PHOTOMASK

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3rd place Best Poster — PUV18

Pattern edge roughness study on OMOG mask repair

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ABSTRACT

OMOG (opaque MoSi on glass) blank is widely used in advanced masks because of its advantage in high resolution and 3D effect1-2. And the manufacture flow is simple compared to phase shift mask. But the repair of this type mask is a challenge. The OMOG material is sensitive to the etching gas thus the etching rate is much higher than PSM. This article presents a problem, the poor edge roughness after repair in OMOG mask, is also related to the high etching rate.

The CD (critical dimension) of advanced masks is very small. If there is some distortion in the features' edge, the AIMS result is easy out of spec. The poor edge roughness we met usually gets poor AIMS result. To find the reason, we checked the manufacture flow and then focused on three steps: repair process, plasma treated process and short clean. Finally we found the plasma treated process was the main reason, and the clean process also contributed to it. Plasma process makes the mask surface oxidization and the oxide layer is high clean durability. The etching rate of oxide is slower than pure OMOG material, and the oxide layer's uniformity is not good. The two characteristics lead to different etching ratio in the defect area. This is the reason of the poor edge roughness. If the oxide layer is uniform in the defect area, the problem won't happen. That's why not all the masks we repaired met the problem.

We also found the removal of the oxide layer by clean process could solve this problem. This is an indirect evidence for explaining the reason.

1. Introduction

OMOG blank repair is different from PSM because the material is sensitive to etching gas. It will occur spontaneous etching3 even the fresh surface exposed to the gas without beam on (Figure 1). It is the mostly hard problem in OMOG mask manufacture. Currently we use an E-Beam tool which provides solutions for the spontaneous etching of OMOG repair. But there is still a problem troubled us: the edge roughness is poor after repairing (Figure 2). It leads to hard control of the AIMS result. As the CD(critical dimension) becoming smaller and smaller, a slight distortion may cause the AIMS result out of spec. OMOG mask are usually used in advanced mask whose feature size is extremely small and intricate so that this phenomenon

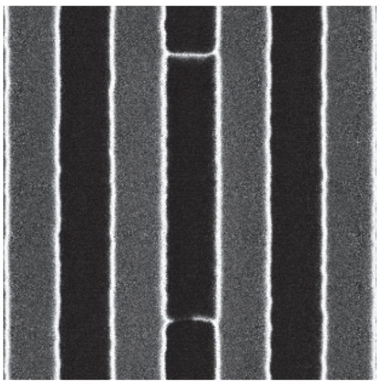
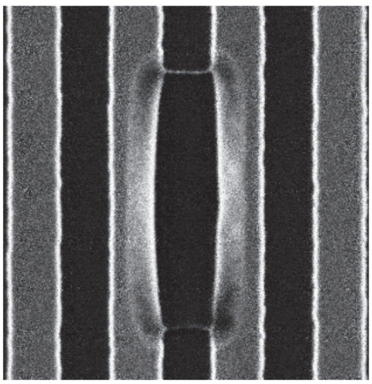
a)  b) 

Figure 1. Spontaneous etching in OMOG mask repair a) image after repair b) exposed to etching gas without beam-on for several minites. The fresh material is etched continuously.

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EDITORIAL

The War, the Slump, and the Reality

Artur Balasinski, Cypress Semiconductor

According to the recent press releases, we are in the middle of a trade war, between the US and China. One may wonder, what would such a situation mean to mask business. Would it be good or bad? Would it cause a standstill or a more rapid progress? Who may the casualties be?

Wars are known to bring in horrors, everybody knows that. However, they are also the times of the most strenuous efforts of the human race, both in mind and body. I am very far from advocating wars, but they led to huge changes in our lifestyles and significant technological progress. One may think that the total isolation between the two sides of the fighting front would cause the lack of new ideas. It turned out to be quite to the contrary. People were trying to outsmart and outlast the enemy. Of course, wars meant huge degradation of the human standards of living. But there were also small and big joys, of small and big victories, due to heroism, friendships, and foregoing old problems.

But these were the material wars, where people died. Without taking it lightly, would any photomasks "die" at the front of a technology war?

Certainly, China would stretch out to do without the American market and inventiveness. The consumers worldwide may pay more for the products, but there are many people claiming that electronic products are already coming too cheaply. We toss out the old versions of cell phones every few years, just to add a few new gadgets and some more speed to the newer ones. Perhaps we would invent a brand new thing making even the cell phones obsolete, just like the desktops are being obsoleted now? Virtual Reality is around the corner, and just in time, because moving human bodies around the world in order to "go places" that contain tourist objects, technical conferences, material products to purchase, or just the nature to enjoy, comes in an increasingly crowded environment. The disruptive technologies one may expect to come from the US, but who knows. Perhaps China would jump ahead when their brains are stirred in a different direction. But in either case, it seems like our business would be entrenched as we are the suppliers behind the front lines and we should focus on the usual, i.e., increasing the productivity within or without the Moore's law, and incremental progress overall.

OK, so how about this slump in the semiconductor industry everybody is talking about? Certainly, it is neither the first nor the last one we have to live through. The semiconductor universe is still contracting on the global scale and companies are merging, not mushrooming as in the expansion phase. It is not just that the fittest ones survive. Survive those, who know how to shape the future to their liking.

So then, what is the reality going to be like? Nobody has a crystal ball but there are still more synergies than disruptions, even with the perceived wars, and everybody wants pretty much the same (even North Korea!) without the need to bother with the war spoils. I think we will keep evolving with ups and downs (which may require a tough stomach) and just need to keep an eye on the ball.

As a BTW. For those wondering where did I get the idea about the continuous progress with no major catastrophes, I reviewed the recent, just-finished EMLC 2019 - 35th European Mask and Lithography Conference. The Technical Program heavy with Multi-Beam Technology developments, made me think of all those wonderful things we can build with the enhanced e-beam. I also looked at the list of participants and noticed Europe is doing a lot of the heavy lifting. From that perspective, the US-China war does not look that scary, does it?

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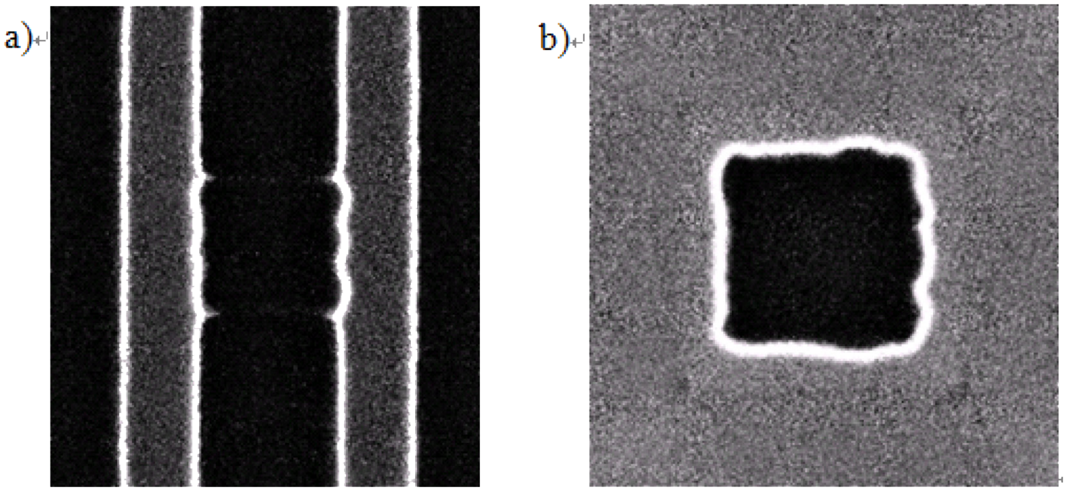

Figure 2. Poor edge roughness after repair a) programme defect b) etching a box.

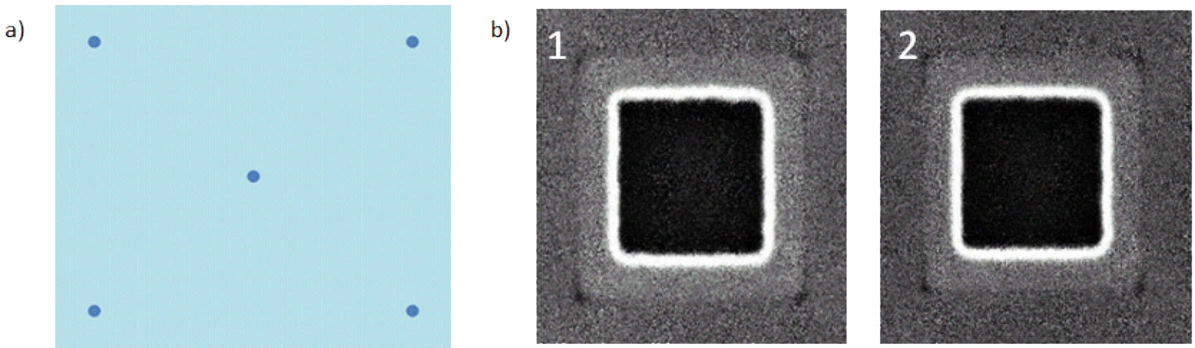

Figure 3. Image a) shows the etching positions which almost cover the whole mask. Image b) is the repair performance in two masks. The poor edge roughness is not found.

may be a killing problem in our mask manufacture. Not all masks we made had this problem. The manufacture processes were checked and finally we focused on three steps: repair process, short clean and oxygen plasma treated.

Short clean is used after repair for more accuracy AIMS result as there may be some residue on the repaired area. Oxygen plasma is for CD protecting in clean process as the clean chemical could remove the MoSi material on the mask surface.

2. Experiment and Analysis

2.1 Repair process check

Repair process stability was firstly checked. The gas flow, system vacuum and beam status were the main items. We checked one months' data and find these items quite stable. Then 2 plates mask without oxygen plasma or clean process were tested. 5 boxes were etched in etch one and the positions are showed in Figure 3a). The repair performance is showed in Figure 3b).

The mask without other two processes didn't get poor edge roughness after repair. So the repair process is not related to the problem.

2.2 Oxygen plasma check

Oxygen plasma oxidizes the surface material and significantly improves the mask clean durability. The oxide layer is hard to remove in different clean chemicals. It is wildly used in other type mask manufacture. Figure4 shows the advantage of plasma in CD protecting. Both masks were cleaned 5 cycles and took the averaged CD movement. ΔCD of oxidized one is set as 1and it is only 1/5 of the pure OMOG.

The mask repair time is also longer after plasma treated (Figure 5). That means the etching rate of the oxide layer is slower than the pure material. But we can't know the etching selectivity because of lack of analysis method for the oxide layer thickness.

We checked the repair performance of several masks with plasma treated. Not all the masks got poor edge roughness after repairing (Figure 6). Mask 1 and mask 2 got severe edge distortion while the mask 3 and mask 4 got smooth one. Mask 5 had the trend to become distorted. All the etching positions were same in the mask. As the result presented in Figure 6, we could say the oxygen plasma play a role in the problem.

2.3 Clean process check

Usually there will be some residue on the etching area after repair. For accurate AIMS result, we will take a short clean. Clean chemicals are combined in different types for different purpose. In this case, we used acidic chemicals for short clean. As the plasma process was finished before repair in mask manufacture flow, 2 masks with plasma treated were tested (mask 3 and

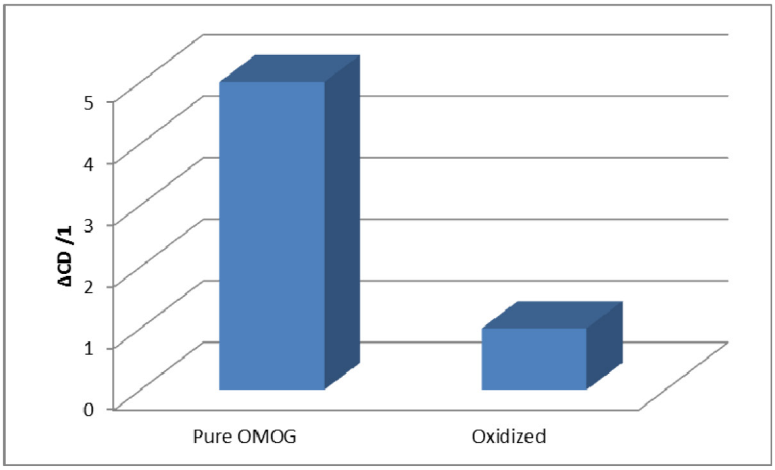

Figure 4. The ΔCD of OMOG masks with and without oxygen plasma treated in clean process.

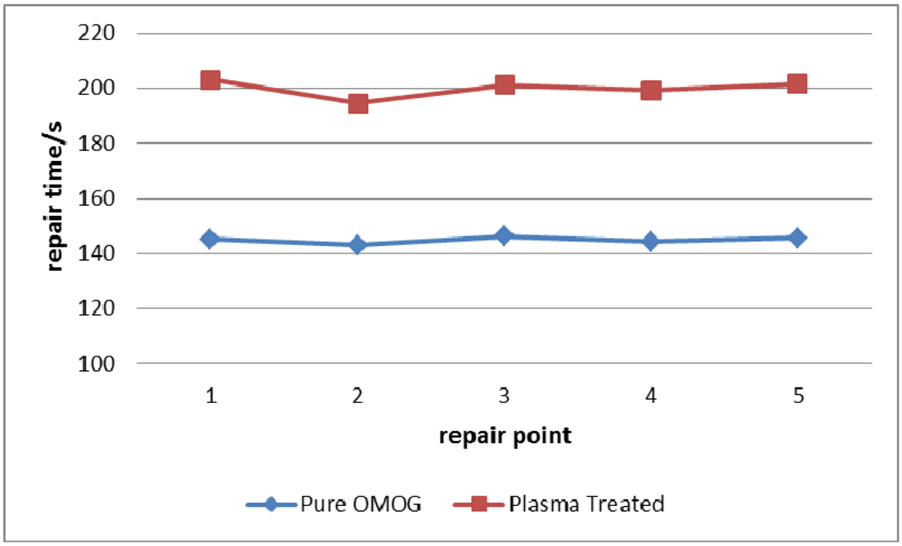

Figure 5. The repair time before and after plasma.

mask 4 in chapter 2.2).

The result is showed in Figure 7. The acidic clean induced the poor edge roughness in repair even the mask had no problem before clean. The effect of clean only was also tested after that and no problem occurred. Other clean chemicals such as Ozone and ammonia were also tested but no problem occurred.

As the results showed above, poor edge roughness is caused by oxygen plasma, and the acidic clean will make it worse. The mechanism of this phenomenon is not very clear currently. We suspect that it comes from the poor uniformity of oxide layer. Because of the different etching rate between oxide and pure OMOG material, there will be some areas with thinner oxide etched faster than others (Figure 8). After the supposed repair area etching finished, the others may be over etching which finally represents a poor edge roughness.

3. Solution Researching

As the reason of poor edge roughness found out, we can remove the oxygen plasma process to get good repair performance. But the CD movement in clean process would be a problem as the strict spec of advanced mask. We did some tests to find whether there are some solutions for better repair performance and keeping the plasma process in the same time.

3.1 Different plasma test

Improving the uniformity of the oxide layer may be a solution of this problem. We tried two ways to improve the oxide uniformity. One was changing a better plasma tool which had a good uniformity control. We used dry etching tool instead of the old plasma (combined in cleaner) but the result is not good. Another way was increasing the plasma time to make the oxide layer saturated. The plasma end point was judged by repair time. It also didn't work.

3.2 SC1 clean

SC1 is a mixture of aqueous ammonia and hydrogen peroxide. it is widely used in wafer clean. The surface of silicon is oxidized by hydrogen peroxide to form silicon dioxide, and then the silicon dioxide thin film can be removed by aqueous am-

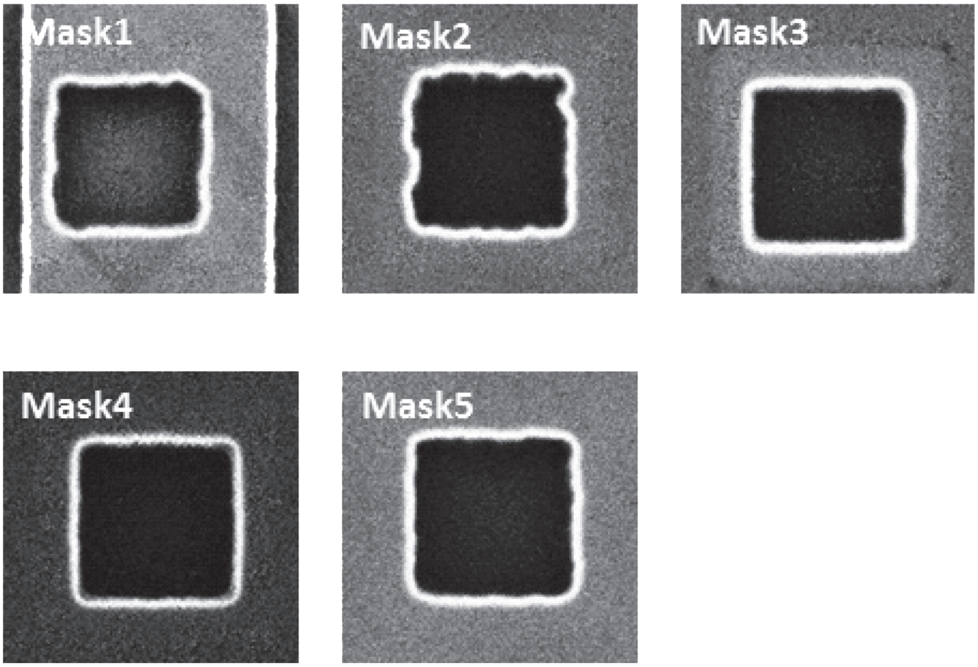

Figure 6. Repair performance in different plasma treated masks.

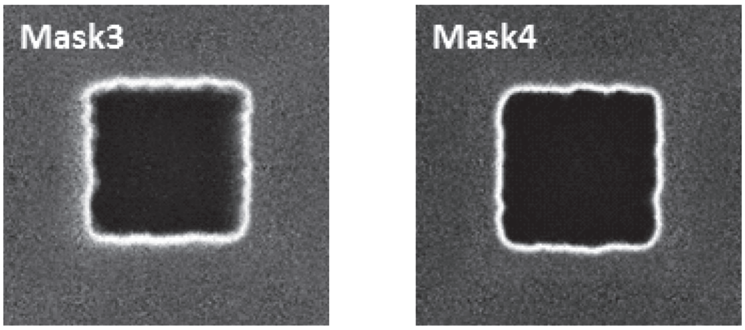

Figure 7. Repair performance after acidic clean in mask 3 & mask 4.

monia, the particle on the surface is also removed. As the poor edge roughness not happened in all masks, we can apply this chemical to remove oxide layer once the problem happened. Different clean times were checked and the repair performance is showed in Figure 9.

As the clean time increasing, the edge distortion disappeared. But the oxidation layer was not removed totally because the repair time was still longer than pure OMOG material. A thinner oxide still had the ability of CD protecting. An extra clean test after the 60 minutes was applied and the CD was almost no change.

4. Conclusion

Oxygen plasma is useful in protecting CD from the clean process. The risk of CD out of spec will increase if the mask without plasma treated needs many repair cycles. Currently we could apply SC1 clean if poor edge roughness appears after repair. But there still has a thin oxide. If we could make a thin oxide film with a good uniformity firstly, the problem may not happen. Maybe a short time of dry etcher's plasma works in this case. We will continue this work for a better solution.

5. References

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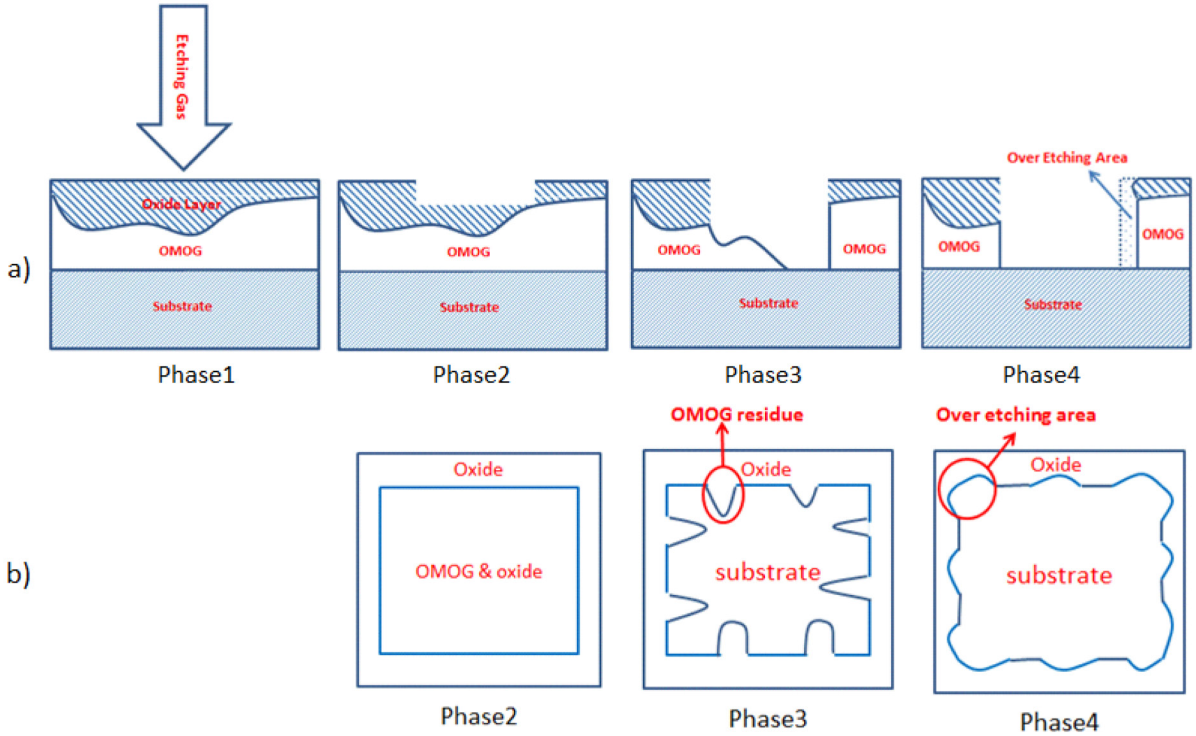

Figure 8. Different etching status in plasma treated mask: Phase 1 is the beginning of etching. Pure OMOG material expose to etching gas somewhere in phase 2 and the substrate appear in phase 3. Repair process finish in phase4 and the over etching area appear. Image a) is the section plane and b) is the overlook.

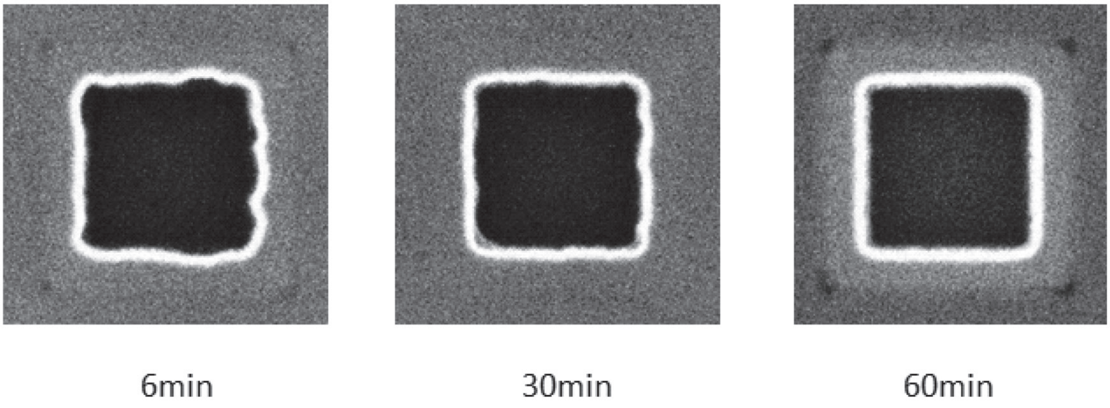

Figure 9. Repair performance of different clean time.

Industry Briefs

Semiconductor Slump 'Worst in a Decade'

World's ten leading chip makers each report declining sales in key market for lasers and optical systems. Analyst firm IHS Markit has declared the current slump in the global semiconductor market as the worst for a decade, after all ten of the world's leading chip manufacturers reported declining revenues.

http://optics.org/news/10/5/42

Chipmakers Open Checkbooks to Bolster Connectivity

Infineon Technologies has inked a deal to acquire Cypress Semiconductor for $10 billion, the latest in a series of acquisitions of connectivity chip suppliers in the last few months. Last week, NXP announced it was acquiring Marvell's WiFi and Bluetooth connectivity assets for $1.76 billion. And in March, Nvidia said it was acquiring networking IC vendor Mellanox Technologies for $6.9 billion. The common thread appears to be connectivity...

https://www.eetimes.com/document.asp?doc_id=1334772

Where IoT, AI & Quantum Computing Meet

Where do IoT, AI and Quantum Computing intersect? The short answer is that they meet where data is growing exponentially. The long answer is... well, it's complicated. Last week, a panel at the Design Automation Conference (DAC) drilled deep into this difficult topic. Participating were the winners of the "2019 Under 40 Innovation Awards" — young engineers and researchers working on next-generation technologies...

https://www.eetimes.com/document.asp?doc_id=1334793

Chip Equipment Billings Plunge

Global billings for chipmaking equipment during the first quarter this year plummeted as the semiconductor industry hunkers down in the trade war between the U.S. and China. Billings in the first quarter plunged 19 percent from the same period a year ago to $13.8 billion, according to global electronics industry association SEMI....

https://www.eetimes.com/document.asp?doc_id=1334792

2020 57thDAC to Co-Locate with SEMICON West!

Probably the most interesting news out of 56thDAC thus far is the announcement that in 2020 and 2021 DAC will co-locate with SEMICON West. It's great news really since this is something that has been discussed over the years but has been deadlocked due to "failed negotiations". Unfortunately, simple logic goes out the window with most failed negotiations. This co-location is a simple case of 1+1=3 in my calculation...

https://semiwiki.com/events/259617-2020-57thdac-to-co-locate-with-semicon-west/

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Founded in 1980 by a group of chrome blank users wanting a single voice to interact with suppliers, BACUS has grown to become the largest and most widely known forum for the exchange of technical information of interest to photomask and reticle makers. BACUS joined SPIE in January of 1991 to expand the exchange of information with mask makers around the world.

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CALENDAR

2019

The 35th European Mask and Lithography Conference, EMLC 2019
17-19 June 2019
Hilton Hotel Dresden
Dresden, Germany

SPIE Photomask Technology + EUV Lithography
15-19 September 2019
Monterey Conference Center and
Monterey Marriott
Monterey, California, USA

2020

SPIE Advanced Lithography
23-27 February 2020
San Jose Marriott and
San Jose Convention Center
San Jose, California, USA

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