So what happened this year at SPIE AL?

Part II: Further Thoughts

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April 19, 2019

Current Status of EUVL and Challenges – Further Analysis

This year's SPIE AL EUVL conference was a bit on the boring side this year, as EUVL is finally in HVM and there was lack of anti-EUVL sentiment which usually comes with a declaration of the end of Moore's Law. So I missed that usual excitement at the conference. Since EUVL is in HVM, there is not much space for criticism.

EUVL is currently being implemented at the 7 nm+ node and is getting ready for 5 nm (Samsung) and 6 nm (TSMC). Intel will be next. Focus is now on getting the yield up, and continued improvement in scanner uptime is helping. With every new version of scanner, users were starting with a low uptime which improved over time. However, with modular design, increased droplet generator and greater collector lifetime, I will expect ramp-up to 90% uptime will be quicker. Source power has a credible roadmap from current 250 W to 500 W. However, High NA and future nodes may need more than 500 W, and the extendibility of Sn LPP beyond 500 W is not clear yet. Defectivity added by scanner is now closer to 1 per 10 K passes, but we are not sure when and if it will be sufficient so that users can do without a pellicle. Pellicle is close to readiness, but not in use in current nodes.

Overall focus has shifted from scanner and ASML and toward infrastructure, as the solution to current challenges will come from the mask and resist community. Mask blank defectivity will need to continue decreasing and current focus is on new, thinner absorber layers that can be integrated into the process flow. I believe high NA scanners will be ready as planned by 2023. However, using them will require these mask and resist challenges to be addressed.

This year I noted the absence of GlobalFoundries, as they were the chip makers which used to have the most papers and had lots of excellent work to report. This year's agenda was mostly papers from IMEC and ASML. IBM continues to be active in EUVL, although they don't have a fab.

"Armageddon was Yesterday, Today We Have a Serious Problem."

This quote from Steig Larson sums up well the current situation. In previous years, many declared Moore's Law to be dead and EUVL was never going to roll out to fabs. Moore's Law continues but there are

several serious challenges coming our way, although I do not believe they are showstoppers at the 5 nm or 3 nm node. I don't believe we have enough data to say what will happen after that.

SPIE this year once again held a panel discussion on the future of Moore's Law. It usually turns into an "Annual Slaying of Moore's Law: How Moore's Law Died This Year And We Were Here To Tell You." I don't know what happened there as I skipped it, and instead went for dinner over kambucha at Good Karma with friends Ken Goldberg and Iacopo Mochi. Last year's discussions on stochastics were seen as the source of "black swans" and untamable defectivity that would herald the end of Moore's Law. That was last year. This year we had two sessions on stochastics with the theme of "Addressing Stochastics, or This is How We Will Address It." I am always impressed by bright people in this industry who never seem to run out of new ideas to solve the latest challenges.

After many years, there was no whisper or rumor of nano-imprint coming from behind and becoming the winner. Nano-imprint, once considered a competitor of EUVL, is now being considered by a smaller memory maker for one simpler kind of memory, and not for storage class memory. Mainly for them the defectivity could not be addressed and so cannot be used for leading edge semiconductor applications, but may have many applications in other areas where defectivity levels are acceptable and cost is a big thing. Best wishes for the technology based on contact lithography. Optical projection lithography is here to stay for leading edge computer chips.

The trail can go a long way – the real question is how far we want to walk. After High NA, High NA- MP and then Blue-X?

This March, I took time off for travel and one trip took me to Ojai Valley in California. One morning I decided to go for a hike in Horn Canyon that the resort receptionist had called moderate to difficult. It was stunningly beautiful scenery along the trail, and after crossing the creek a couple of times, I noted Google Maps telling me I was at least a mile beyond the official end of the hike. But I could see an okay trail, so I kept on walking until I ran into a barefoot local with a walking stick who was returning from a hike. He said he grew up in the area and walks there all the time. So I asked him, "How far does this trail go?" He looked at me and said, "The trail goes another 60 or 80 miles. The real question is, how far are you ready to go?"

The same can be said about Moore's Law. The Vanderwall radius of silicon and tin atoms is 0.2 nm, and for copper 0.15 nm. So we have still many atoms when we are talking 10 or 20 nm geometry. How far we want to or can go will depend on overall cost and complexity of manufacturing. There are talks on 150 B USD investment in new fabs by some chipmakers, so I see only increased investment to keep up with the Moore's Law. In many cases it is a matter of perception how far we want to push transistor density before we consider

it not worth the investment. As I said last year in this blog, it is all about speed of information processing. Precision manufacturing is only part of the story, although a major part for now.

I believe that once High NA scanners are in fabs, they soon will be put to use via multipatterning to continue to print smaller features. I believe now is the time for us to have another look at an idea of further reduction of wavelength to continue extension of EUVL. This new extension I am calling “Blue-X” because we don’t know yet what will be the best wavelength. For full consideration we need to look at optics, sources and resists at potential shorter wavelengths and discuss pros and cons. There will be two sessions on these topics in the upcoming EUVL Workshop in Berkeley in June. I will have a separate blog coming up to go into more detail on this and other EUVL related topics to be discussed in the Berkeley workshop. You can find out more for now by looking at the agenda at www.euvlitho.com

Case of Human Perception

During my travels, I had time for reading and got to read a translation of a classic text called Ashtavakra Samhita. This particular translation was recommended by a friend as it had the original Sanskrit together with the translation, so I could look back at the original language, when the translation did not quite make sense. Here are some verses that I liked and hope you enjoy as much as I did:

muktābhimānī mukto hi baddho baddhābhimānyapi
kiṃvadantīha satyeyaṃ yā matiḥ sā gatirbhaveta 1.10

He who considers himself free is free indeed, and he who considers himself bound remains bound. “As one thinks, so one becomes” is a popular saying in this world, and it is quite true. (1.10)

koḥ asau kālo vayaḥ kiṃ vā yatra dvandāni no nṛṇām
tānyupekṣya yathāprāptavartīṃ siddhimavāpnu yāt. (9.4)

What is that time or age in which the pair of opposites do not exist for men? One who, quitting those, is content with what comes of itself attains perfection. (9.4)

(Swami Nityaswarupananda, Advaita Ashram, New Delhi, November 2017 edition)

Mary Oliver

My favorite poet, Mary Oliver, passed away this year on January 17. She left behind a beautiful collection of poetry. I leave you with this selection from her poem, “In Blackwater Woods”

To live in this world
You must be able
To do three things:
To love what is mortal;
To hold it
Against your bones knowing
Your own life depends on it;
And, when the time comes to let it go,
To let it go.

(Devotions, Penguin Press, NY, 2017, pp. 389)