photolithography etching process requires a clean vacuum and the use of precision air-bearings that use a thin layer of compressed gas between the load surfaces instead of oil or rollers. These air bearings are sensitive to micromovements and very small pressure variations have great impact on the accuracy of the etching. "In such systems, physical testing can take far too much time. In fact, some of these phenomena are so small, it is difficult to test or measure [them at all] because the deformations sometimes are of an order of magnitude that is lower than the measurement accuracy." In that case, the only engineering insight available is through numerical simulation.

⇨ A COMPLETE TOOLBOX FOR AIR-BEARING DESIGN

Huizinga joined ASML after 25 years directing engineering activities in the automotive industry. "To design and analyze our machines requires access to so many different physics, we need to use a lot of simulation tools. There are many such tools available as long as you are confined to what you might call 'single physics'; say, analyzing a problem that is entirely thermal or entirely mechanical." For him, the COMSOL® software is an especially useful tool in multiphysics modeling, since "nanometer phenomena and

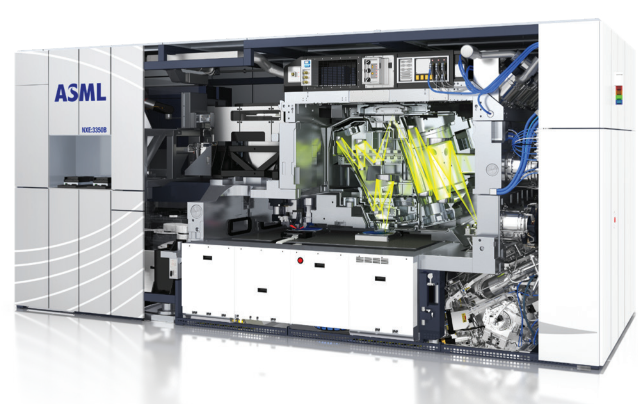

FIGURE 2. The ASML® TWINSCAN® NXE:3350B production-ready EVU system produces 125 computer wafers per hour using 13.5 nm wavelength light. It must keep a perfect vacuum while moving wafers at high speeds and loads, maintaining distortions to less than 1 nm.

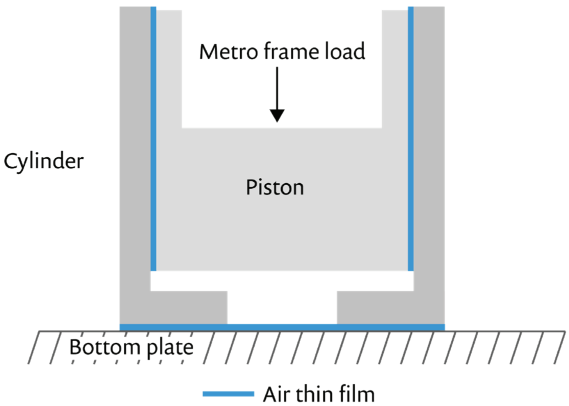

FIGURE 3. Schematic of an air bearing used in the photolithography systems at ASML.

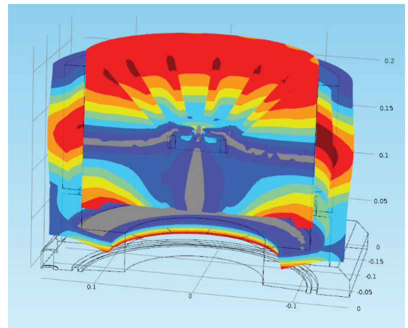

FIGURE 4. Radial deformation of the cylinder and piston in an air bearing.

> *"COMSOL® software is an especially useful tool in multiphysics modeling, since nanometer phenomena and complex systems demand a multiphysics approach, a complete simulation toolbox."*
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A good example where multiphysics simulation is mandatory is their development of an air-bearing model (Figure 3). These are important to ASML because there is a lot of physical movement in photolithography machines. Air-bearings also provide higher stiffness and thermal isolation and don't release particles due to friction.

However, this precision presents new challenges. The pressure distribution of the air film will locally deform the structure and influence the width of the air gap between the bearing surfaces. Since the gap width will change the flow of air between the surfaces, it in turn affects the pressure distribution and, again, affects the deformation (Figure 4). The problem requires a fully coupled fluid-structure interaction (FSI) model, which they implemented in COMSOL. The result is a simulation that helps engineers specify important design criteria, including translational and rotational stiffness, gap size under load, and the amount of air consumed.

Another important example Huizinga pointed to for the future is simulating the load on wafers as they are placed on the table for processing. The deformations of consequence are so small (nanometers!) that the wafer must be modeled as an elastic body affected by gravity, friction, thermal heating, and adhesion while held in place with clamping forces using a vacuum or electrostatic field — again, a fully coupled multiphysics problem. The model will help designers to optimize their design without the need for a time-consuming and expensive prototyping process.

➪ COMPLEXITY MADE ACCESSIBLE WITH SIMULATION APPS

Just as important as modeling is accessibility. Even for engineers who are competent in using multiphysics software, accessibility means providing simulation applications that take much of the routine or complex work from the user. This is where ASML finds the Application Builder tool available in COMSOL Multiphysics® handy, using it to create an Air-Bearing Calculator app that allows colleagues throughout the team to virtually test the performance of different bearing designs without digging into the original model (Figure 5). "It takes away the effort of creating a mesh, analysis setup, and postprocessing," said Huizinga.

Developing multiphysics models, validating them as much as possible, and making them accessible is where ASML found value in the COMSOL product suite. And like ASML, the search for quality, performance, and cost-effective operation is driving many industries into building smaller products with tight tolerances and assemblies with closely fitted parts measured in microns. While ASML and the photolithography industry are undoubtedly on the frontier of this trend, it is an inspiration to others as well. Multiphysics modeling may often be the only practical solution as engineering problems measured in nanometers emerge. ❖

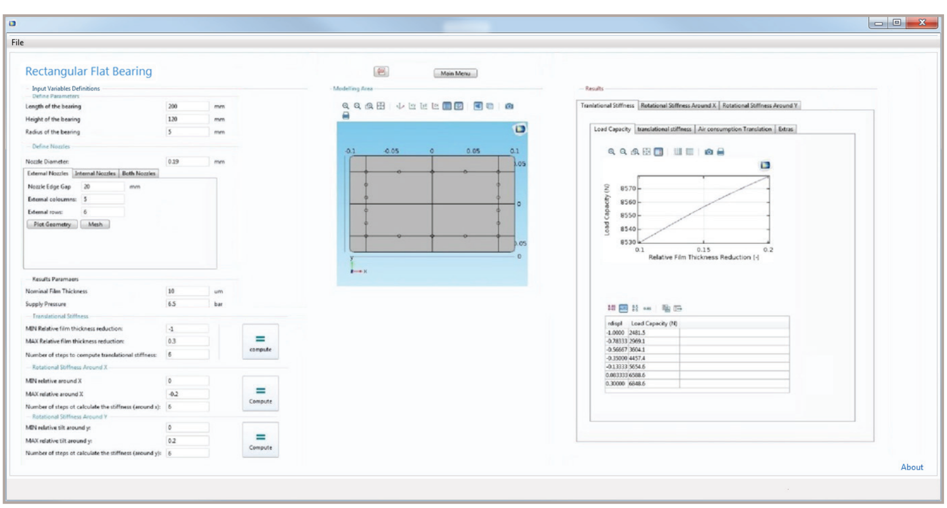

FIGURE 5. ASML created an air-bearing analysis calculator that allows engineers to input dimensions and other variables and get results, without having to specify a mesh and other model setup and postprocessing tasks.