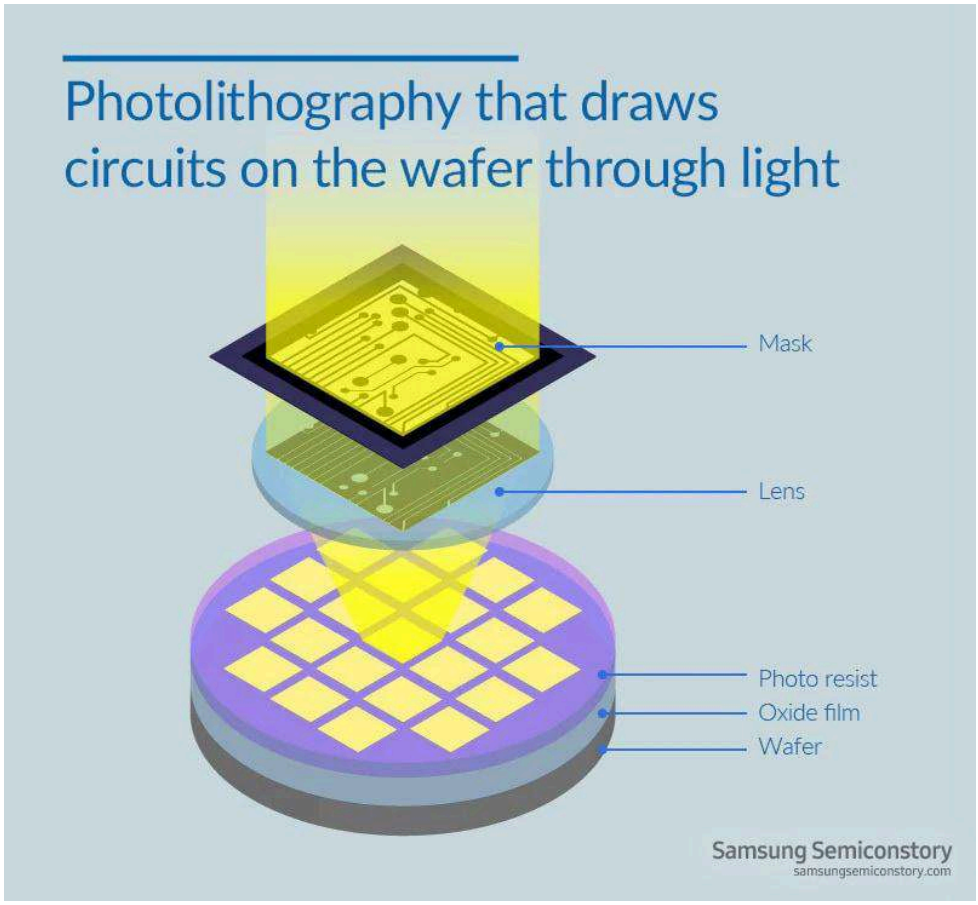
Masking Techniques: From Chip Manufacture to Art Practice.

By David Matunda

Smart devices are everywhere: phones, computers, cars, fridges, vacuum cleaners, lights... What a lot of people don't know is that what makes these devices 'smart' and enables them to compute is little microchips within the device. What even fewer people know is that designing these microchips involves a sophisticated process using light and 'masking' techniques which incorporate processes from art, science and engineering disciplines.

Check out my 'PHOTOMASKS AND THE MANUFACTURE OF MICROCHIPS' guide to find out what 'masking' actually is in this context before you delve into this blog post's main exploration of masking, digital arts and how this relates to my own artist practice. We will go on some beautiful tangents along the way, but I invite you to come along for the journey. For the full experience I recommend that you click on as many of the reference links as possible!



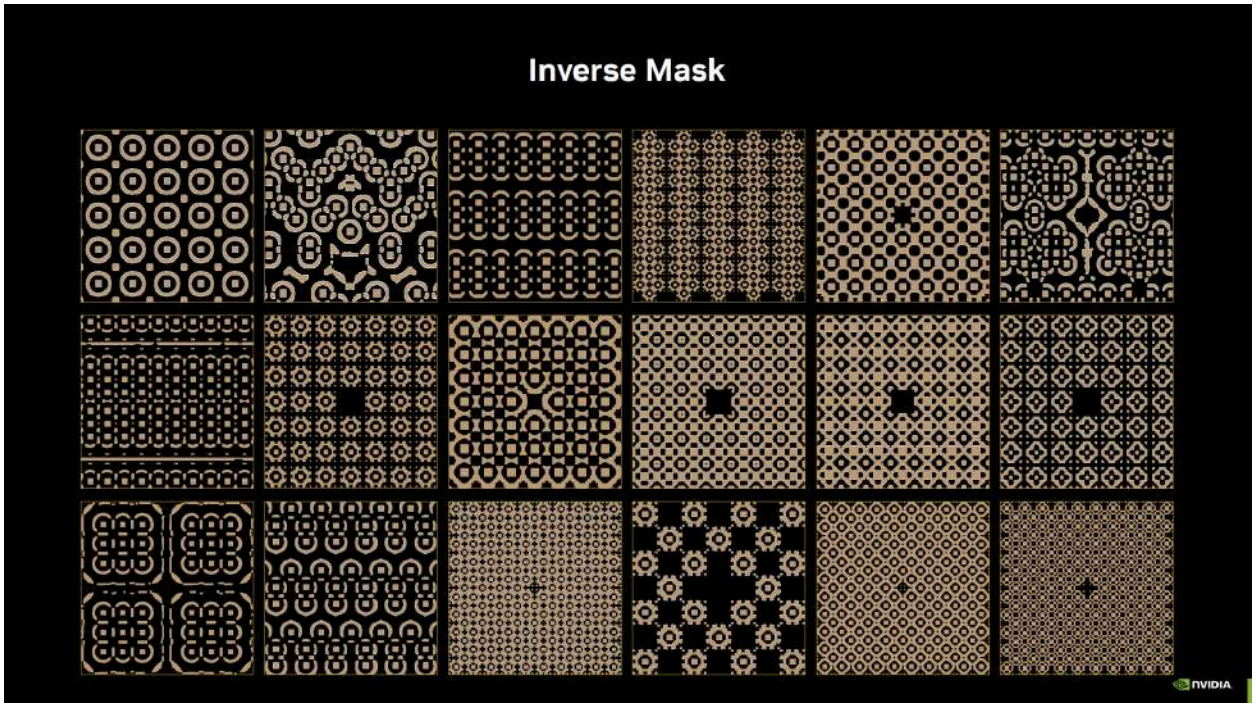
[source: Drawing Structures in Nano-Scale | Samsung Semiconductor Global]

(Appendix A)

Why I'm interested in Masking:

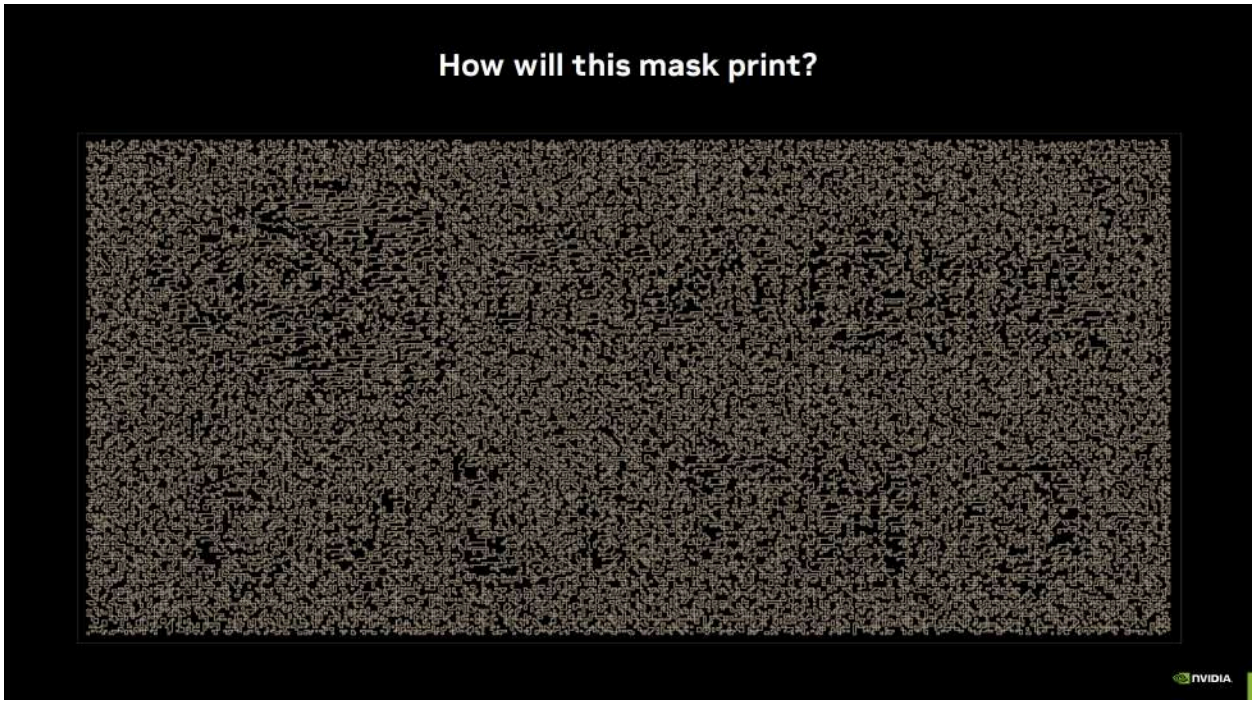
The most cutting edge innovations in masking (used to design the next generation of microchips such as Nvidia's AI-enhanced cuLitho library of software), link us right back to the physical techniques used in older forms of printmaking.

Initially it was the Nvidia Vice President's description and demonstration of the mask designs created by their inverse lithography software library that inspired me to explore the topic of masks for this blog.



[image: These photomasks have been designed to inversely print the holes required on chip. An inverse mask of the design is used due to the small size of the features.]
(Appendix C)

"..very unintuitive, curvilinear... kind of pretty", I liked that it sounds like an engineer describing an artwork. The demonstration of the library and further research has led me to reflect on a wider understanding of masks as they relate to technology, particularly e-waste and legacies of the British empire, which will briefly be addressed in this blog post as well.



[image: A chromeless phase-shift mask. This mask has been etched to print an image onto a silicon wafer once light has scattered through the mask. The mask design was created with the Nvidia cuLITHO library.]
[video: https://youtu.be/Zs1XZaimaUs?t=1500]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]
(Appendix C)

[image: Would you have guessed this was the printed image?]
[video: https://youtu.be/Zs1XZaimaUs?t=1521]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]

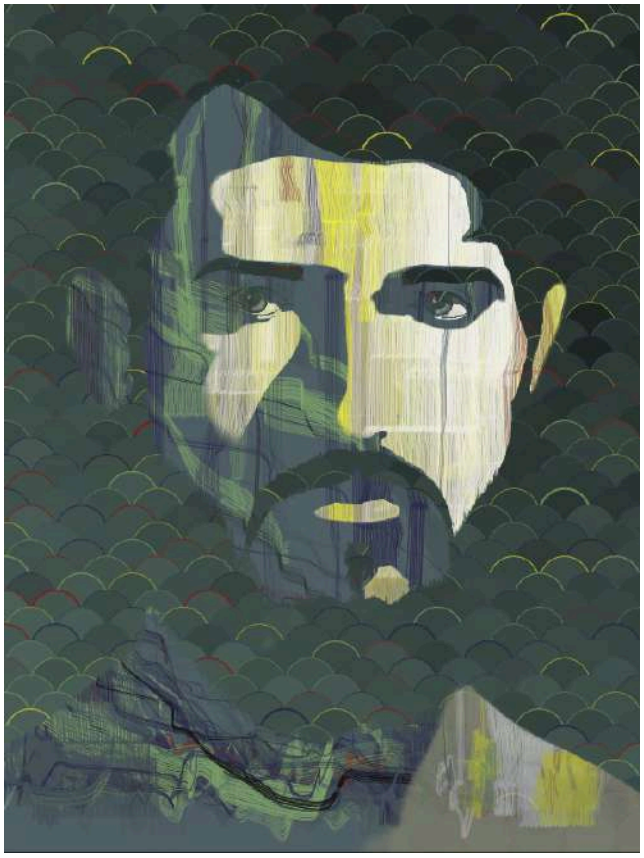
(Appendix C)

But first I will explore how a variety of artists, with a digital art practice, approach the concept of masking techniques. The artists I refer to use **broad** creative interpretations of masks as a tool to copy images from one source to another but also to isolate, hide or reveal a design/motif in some or all parts of an image.

The practitioners I refer to work in a range of digital mediums from creative coding, photo editing apps, AI tools and games.

Masking and Code Art

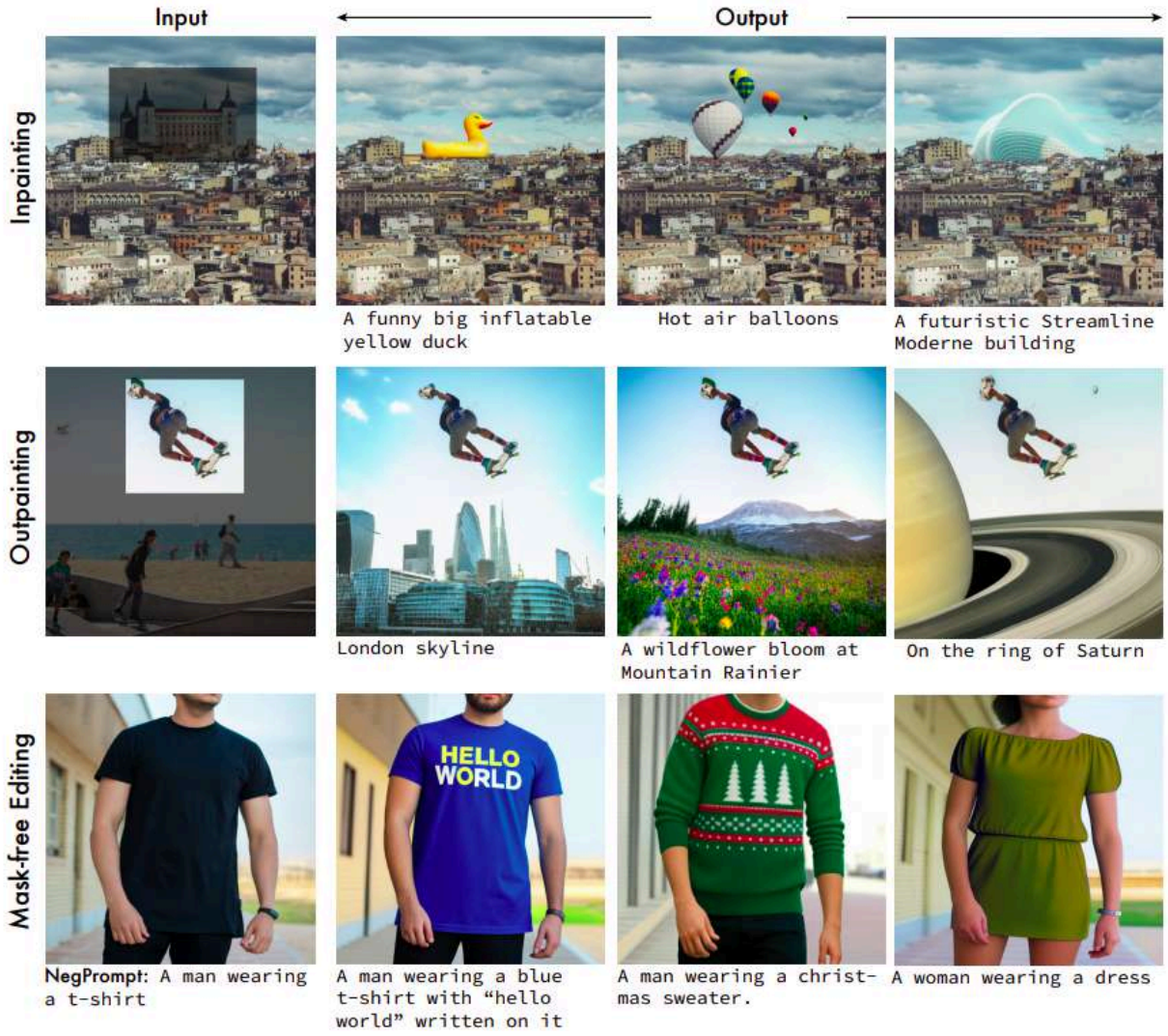
Tyler Hobbs is an American artist working with paint, code and plotters. He wrote a tutorial for one of the ways you could combine hand-drawn images with software and code. In the tutorial he applies masks onto a hand-drawn self-portrait using MyPaint and then applies different generative art graphics on the different mask layers with Processing code.



[source: Integrating Drawings and Generative Artwork: Masking — Tyler Hobbs]

Masking and AI Art

Like in the previous example, the same concept of masking where a part of the image is isolated has also been the subject of AI research. Google Research announced Muse in 2023. The full name hints more at what Muse does, *'Muse: Text-To-Image Generation via Masked Generative Transformers'*.

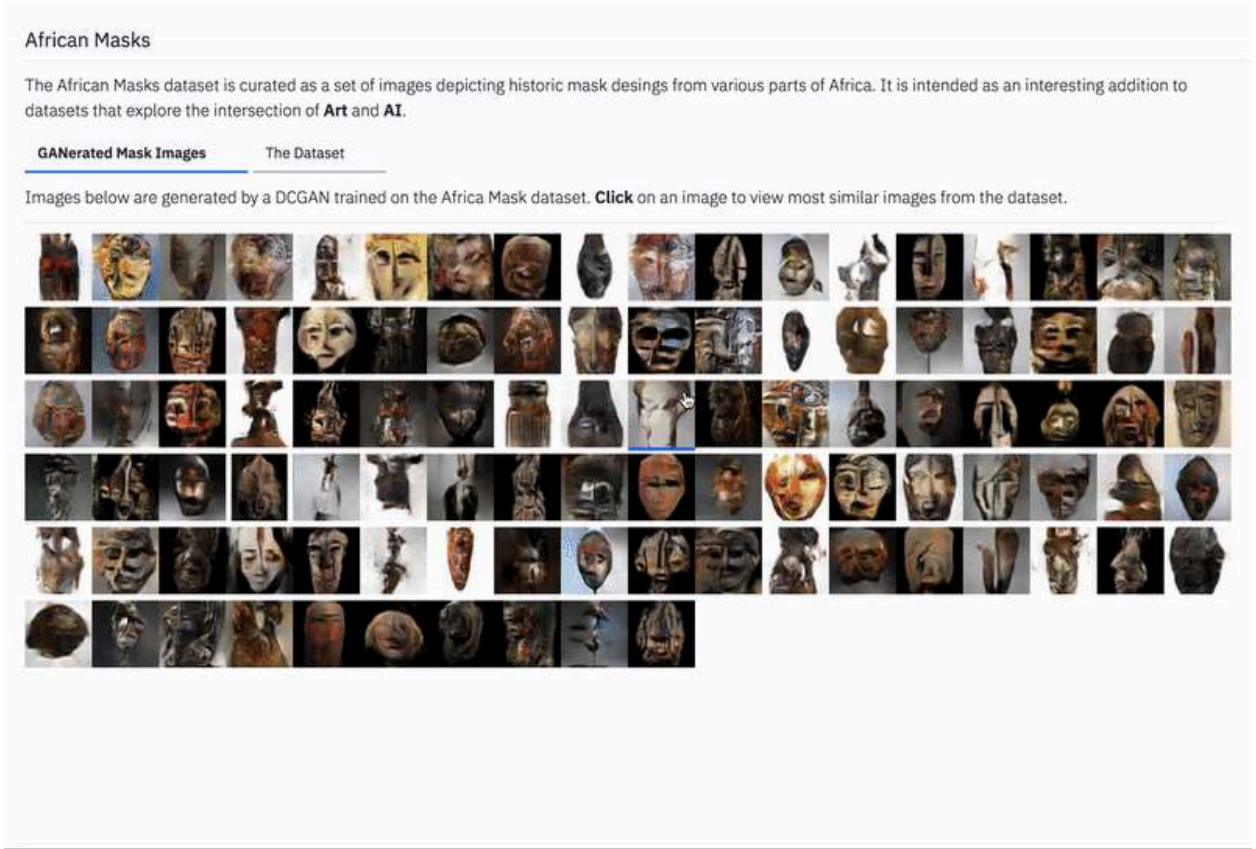


[source: Google Muse AI Explained: How Does It Work? - Dataconomy]

Some of the researchers for Muse previously developed MaskGIT: Masked Generative Image Transformer, a similar but less advanced tool. With Muse you provide an image and a prompt, then you can select a part of the image to be the masked region. Muse's AI model will then generate an image from the prompt in the masked region but it also supports maskless image regeneration. To try Muse, there is a pytorch implementation.

[image: Class-conditional Image Editing by MaskGIT]
[source: MaskGIT: Masked Generative Image Transformer]

Victor Dibia is a Research Software Engineer on the Human-AI eXperiences (HAX) Microsoft Research team. He's the creator of COCO-Africa: A Curation Tool and Dataset of Common Objects in the Context of Africa, images generated from this project form Dibia's 'Ikenga Collection', a series of six GAN(AI) generated images trained on a manually-curated dataset of approximately 9300 images.



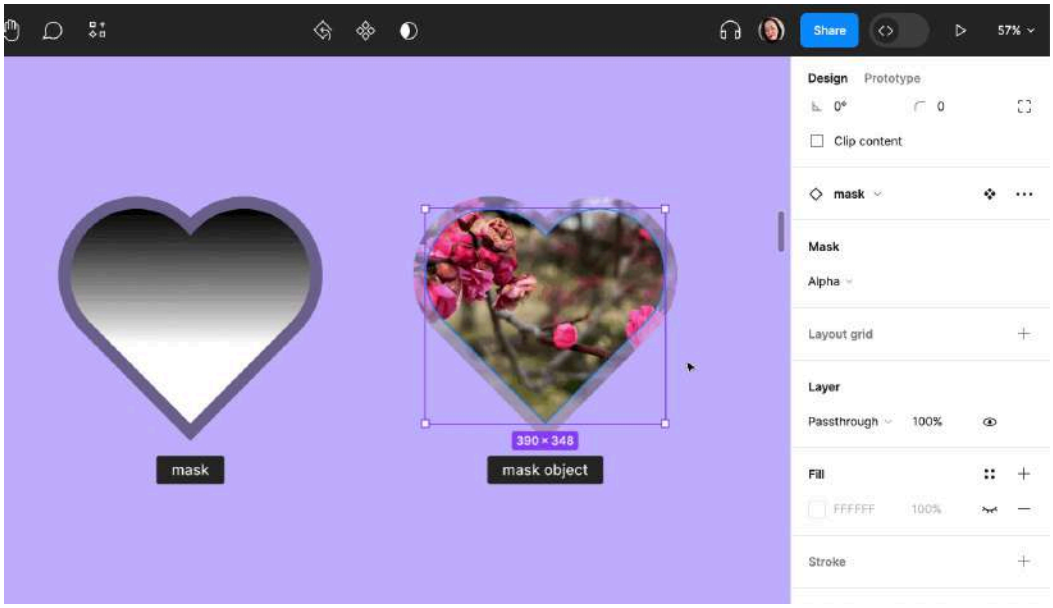
[source: ART + AI — Generating African Masks using (Tensorflow and TPUs) | by Victor Dibia | Towards Data Science]

Dibia's AI art practice uses masks in a totally different interpretation to Google Research's Muse or MaskGIT but still an interesting exploration of thinking about masks in relation to AI art.

[source: The Ikenga Collection: African Mask Art (Art + AI) | Victor Dibia]

Art using Masking Tools in Photo Editing Mobile Apps

If you've ever used paid photo-editing software like Adobe's Photoshop or free alternatives like Figma, you might have come across a specific masking tool.



[source: Masks – Figma Learn - Help Center]

In the context of image editing and creating vector graphics, to use masks involves layers. Frank Dorrey is a Haitian-American artist combining masking as well as layers and photo manipulation, he uses an iPhone 8s and the Picsart app.

[image: "THEN SHE TELLS ME SHE WANTS TO DO DA PHOTO OVER CUZ HER EYES WERE CLOSED" BY FRANK DORREY]
[source: Frank Dorrey's freaky artworks are made using a surprising tool]

In a 2023 interview Dorrey says “You’re going to become that monster in somebody’s eyes.” He's specifically talking about the references to create one work in particular.

[source: Frank Dorrey’s Pop Culture-Laden Art…]

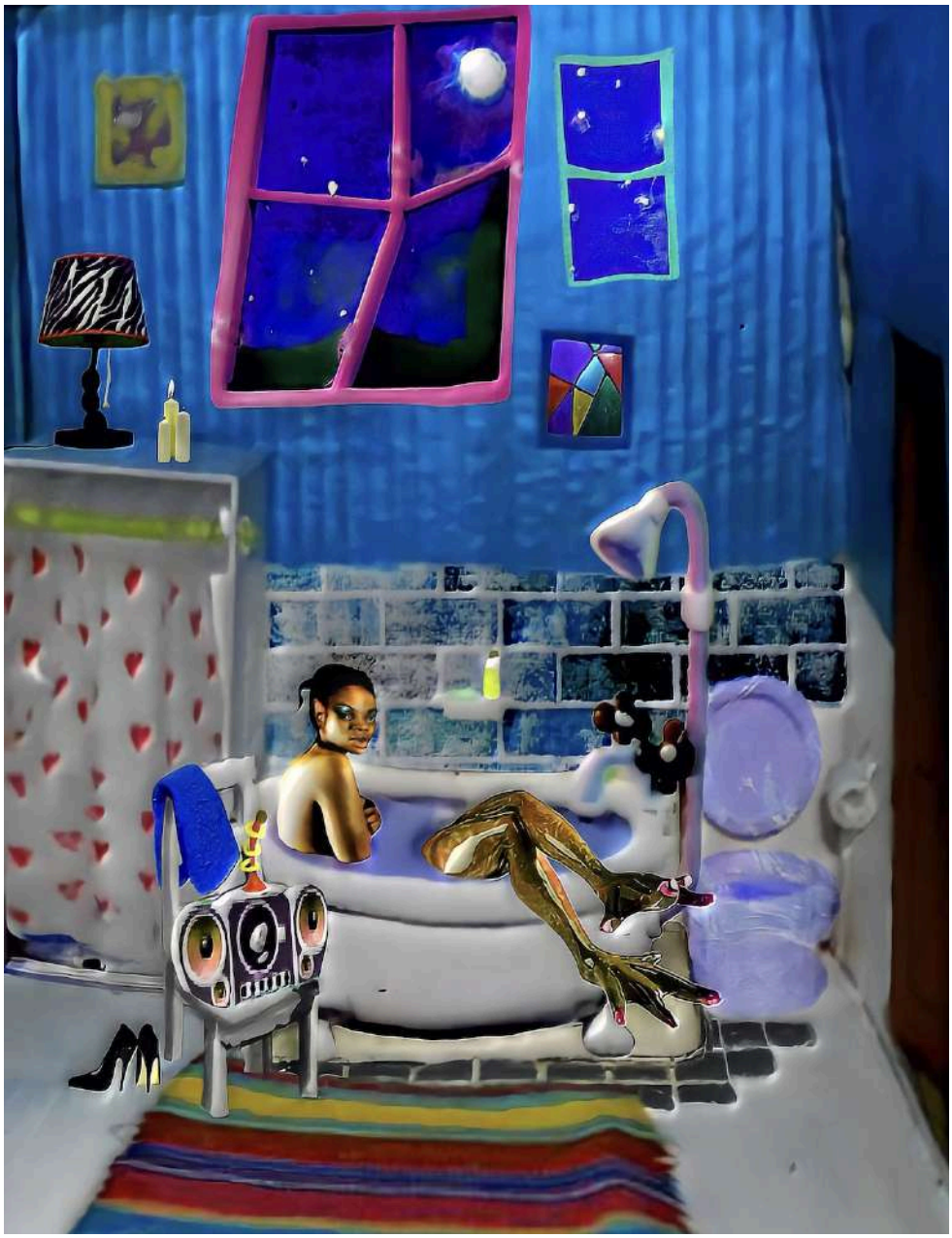
In the interest of this blog’s exploration of *masks*, there’s a connection between Dorrey’s comment about being a monster and the 1952 book, ‘Black Skin, White Masks’(BSWM) by Frantz Fanon(1925-1961), the postcolonial philosopher and psychiatrist from the former French colony of Martinique.

[image: "SIMPLE LIFE" BY FRANK DORREY]
[source: Frank Dorrey's Pop Culture-Laden Art...]

In BSWM Fanon develops a concept called '*sociogeny*'. An oversimplified definition is that sociogeny is a concept which challenges ideas about how different groups are socially *constructed* rather than natural and self-evident, as a concept it places importance on lived experience in relation to other groups.

[image: "BLOODER" BY FRANK DORREY]
[source: Frank Dorrey's Pop Culture-Laden Art...]

Dorrey's work uses images of people he knows, his colour and texture preferences are drawn from his Haitian background. The editing tools in the Picsart app enable Dorrey to distort people and entire scenes. In making the aesthetic choices that Dorrey does as well as his choice of subjects, Dorrey fully embraces digital artifice in the *construction* of the grotesque image. True to his response and arguably forming a link to sociogeny, Dorrey's work reveals the 'monster in somebody's eyes'.



[image: "SHAPESHIFTINGLADYBOMB" BY FRANK DORREY]
[source: Frank Dorrey's Pop Culture-Laden Art...]

It's not entirely clear how a masking tool would fit into Dorrey's Picsart process(if it even does at all) but you can see how a digital artist *might* use masks and layers to isolate one graphic onto an object in the scene to enhance an uncanny cartoon effect, similar to collage but more expressive and polished.

[source: @frankdorrey]

How Tech is Material

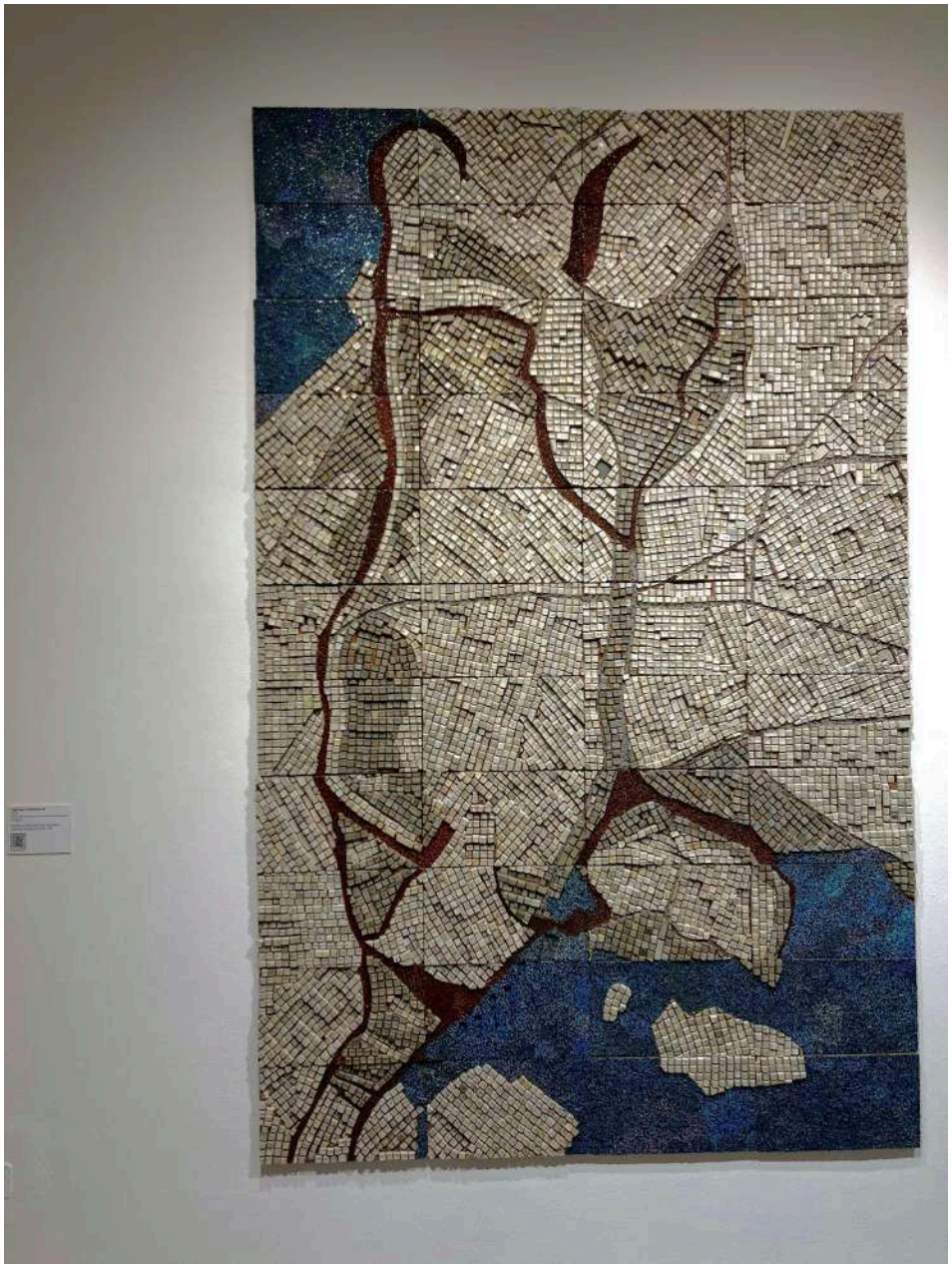
Elias Sime is an Ethiopian artist whose recent show at Arnolfini Arts in Bristol provides an alternative use for tech surplus and tech waste that ends up in Africa. Forcing us to consider other ways of understanding how tech is material.

[image: Tightrope Concave Triangle #2, 2020]
[source: Elias Sime: Eregata እርጋታ - Arnolfini]

Elias Sime doesn’t make digital art but he’s included in this blog post because it would be impossible to make digital art without his choice of materials for the most recent works in the Eregata exhibition.

[source: Elias Sime: Eregata እርጋታ - Arnolfini]

Some artworks also definitely make use of masking techniques. Electrical cables braided and held in place by nails on panels of varying shape provide a background. Masked shapes made of keyboard keys sit on top of the braided cable background. In other pieces instead of keyboards keys and braided cables it's printed circuit boards and other electrical components found in computers.



[image: Tightrope: Noiseless 18_2019]
[source: Elias Sime: Eregata ኤርጋታ - Arnolfini]

The influx of discarded consumer electronics and consequently, e-waste into Africa was mentioned by Kojo Koram in 'Uncommon Wealth: Britain and the Aftermath of Empire' (2022). One passage highlights this ecological reality:

> "An avalanche of unsellable commodities, shipped in from London and Rotterdam as well as Lagos and Kumasi, piles up here, at the ultimate depository of capitalism's global supply chains. The amnesia of empire leads many in Britain to think that the problem of the Third World is that the people living there just can't get access to the by-products of Western consumer capitalism. The reality is that they can't escape them."

-pp.150

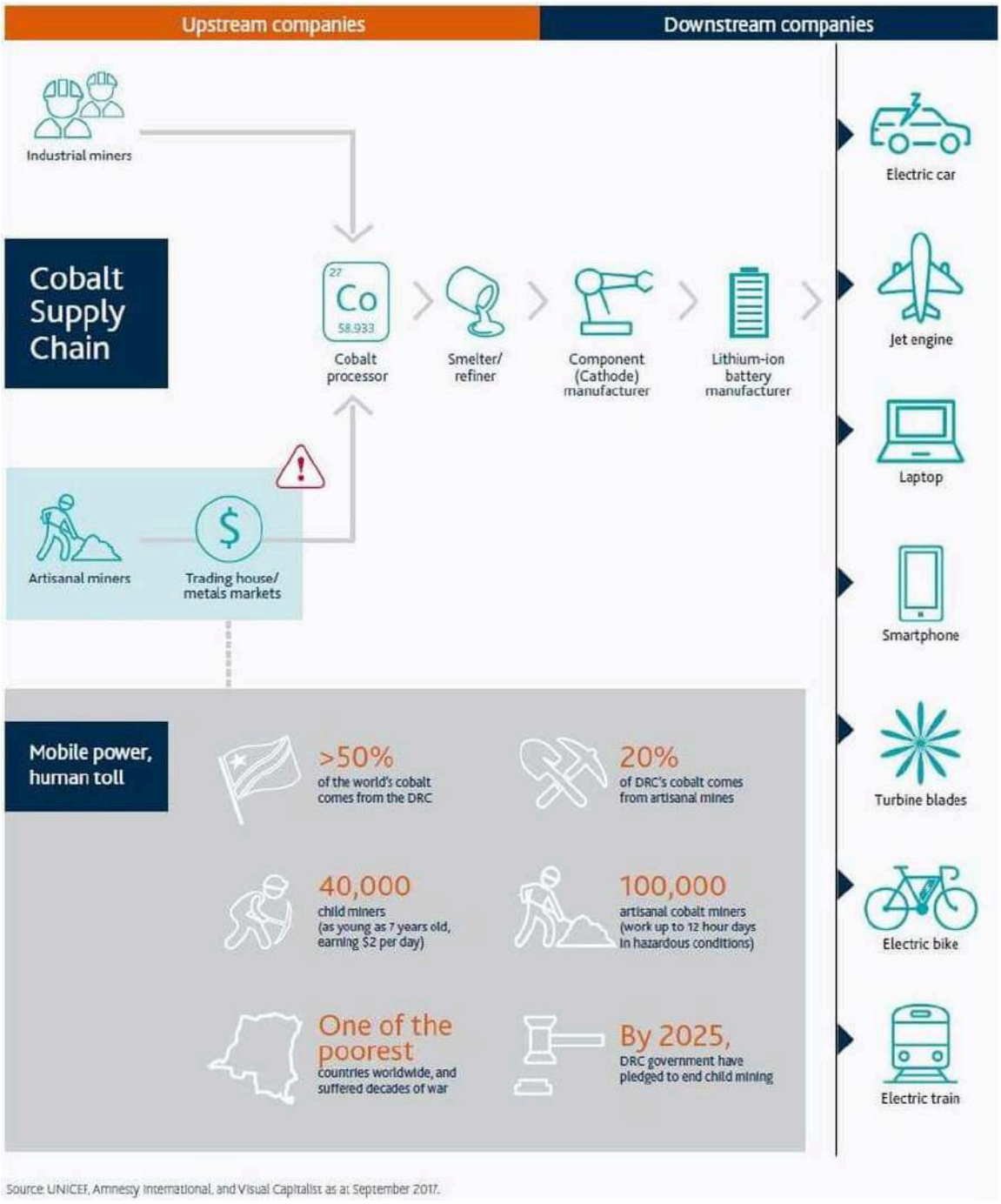
[source: Experience by DECIMAL POINT UG | TikTok]

Whether using a photo editing mobile app or hand assembling electrical components. The ability to *add* layers and transform a material whether through masking techniques or other means is irresistible for both Sime and Dorrey. A direct line can be drawn from this desire and the global rising consumer demand for more electronics, better photo editors, etc...

[image: Tightrope: 99]
[source: Elias Sime: Eregata እርጋታ - Arnolfini]

Knowledge about the human cost of the demands of the modern smart device supply chain is growing widely among consumers and is rightly increasing in politicisation.

Artisanal mining in Congo for cobalt is notorious for exploitation, child-labour, dangerous working conditions and environmental harm. The cobalt is used in batteries for everything from mobile phones to electric car batteries. There's evidence to suggest the recent chip shortage affected inflation, this would have had a greater negative impact on poorer groups.



[source: Child Miner - POVERTY POLLUTION PERSECUTION]

Supply of copper for use in electrical components also presents its own challenges for the increase in demand predicted. Semiconductor chip manufacturers are also looking at ways to reduce the resource intensity of the process. Not to mention the geopolitical consequences as a result of 'chip wars' and sanctions.

Masking E-Waste

There is also a personal connection for me. My dad is from Tanzania but when we moved to the UK he began a new hobby of visiting early morning markets and liquidation auctions looking for secondhand PCs, laptops, screens, scanners, fax machines and printers to repair and resell on his ebay shop, ‘sitaki_tena’ (which translates to ‘I don't want it anymore’ in swahili).

By the time we moved to the UK, he was long-retired from an office IT business selling to other businesses in Zambia (where I was born). Ironically the machines sold in the Zambian business were never second hand, always new.

The ebay shop was never for profit but for the challenge. The hardware was *always* visibly out-of-date and very inexpensive to acquire so there weren't many electrics he *wouldn’t* bring home. When he alone wasn’t able to problem solve some hardware out of obsolescence there was a trusted network of local repair shops on the high street(all closed now) which he could rely on to help repair the gadget for its next life.

The sense of community and regeneration from the repair and resell of used tech feels current, but he was one person and while more repair and circularity for used tech is good there is a problem of e-waste today. Artists like Elias Sime offer one solution, but there’s a danger in the West of romanticising the use of salvaged e-waste while the problem of e-waste management is *masked* in distant remnants of the Empire.

Masking and Games

Playing games is a great way to suspend reality and enjoy escapism while also problem solving. Heather Mahan is a programmer, artist and creator of the game 'Cozy', on itch.io.

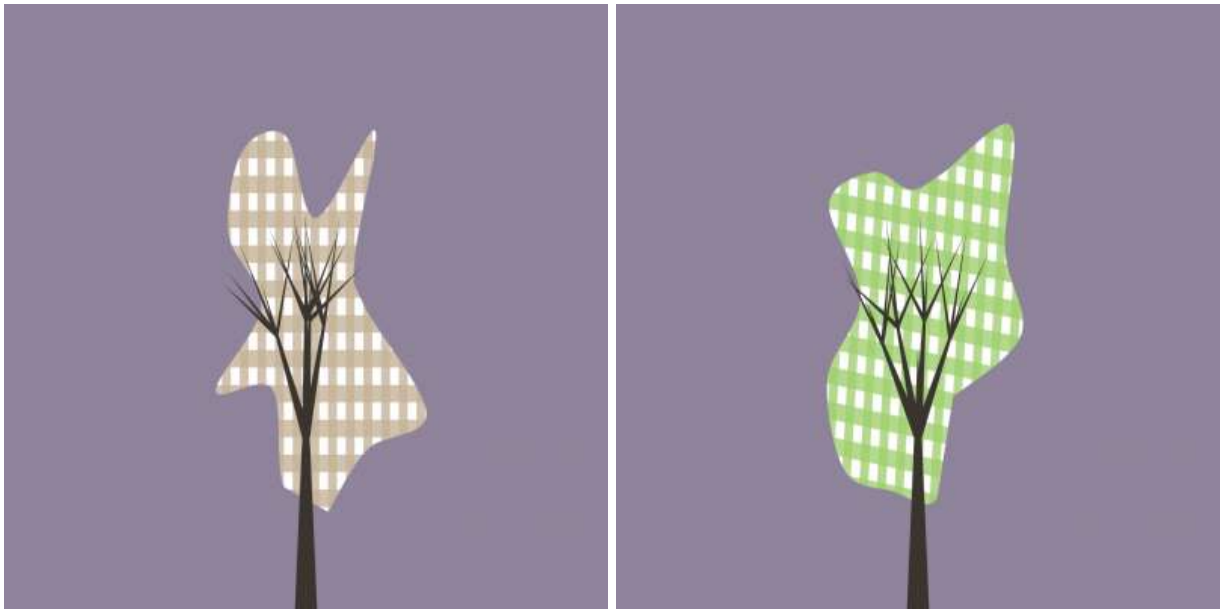
[source: Cozy by Heather]

Cozy is an example of a #flatgame, a 2D game with simple controls in which the player is usually only able to explore a scene. The most widely known form of masking is arguably collage and the DIY look of collage and art crafts is fully embraced in Cozy.

[source: knit mask by Heather Mahan]

A flatgame doesn't necessarily need the creator to write any code for the game. But Heather has an openprocessing page with p5.js code sketches implementing

masking with code. The result is a layering process made visible with distinct shapes containing contrasting images.



[source: Tree 6: fixed pattern rotating mask by Heather Mahan]
[source: Tree 4: fixed mask rotating pattern by Heather Mahan]

My Practice and Masks

In my own art practice I prefer live coding visuals, I see the performance as the artwork and not just the image that's generated by the code.

When I use the hydra-synth engine for browser-based live code performances, I know that when I type .mask() in a sketch, I'm aestheticising the intention to conceal and reveal or superimpose and isolate at least two visual inputs in relation to one

another.

[source: sliced-hydra-demo 7.mp4]

Speaking for myself, it's not the most important thing in a live code performance to turn on my webcam but if I do, it feels more like an extension of sharing your screen in a live code performance. Like a transient declaration of authorship rather than a symbolic tool for making a statement about representation or another social message which is important, just not what I'm trying to do.

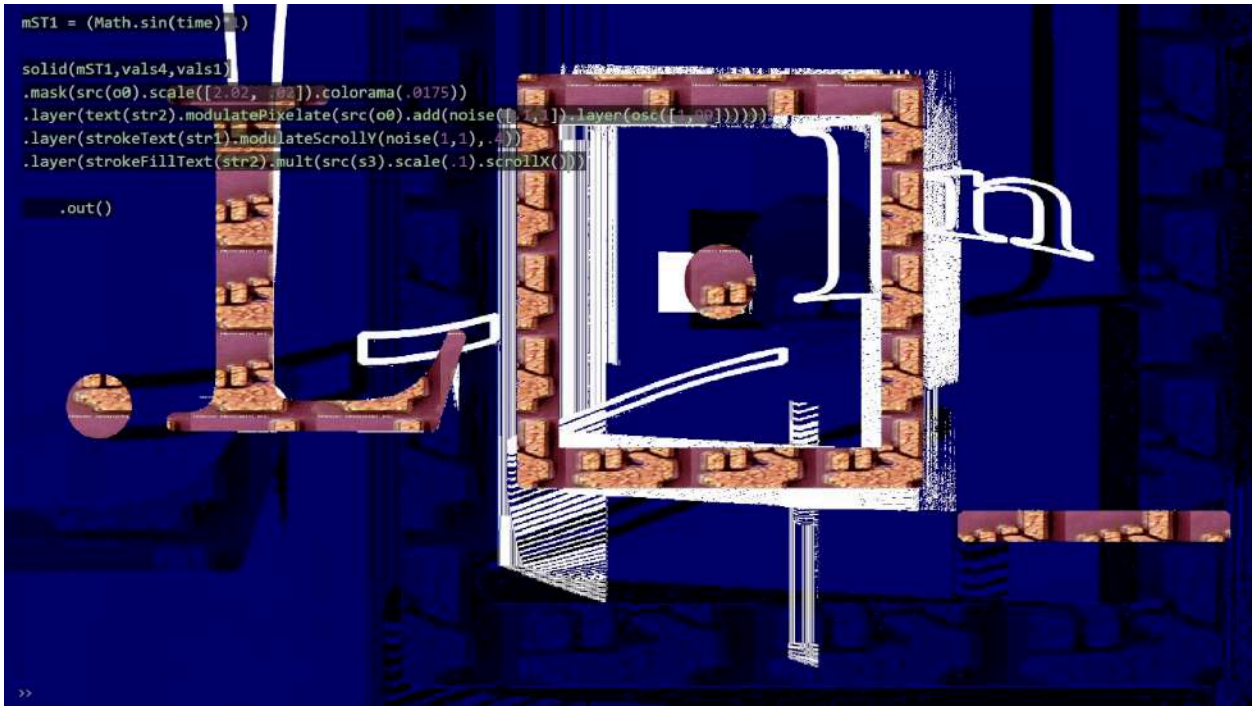
[source: Live_Code_Clip.mp4]

As a recipient of the 2022 hydra micro-grant I wrote a tutorial showing one way to combine an augmented reality(AR) javascript library together with hydra and the creative coding library, p5.js.

The tutorial was a contribution to hydra as an open source tool so it felt more important to detail one possible way to connect the different libraries as an intermediate level project for a creative practitioner looking to extend and modulate the reality of an existing graphics project or visual artwork.

[source: Hydra Microgrant 2022: Augmented Reality, Hydra-Synth & p5.js Poster Tutorial]

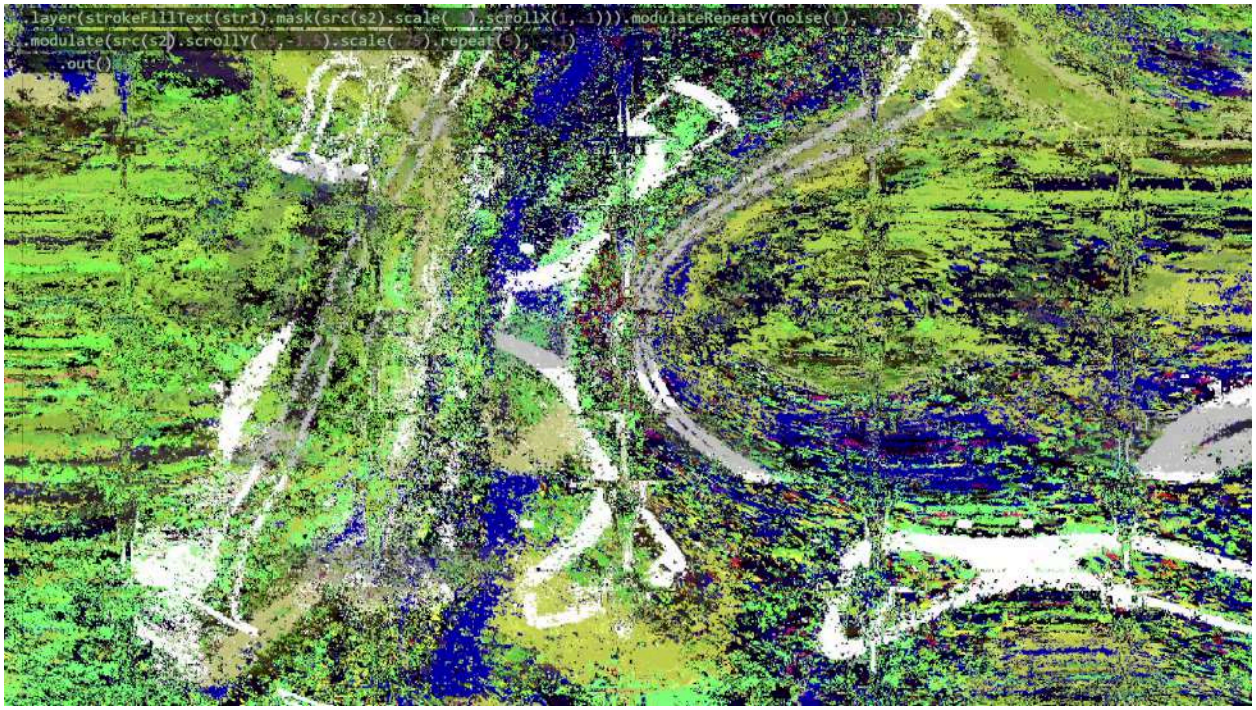
The tutorial explains how to mask live hydra graphics onto a shape within a p5.js sketch. The AR work is tracked using a target image. In the demonstration image above to promote the tutorial, the sketch is rendered on a tablet but uses the webcam feed from the laptop webcam to trivially create a feedback loop which is a subtle reference to the hydra-synth engine's capability with modulation, feedback and networked visuals.



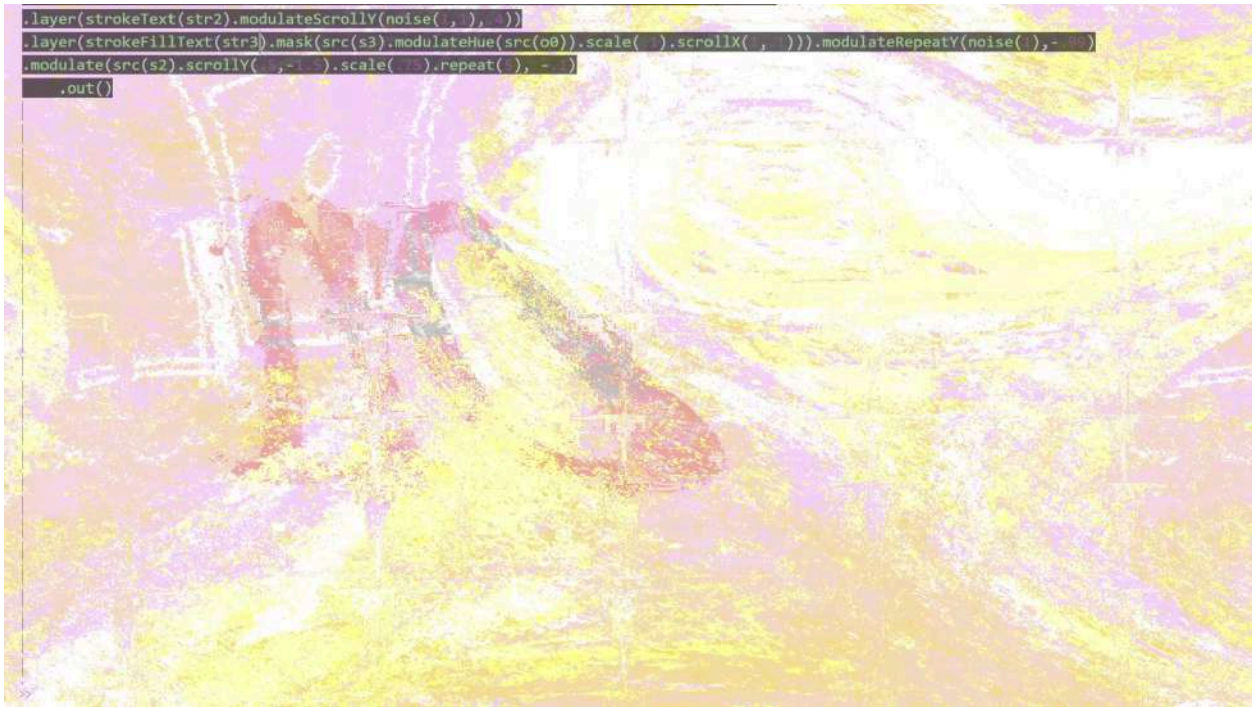
[video source: https://youtu.be/84_jsYLlTgc]

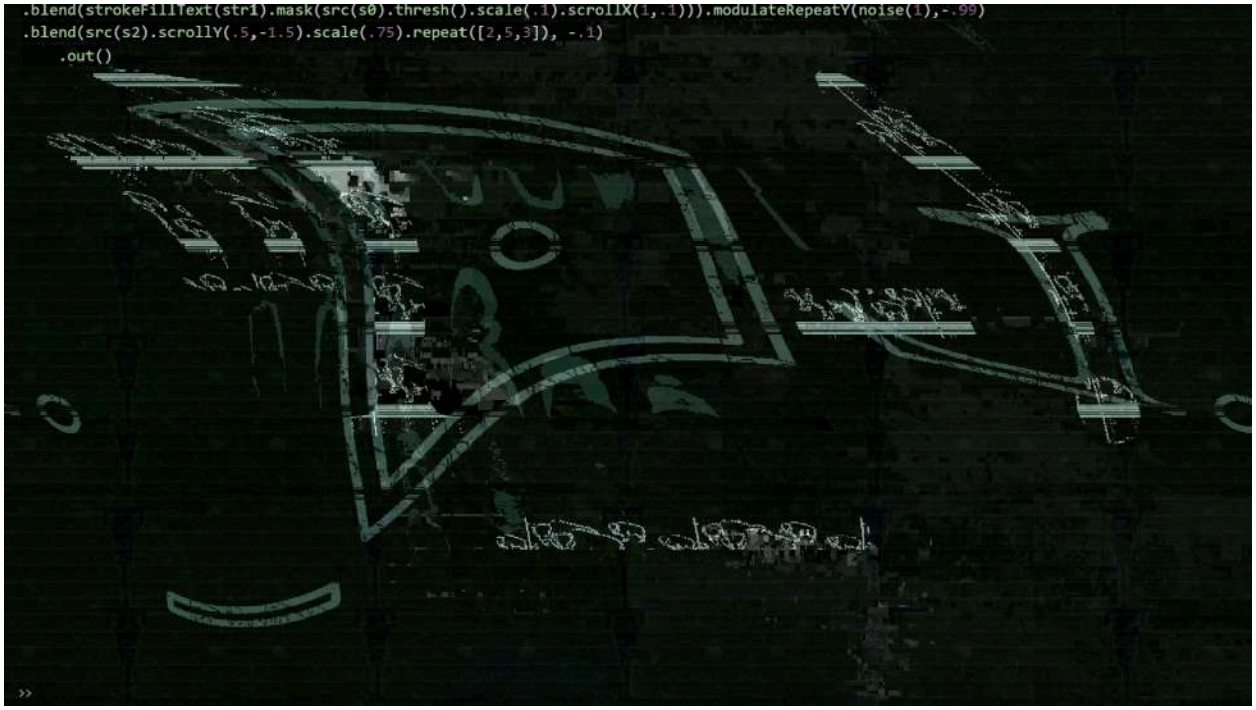
The video linked above and the following images are from an earlier hydra live code sketch response to the '*tech is material*' brief for this blog post, again containing chip art references(Appendix D).

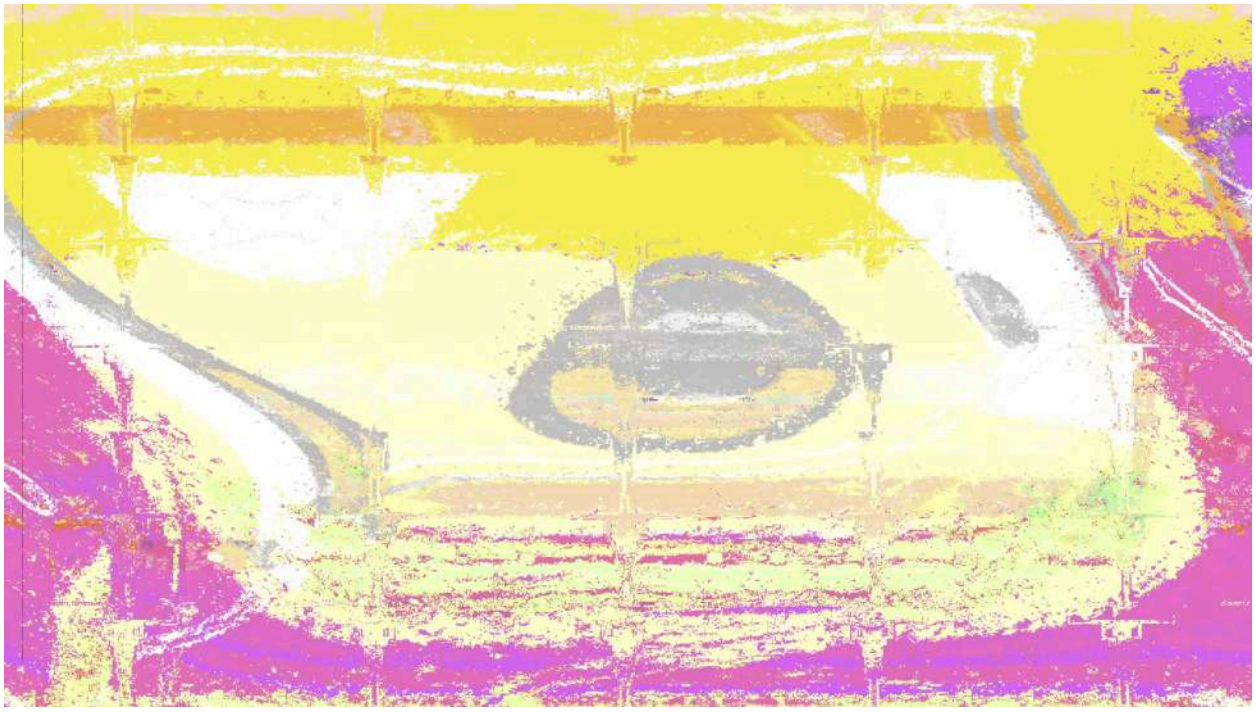
Hydra natively has masking functionality and now an extension for easier implementation of text. In both responses I've used both text and masking with external images of found chip art.

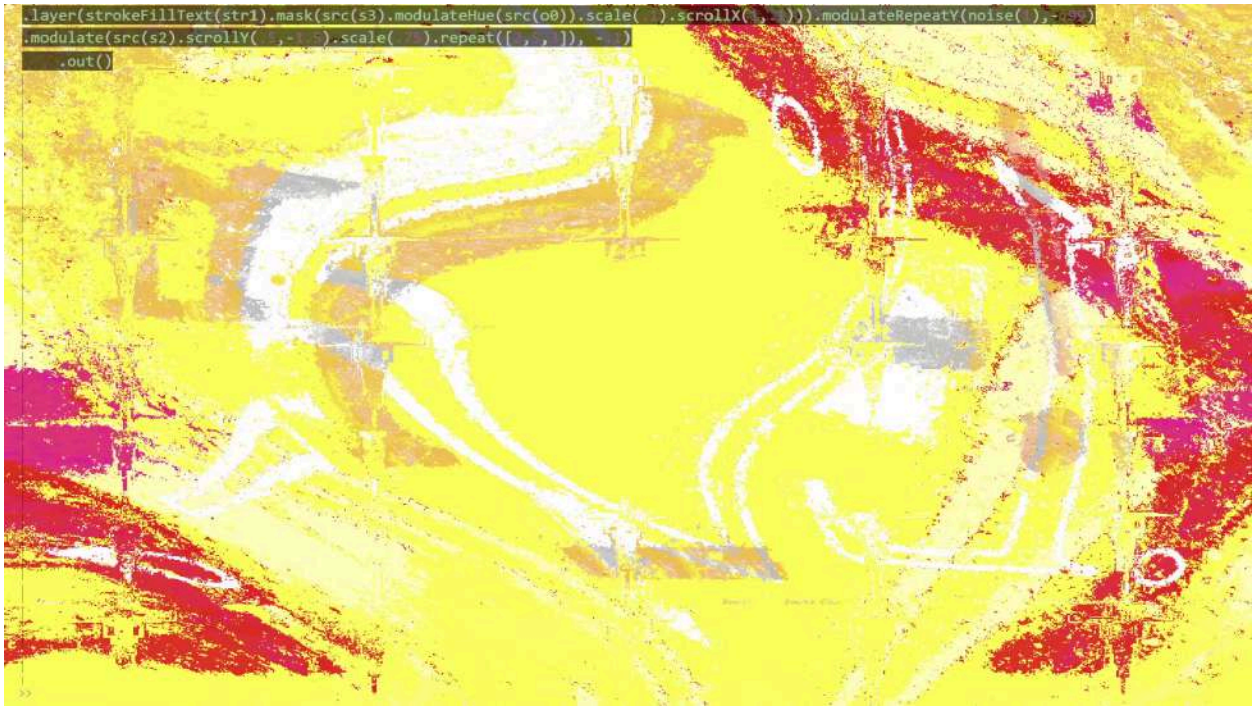


[video source: drive]




.blend(strokeFillText(str1).mask(src(s0).thresh().scale(.1).scrollX(1,.1))).modulateRepeatY(noise(1),-.99)
.blend(src(s2).scrollY(.5,-1.5).scale(.75).repeat([2,5,3]), -.1)
.out()



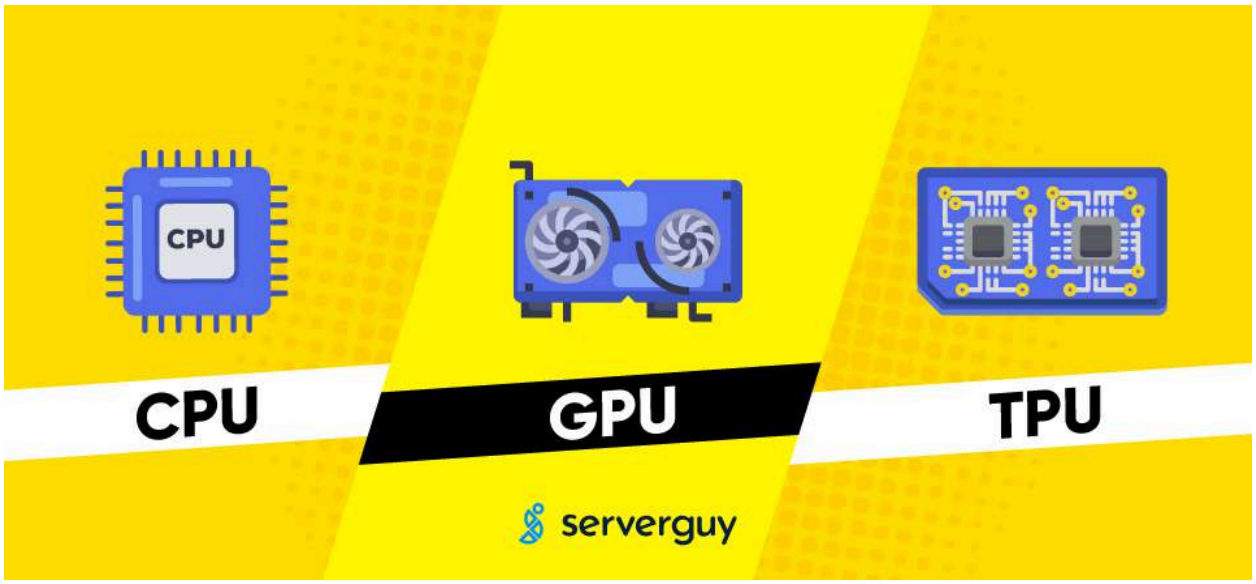


Thanks for reading the post!

[sources: 238 words]

APPENDIX

A) PHOTOMASKS AND THE MANUFACTURE OF MICROCHIPS:

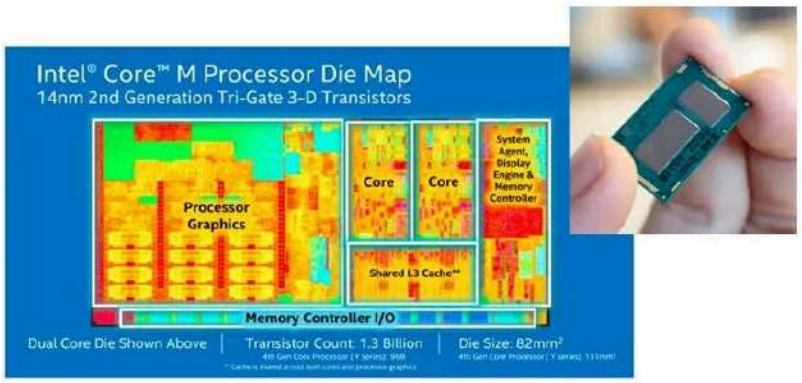


[source: CPU vs GPU vs TPU: Understanding the difference b/w them]

In an Integrated Circuit for a processor chip, the clue is in the name. The transistors and other electrical components are *integrated* into the circuit in multiple layers at the nanometer scale. A chip the size of a fingernail can contain over a billion transistors.

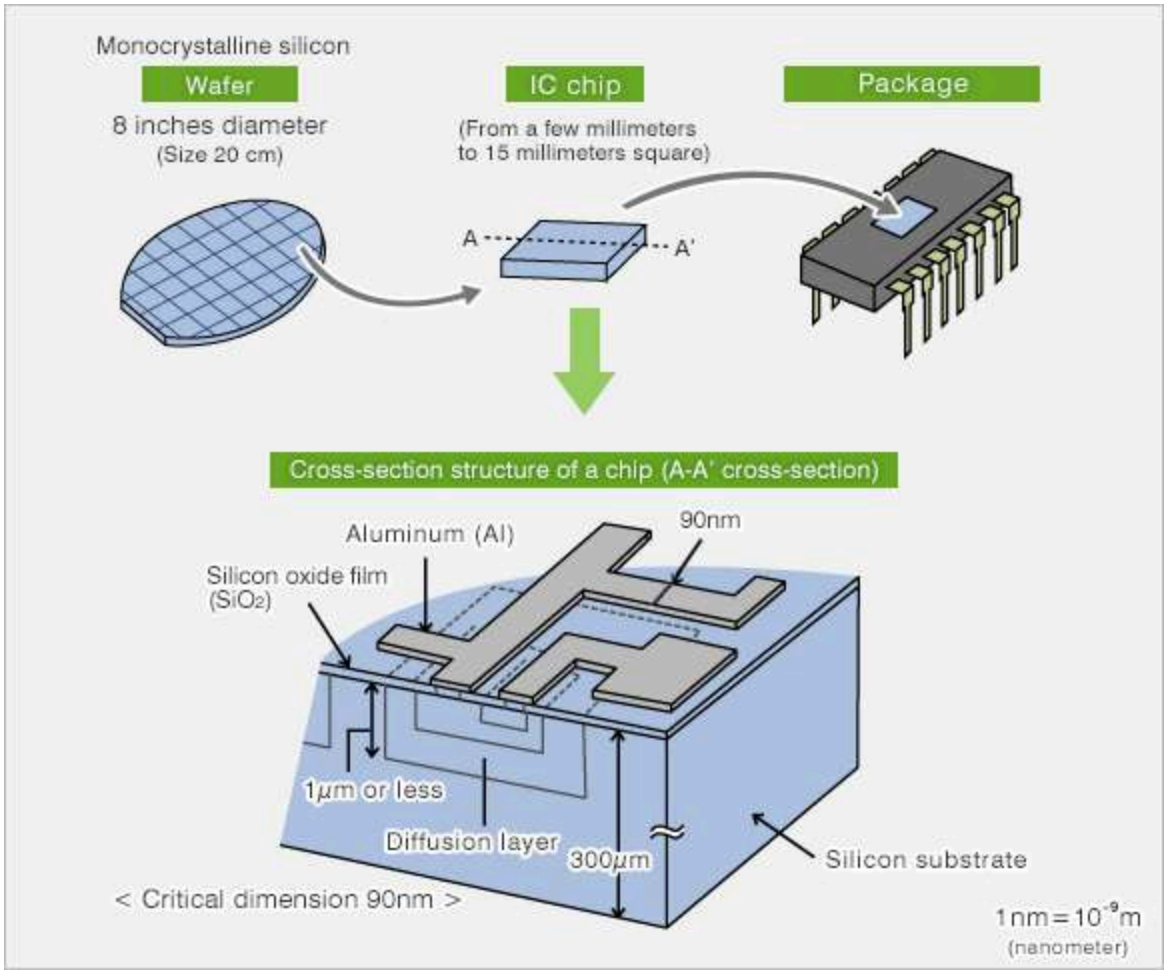
CPU
Intel Core M 14nm
Die area 82 mm^2
Transistors 1.3 Billion
Two chip solution
Price-point $150

SoC
Apple A8 20nm
Die area 89 mm^2
Transistors 2 Billion
Single chip solution
Price-point $15



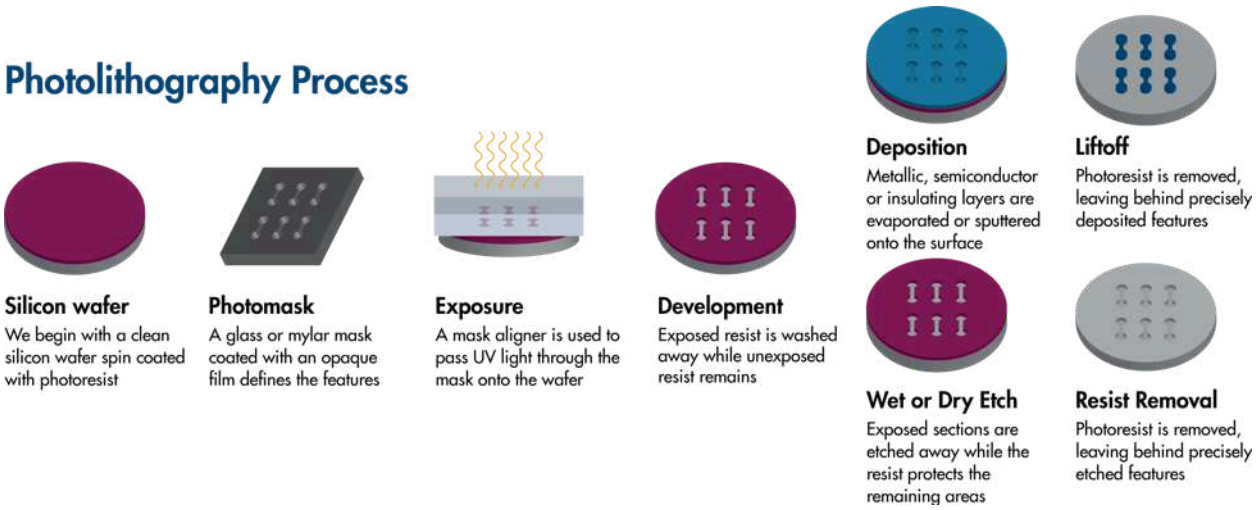
[source: How the SoC is Displacing the CPU | by Pushkar Ranade | Medium]

But how do we go from the silicon wafer to the chip in your device and what does it look like?



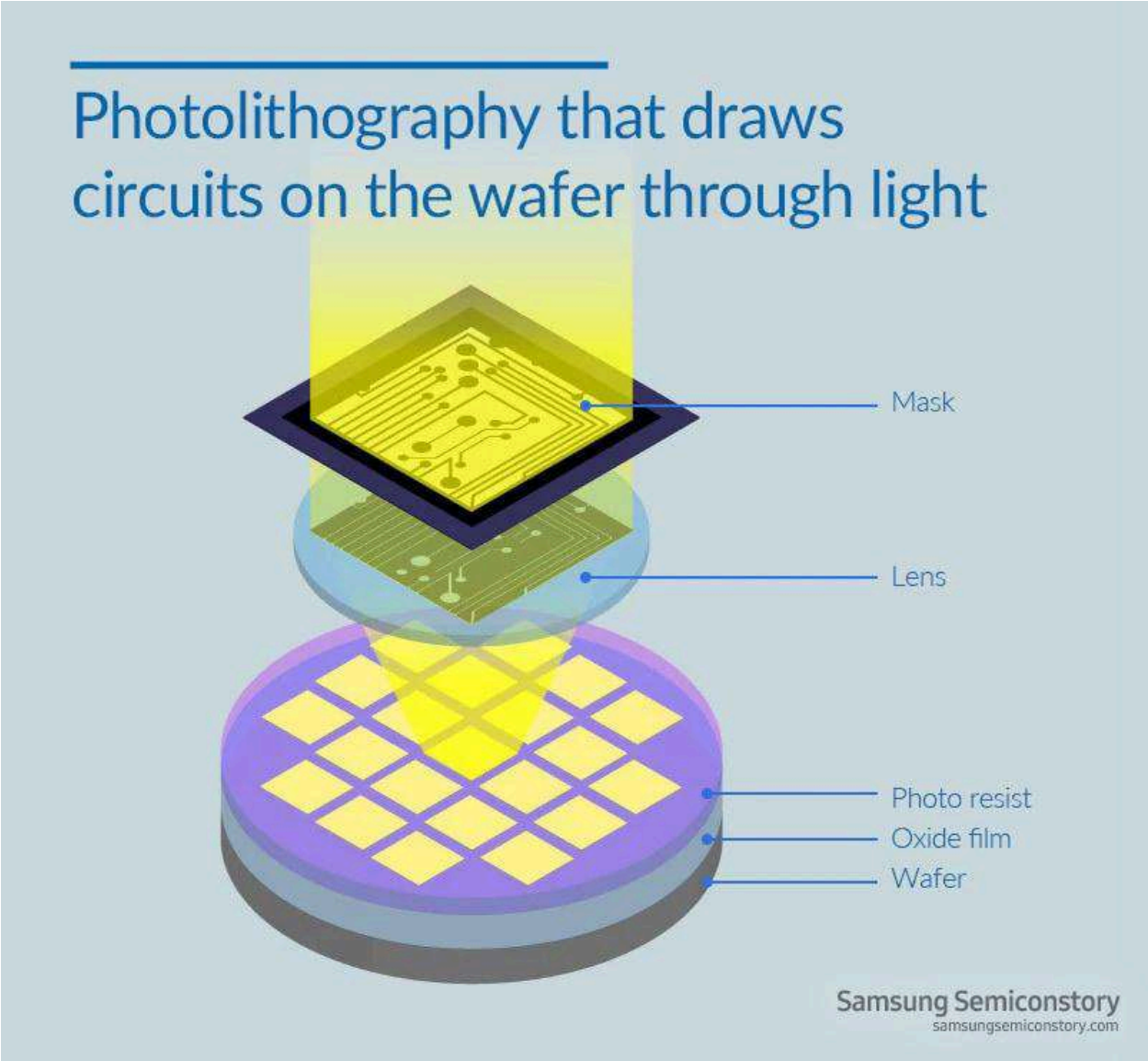
[source: 5. Integrated circuit (IC) : Hitachi High-Tech Corporation]

The diagram below shows the process of making a chip from a sheet of silicon in a chip fabrication plant(fab) facility. This blog post will focus on masks used in the photolithography stage.



[source: Advanced Lithography - Brewer Science]

Photolithography is a process of printing with light. In chip fabrication this light is lasers and the circuit design being printed is a mask/photomask reflected onto a lens.



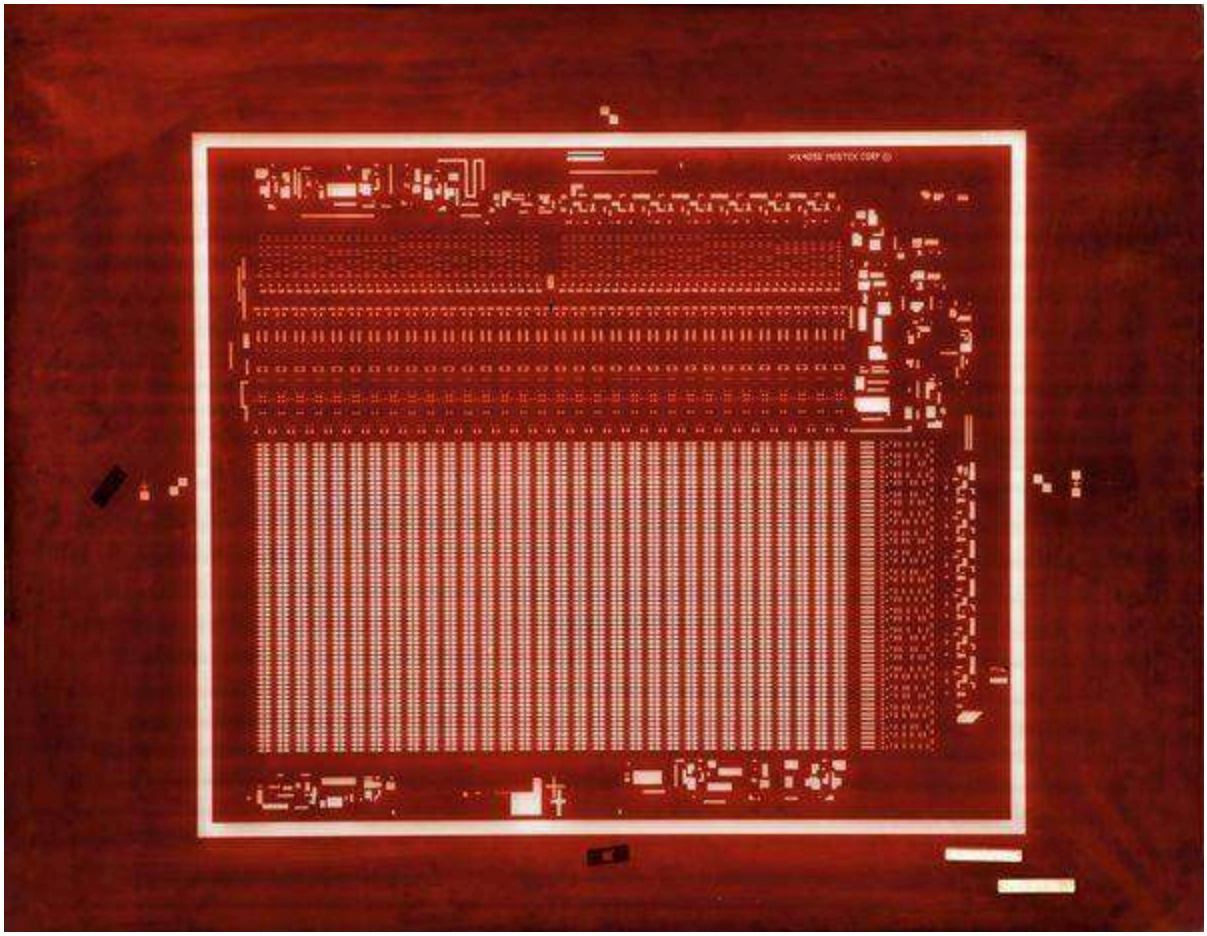
[source: Drawing Structures in Nano-Scale | Samsung Semiconductor Global]

B) PHOTOLITHOGRAPHY's PRINTMAKING ORIGINS:

Before photolithography and Computer Aided Design(CAD) software, the chip design was drawn on Rubylith film that technicians cut out by hand on a light table. The designs were then scaled down for semiconductor fabrication.

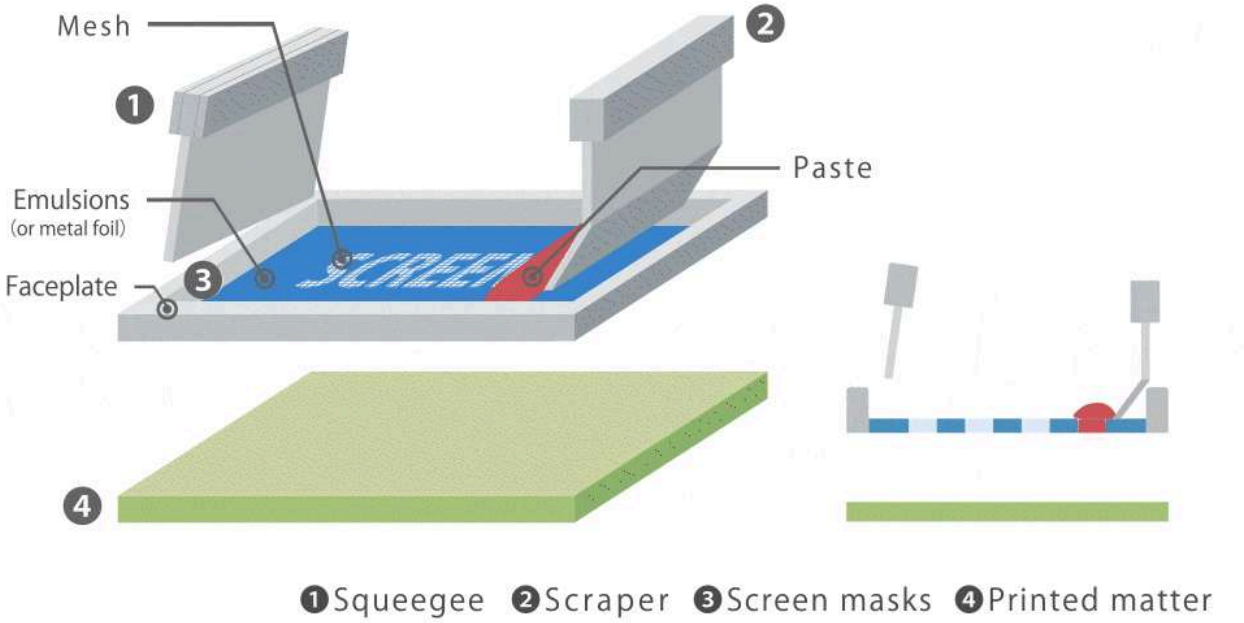
[source: Rubylith operators - CHM Revolution]

This mask layer for the Mostek MK4096 4K DRAM has been prepared for photographic reduction onto a glass plate. The design was transferred to the Rubylith film and selected areas cut and stripped by hand to create the pattern. [source: Mask Rubylith Layer for 4K DRAM - CHM Revolution]

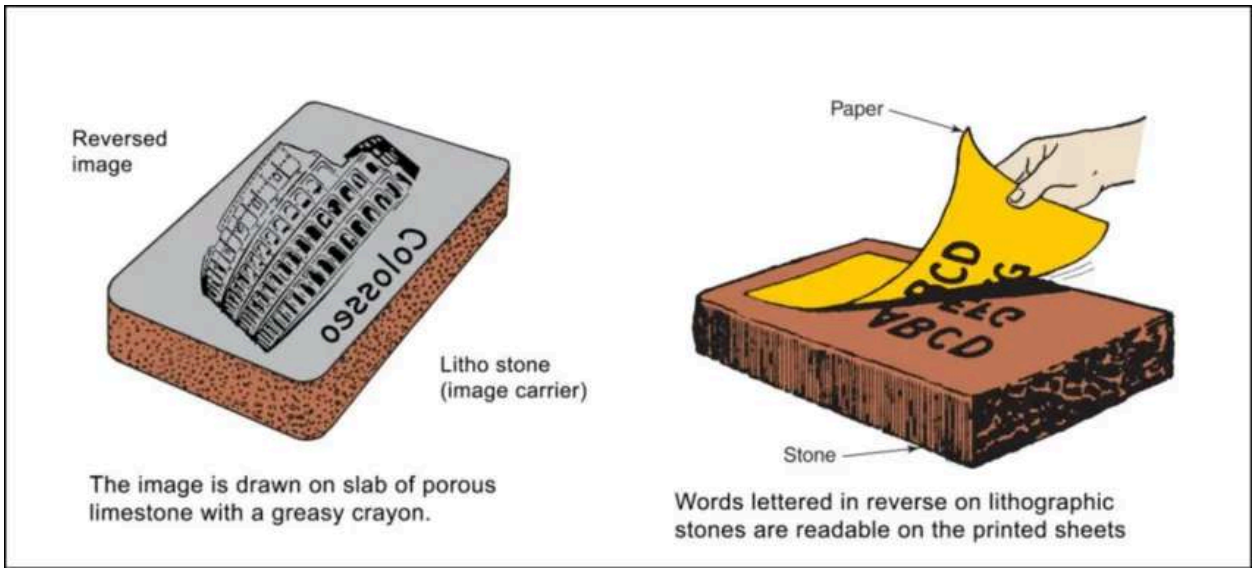


[source: Mask Rubylith Layer for 4K DRAM - CHM Revolution]

If you've ever done screen printing, the process of photolithography should feel familiar.



[Source: Screen masks - High-precision printing is achieved by utilizing different mesh, emulsion, and frame types to meet the given project.]



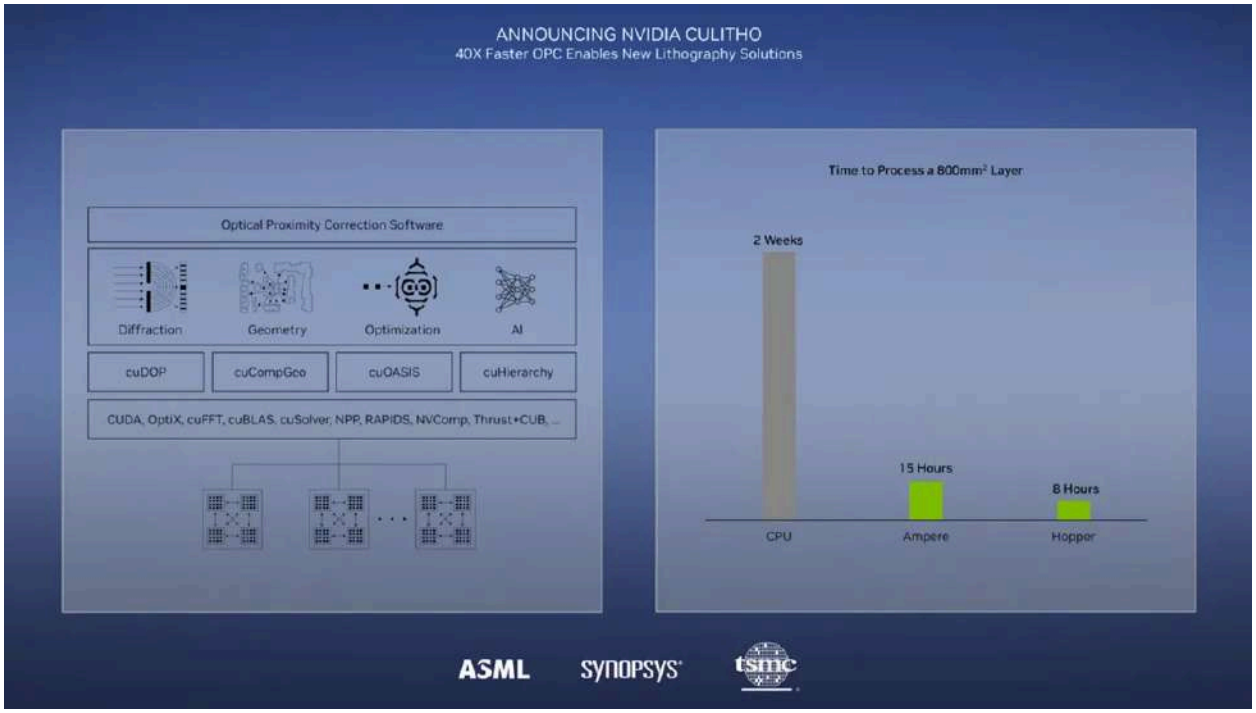
[source: What is lithography and what is its application? | by tarhmarkt | Medium]

As you can see it's the same principle of printing images as found in the older forms of traditional lithography.

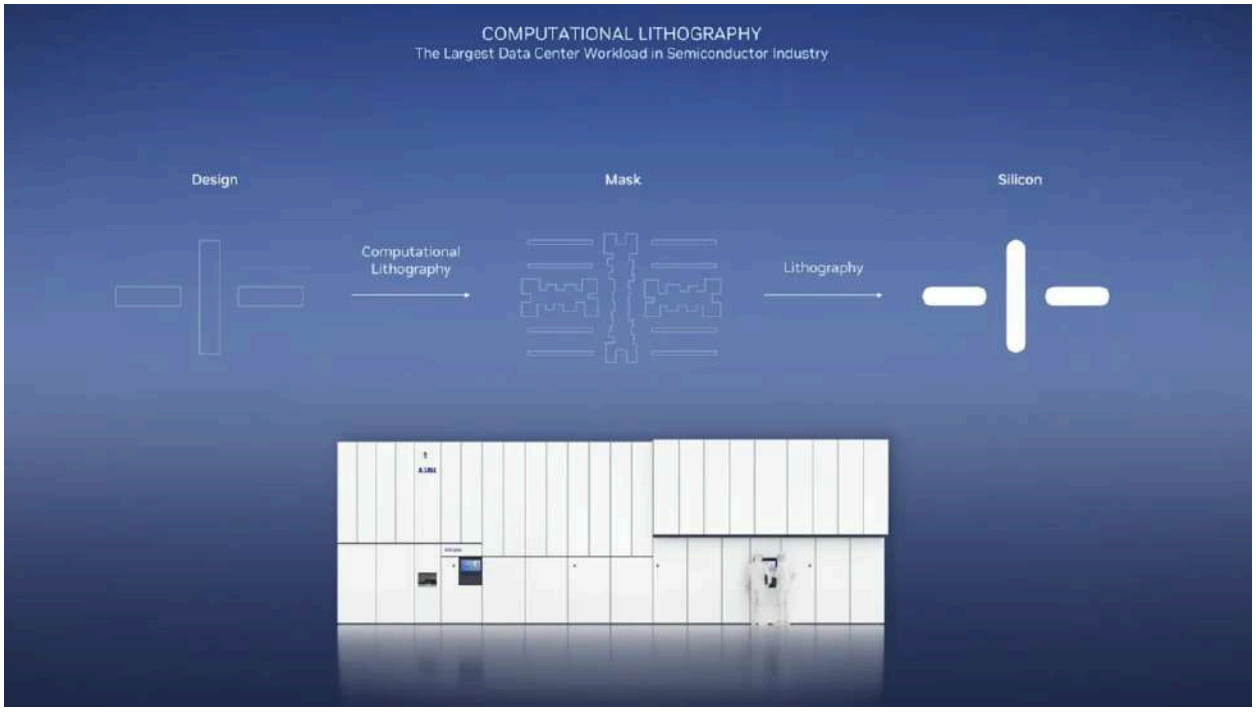
C) NVIDIA's COMPUTATIONAL INVERSE LITHOGRAPHY:

Nvidia is a company known for their graphics processing units(GPUs). The nature of these chips makes them ideal for AI applications as well as rendering graphics.

Interestingly, Nvidia is referred to as a *fabless semiconductor company* because they outsource their chip production to foundries.

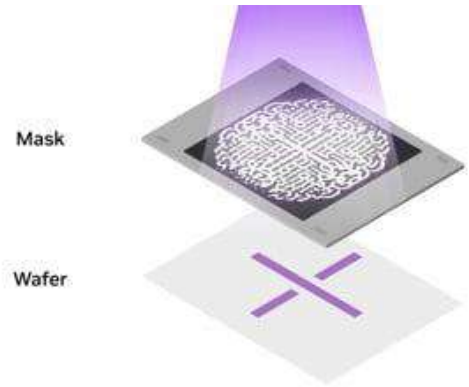


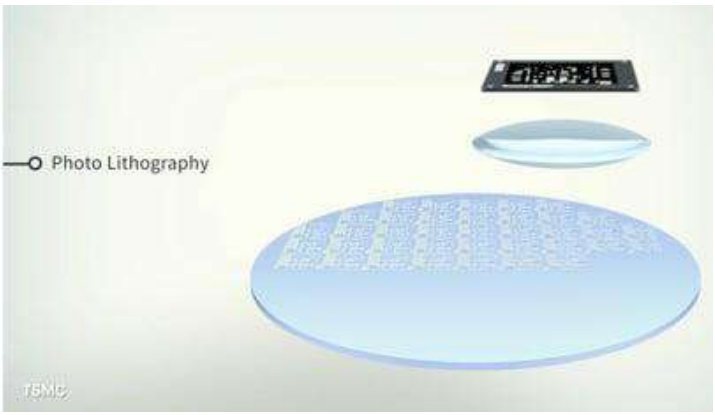
[source: Nvidia Tackles Chipmaking Process, Claims 40X Speed Up with cuLitho | Tom's Hardware]



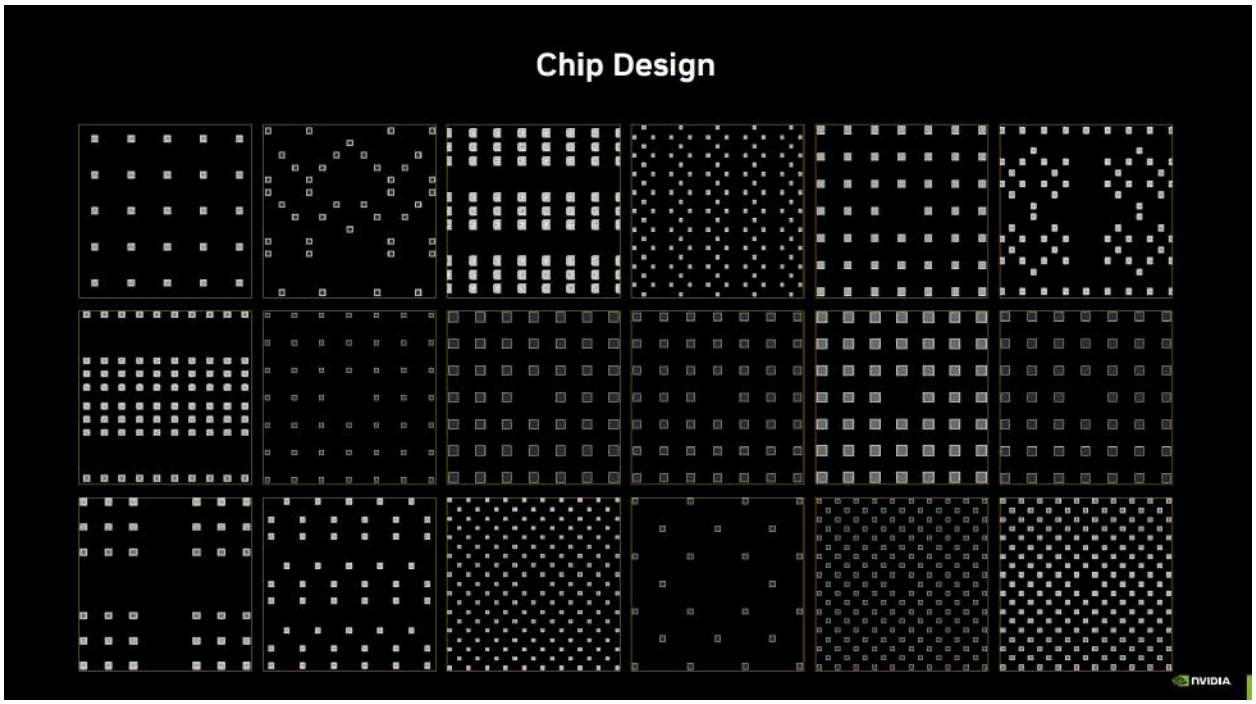
[image: Image of one of ASML's EUV Lithography Machines]
[source: Nvidia Tackles Chipmaking Process, Claims 40X Speed Up with cuLitho | Tom's Hardware]

Because of their close relationship with foundries and the manufacturers of the photolithography machines which will print the circuits onto silicon wafers, Nvidia has been able to develop the Nvidia cuLITHO library to accelerate the chip design and production process which they claim will reduce costs and bring other benefits (such as improving the energy efficiency of data centers) with this advancement in computational lithography.

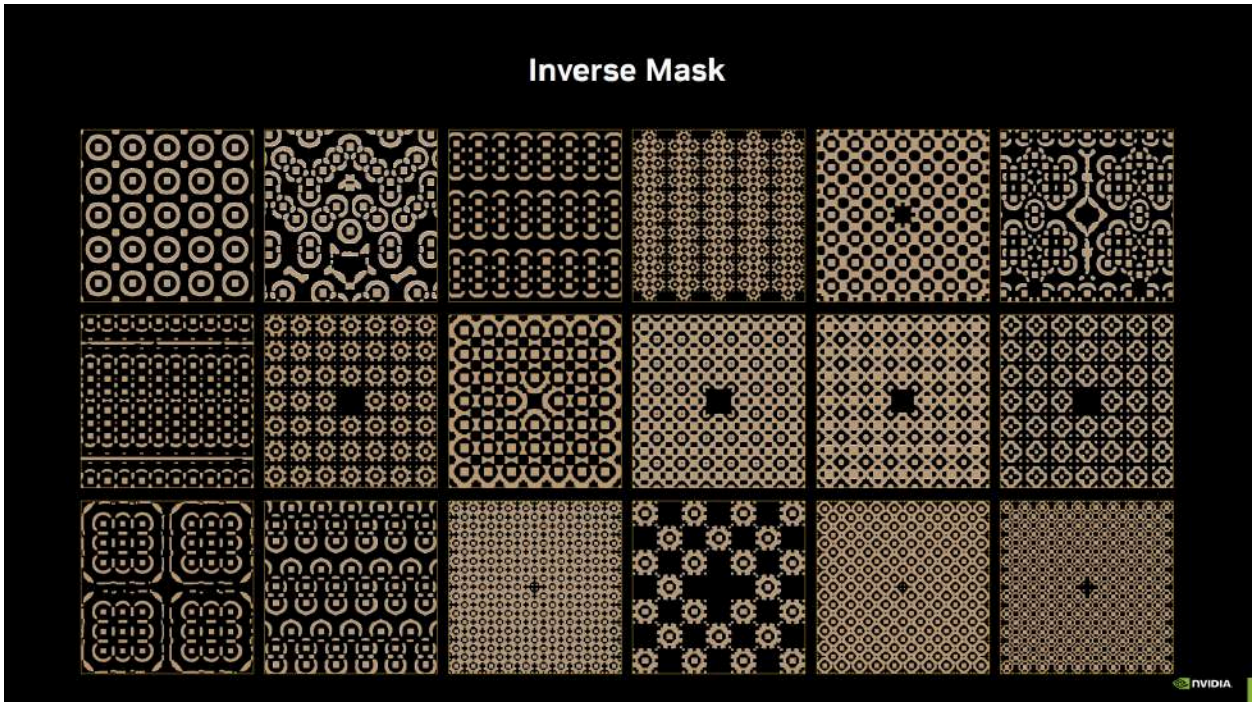




[source: NVIDIA cuLitho GPU-Accelerates Chip Fab Lithography For A Huge Efficiency Lift | HotHardware]

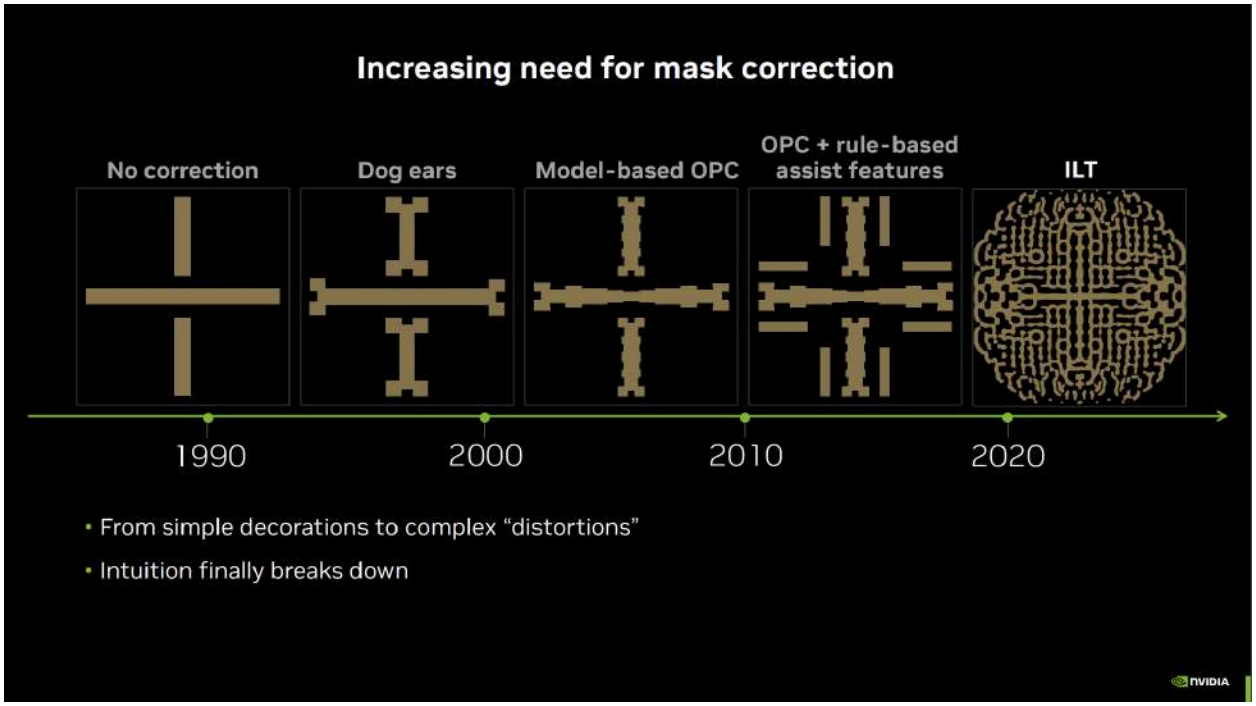


[image: Designs required on the silicon wafer, these are holes for connecting wires on different levels of the chip.]
[video: https://youtu.be/Zs1XZaimaUs?t=1119]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]



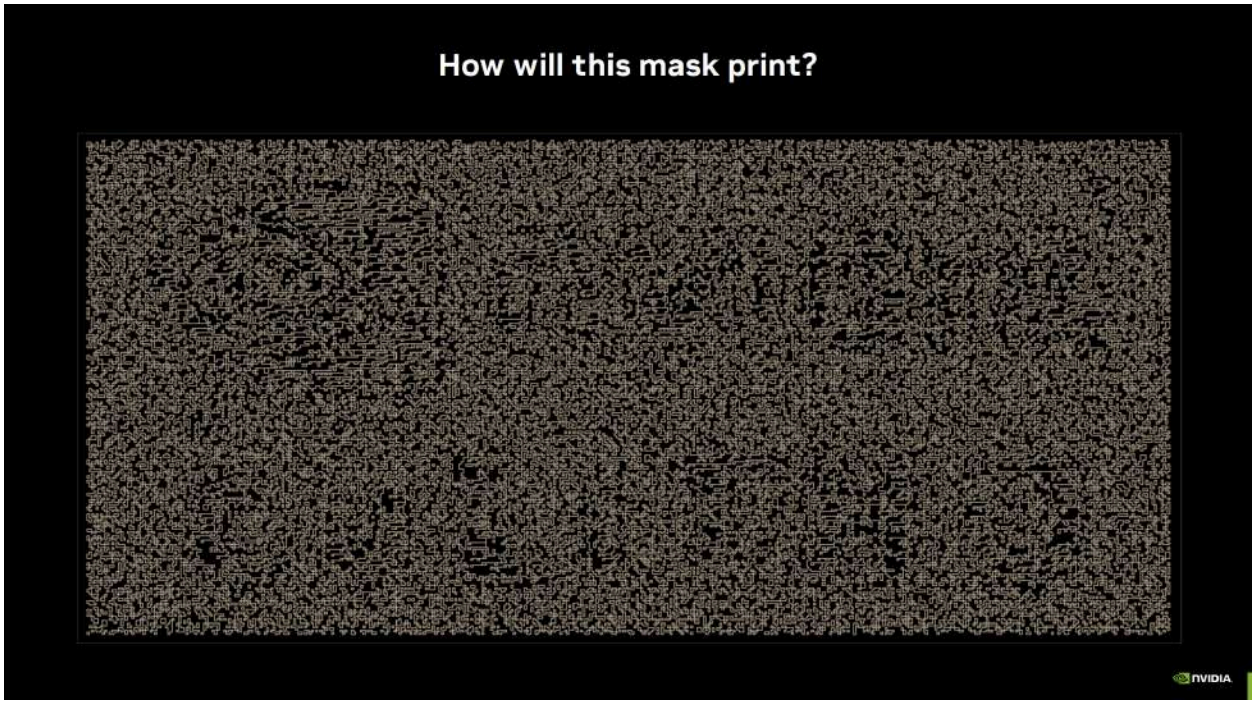
[image: These photomasks have been designed to inversely print the holes required on chip. An inverse mask of the design is used due to the small size of the features.]
[video: https://youtu.be/Zs1XZaimaUs?t=1161]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]

The cuLITHO library's tools run on a GPU rather than the CPU. Nvidia's cuLITHO performs AI optimisations to the designs of masks for semiconductor chips, particularly as photolithography is reaching the limits of physics. This means printing even smaller features onto chips requires masks which contain the inverse of the chip design, known as inverse lithography technology(ILT).



[video: https://youtu.be/Zs1XZaimaUs?t=418]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]

Described by Nvidia VP, Vivek K Singh as "...very unintuitive, curvilinear... kind of pretty". This particular advancement of tools from Nvidia presents an interesting self-referential paradox if you fully opt into the Nvidia ecosystem. Hypothetically, you could have the latest Nvidia GPU chip which Nvidia designed using their own tools which themselves require Nvidia GPUs to run the processing intensive tasks which could include designing the next generation of that very same chip. Can you guess what image has been designed with this mask?



[image: A chromeless phase-shift mask. This mask has been etched to print an image onto a silicon wafer once light has scattered through the mask. The mask design was created with the Nvidia cuLITHO library.]
[video: https://youtu.be/Zs1XZaimaUs?t=1500]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]

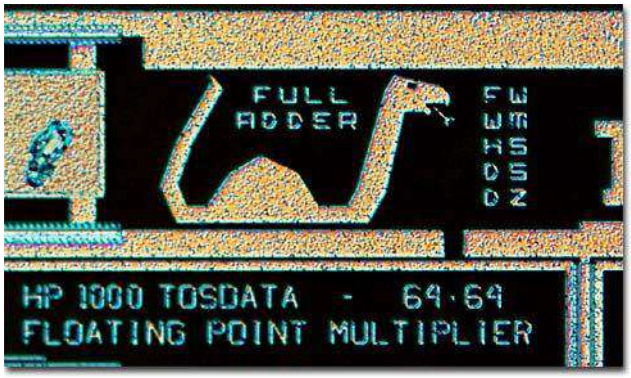
[image: Would you have guessed this was the printed image?]
[video: https://youtu.be/Zs1XZaimaUs?t=1521]
[source: Accelerating Computational Lithography: Enabling our Electronic Future | NVIDIA On-Demand]

D) CHIP ART:

Copyright law in the USA before 1984 didn't grant legal protection to chip designers without proving a design was used without permission. To fight this, designers included chip graffiti/ silicon art onto chip mask designs. A stolen chip design when inspected will reveal the designer's chip art from the original mask design.

[source: The Secret Art Of Chip Graffiti - IEEE Spectrum]

There was no longer any need to include chip art on masks after a 1984 semiconductor chip protection law was passed making all chip mask designs copyright protected automatically. A community of enthusiasts formed around identifying silicon chip art, with Silicon Zoo being one of the most popular online records of these hidden artworks.



[source: Molecular Expressions: The Silicon Zoo - The Full Adder]

[source: Molecular Expressions: Electricity and Magnetism - Interactive Java Tutorials: Creating A Silicon Yin Yang]