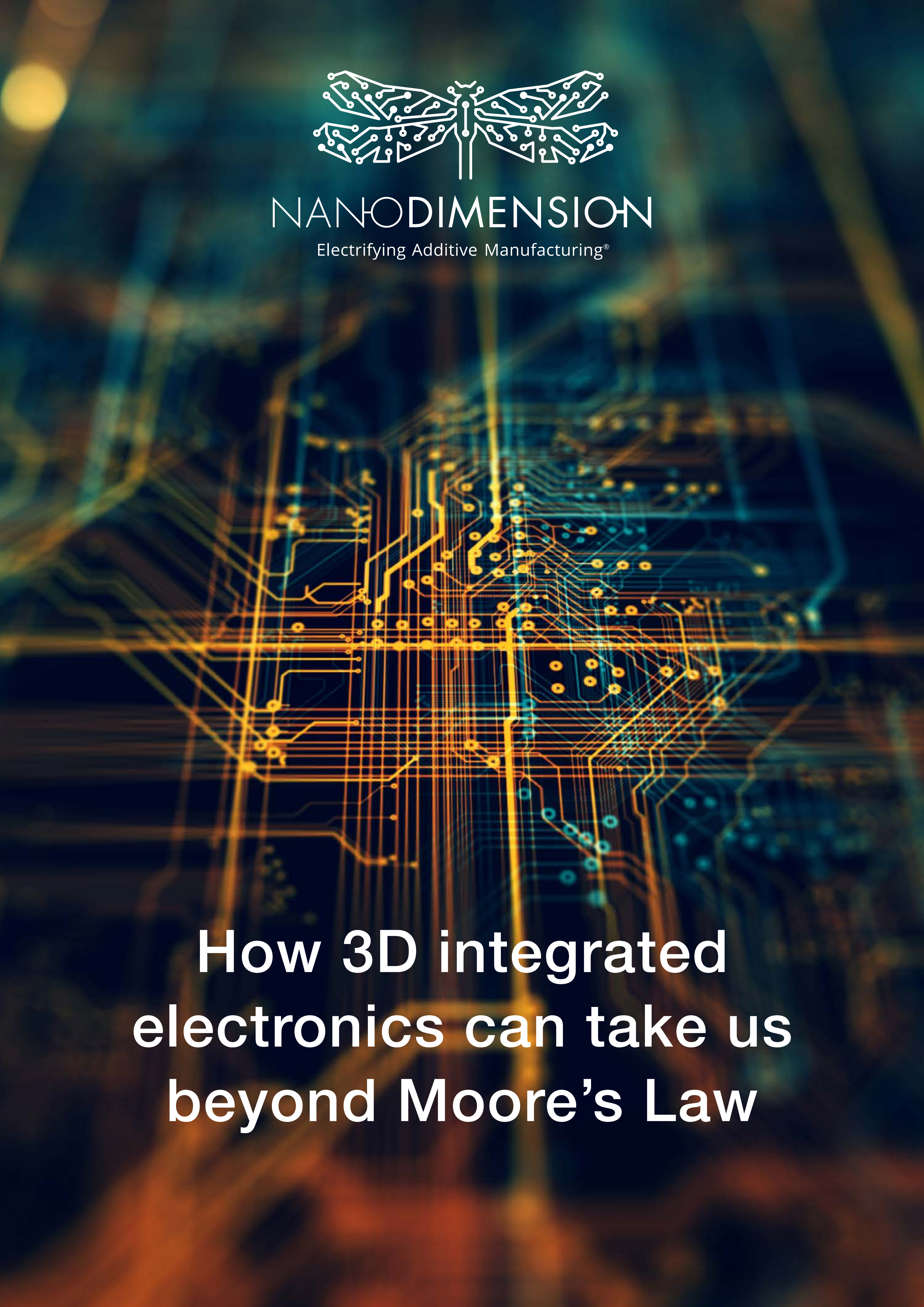
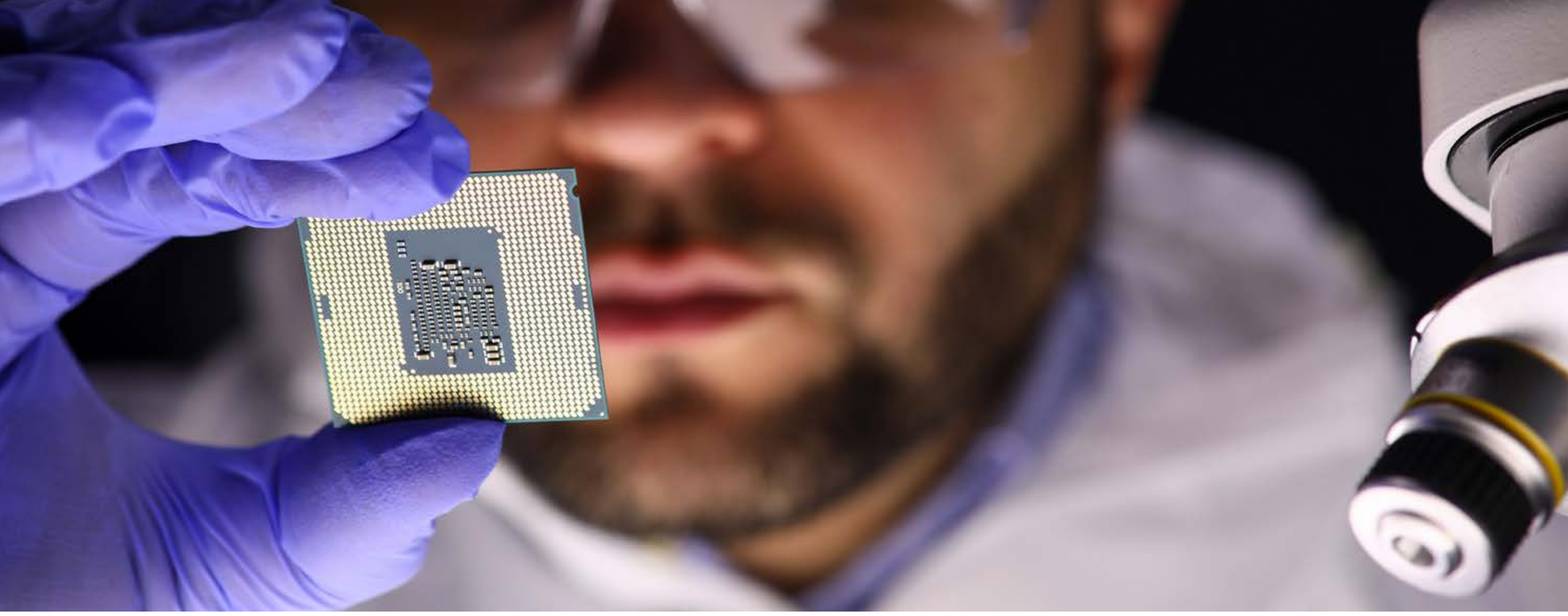


NANO DIMENSION

Electrifying Additive Manufacturing®

How 3D integrated electronics can take us beyond Moore's Law



INTRODUCTION

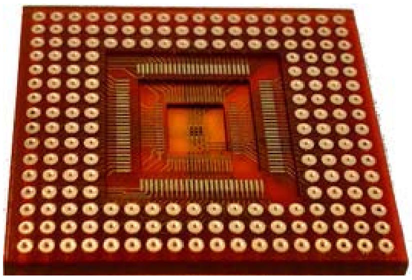
Moore's law is coming to an end according to many science and technology commentators. Among them is the celebrity theoretical physicist Michio Kaku who predicted in 2012: "In about ten years or so, we will see the collapse of Moore's law."[1]

While it hasn't collapsed yet, electronic engineers have needed to innovate continually to ensure that computers are able to regularly expand their capability, speed and performance. They've done this largely by doubling the number of components in an integrated chip every two years, which was Gordon Moore's primary observation back in 1975.[2]

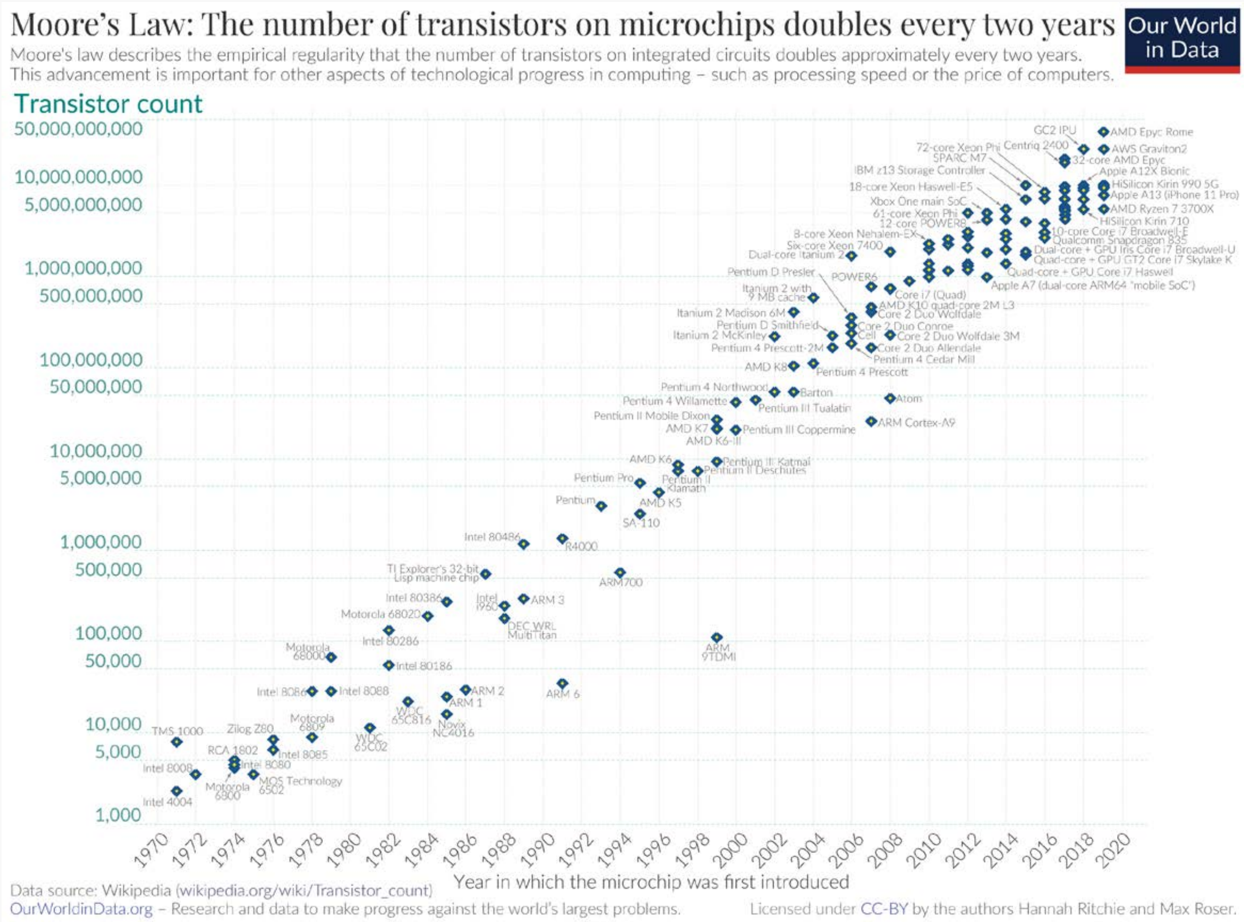
There are physical limitations to this, as physicists like Kaku point out. But they are also excited about alternative approaches that could extend, or at least complement Moore's law with additional functionalities. Approaches such as molecular transistors, and quantum, biological, protein and DNA computers, which are coming down the line in the distant future.

Available today, however, is a promising approach that has been termed "3D heterogeneous integration". This is a method of 3D printing complex functional circuits and devices, using Additively Manufactured Electronic (AME) Technolgy and Systems. The key feature is that the method allows engineers to define every voxel (3D pixel) as conductor or isolator. For example, the technology has the ability to integrate various disciplines such as electrical, optical, thermal, magnetic, or mechanical properties and encapsulate them within a single package.

Using AME, it's possible to migrate from the system board-level into the multilevel functional pacakage level in order to increase functionality and performance. This is creating a new wave of possibility and innovation for end users in industries such as defense, medical, communications and research, but also has ramifications for many other sectors - and the very future of microelectronics itself.



1. Michio Kaku: Tweaking Moore's Law and the Computers of the Post-Silicon Era
2. Moore's law, Wikipedia



Moore's Law mapped: Although its demise has been predicted, manufacturers have consistently risen to the challenge. So, where next? (Image Credit: Max Roser, Hannah Ritchie, CC BY 4.0, via Wikimedia Commons)

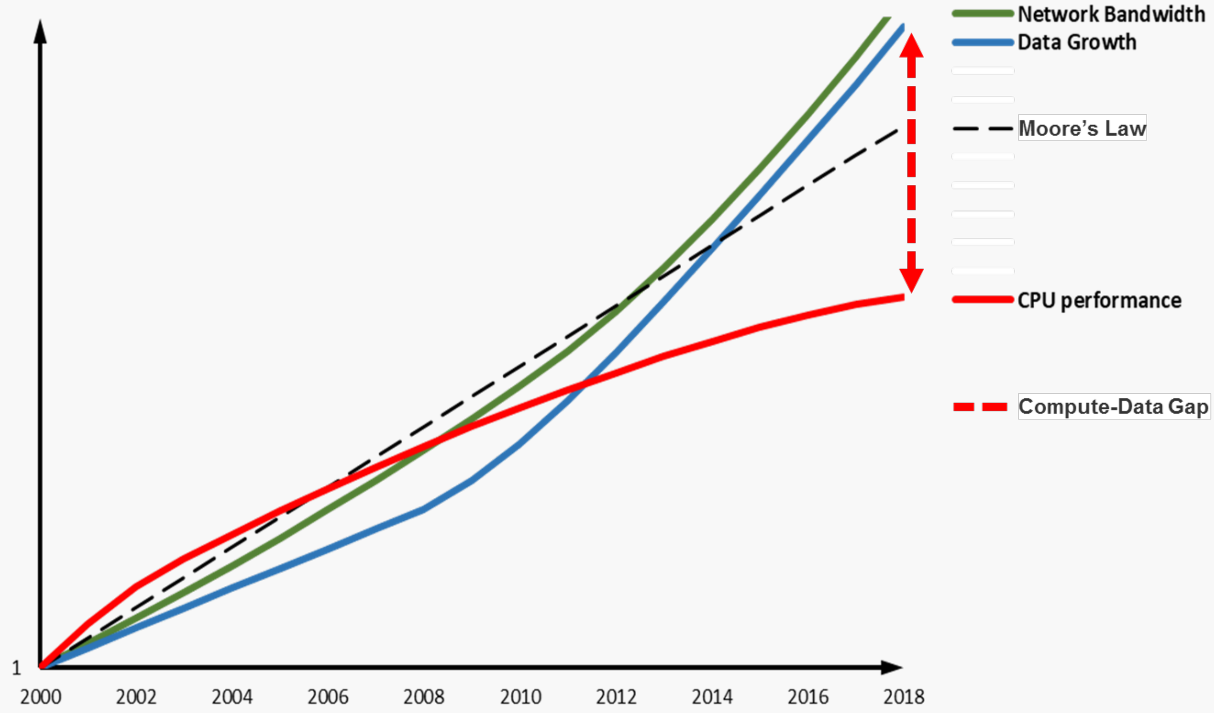
MOORE'S LAW UNDER THE MICROSCOPE

Moore's Law centers on the number of transistors a microchip can contain, and there are physical limitations, as mentioned. For example, as you follow the miniaturization route, the smaller you go, the more excess heat you generate, and you also encounter the phenomenon of electron leakage.

Consequently, there are two main routes that engineers are exploring to extend Moore's Law. The first has been termed "More Moore" and uses digital technology manufacturing innovations to enable further miniaturization of integrated circuit (IC) features. It involves integrating digital system functions such as memory, logic and graphics, in a single die – a.k.a. "system-on-a-chip" (SOC).

The second way is termed More than Moore (MtM) and is more viable in the short-to-medium-term as it complements Moore's Law at the back end: by innovating printed circuit boards (PCBs). It enables PCB designers to incorporate additional functionalities into devices that don't necessarily scale according to Moore's Law, but do provide additional value in different ways.

For instance, MtM integrates multiple related devices, such as power, power management, and interfaces with the outside world, in a single package, along with the IC, to create a "system-in-package" (SiP). The beauty of AME-driven design and development is that these SiP creations can be highly complex and fully three-dimensional.



Close the gap: With the compute-data gap widening, Nano Dimension's AME is enabling new approaches to moving beyond Moore's Law.

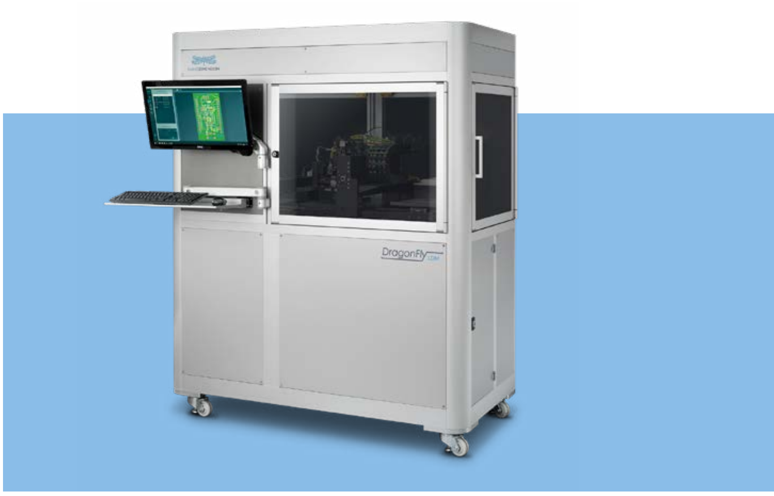
MOORE'S LAW VERSION 2

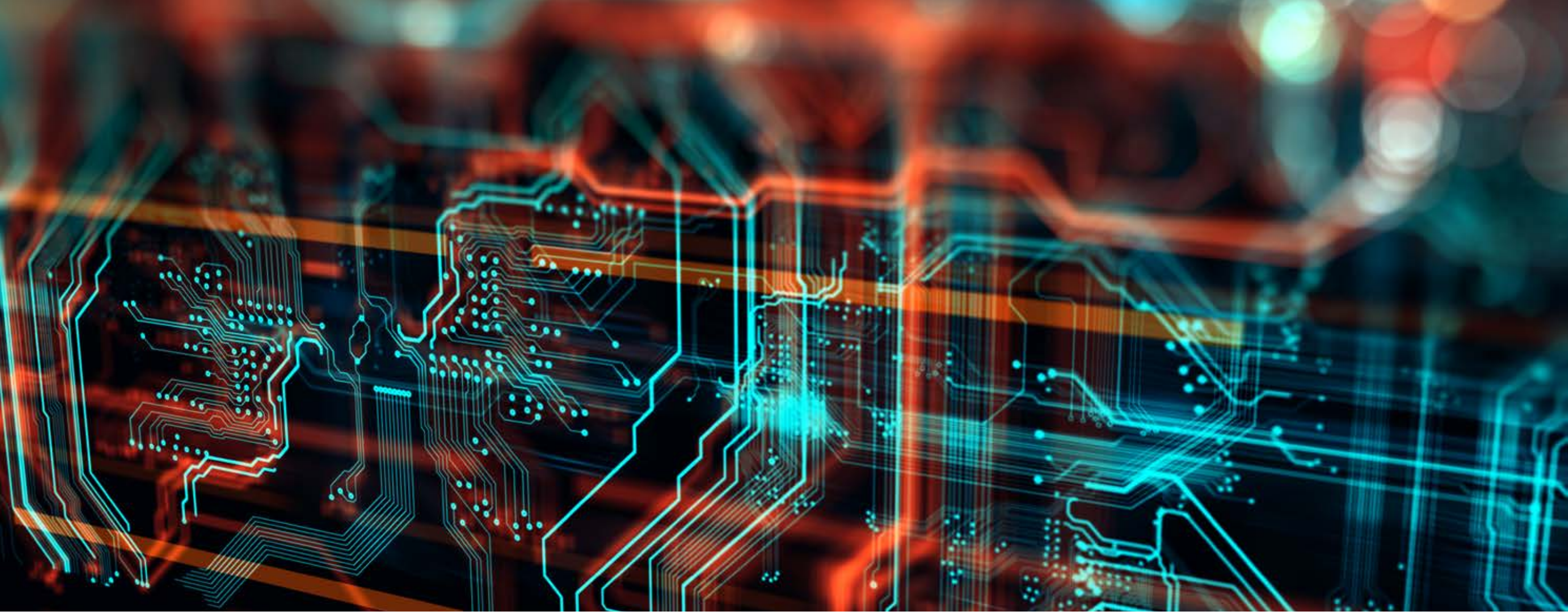
Electronics component manufacturers are currently using IC package integration technologies and techniques such as die stacking, wafer thinning, flip chip, package on package, flip chip scale packaging, and wafer level packaging. These are used for applications such as computers, cell phones and automotive electronics, among other things.

But what AME-based heterogeneous integration brings to the table is that it can build complex, 3D printed integrated electronics from the ground up, at the push of a button. Up until now, PCB manufacturing, which is a 90-year-old industry, has been based on wet chemicals, and complicated non-digital processes that are used to put layers together.

3D electronics printing specialist Nano Dimension has developed an AME machine the size of two refrigerators that can produce functional circuits and devices with little or no operator intervention. The Dragonfly Lights-out Digital Manufacturing (LDM) printer is an advanced platform ideal for rapid prototyping and low-volume manufacturing of precision 3D printed electronics.

As well as enabling rapid prototyping, the Dragonfly LDM also makes it possible to carry out agile electronic engineering techniques to produce products that are better than ones currently available, with heterogeneous integration leading to better performance, smaller sizes, and new electronic circuit shapes and form factors. Prototyping for backend, IC Packaging is a time consuming and expensive process.





UNPACKING NANO DIMENSION'S APPROACH

Being available today, this 3D integrated components technology offers a way to enhance Moore's law at the backend, the packaging level, and complement the use of miniaturization of 'front-end' silicon-based microelectronics. AME also allows end-user organizations to benefit from fast prototyping; rapid time to market, value and innovation; competitive edge; and make significant cost and time savings.

The Dragonfly LDM reduces development cycle times and enables on-site prototyping in a matter of hours instead of weeks, even for complex designs. It does this through long, uninterrupted runs round-the-clock, with minimal supervision required. And it features an automatic printhead management mechanism and algorithm, which allows for uninterrupted inkjet printing with minimal print job setup and preventative maintenance.

As for cost benefits, the solution eliminates the need for large order minimums, and enables operators to discover design errors in the early development stage with agile rapid prototyping.

One of the huge advantages of AME-based heterogeneous integration is that electronics professionals can incorporate the latest available science and technology developments and innovations.

Previously, product designers had to compromise in the face of "technology push" - pressure from the user-focused technology industry to incorporate the latest features. The main problem was that the science wasn't mature enough, with traditional PCB fabrication processes still evolving through their physical limitations.

With heterogeneous integration, on the other hand, electronics professionals can produce components that meet the current, rapidly changing, hardware and software requirements for commercial microelectronic products such as smartphones, autonomous drones and satellites. As a result, product developers don't have to wait for the science to catch up with the technology before they prototype and roll out new products, and this can give them the edge over competitors.

Nano Dimension's unique offering is it can 3D-print electrically conductive and dielectric insulating materials at the same time, in-house. All AME circuits are based on the digital processing of silver nano-particle (conductive) inks and acrylate polymer (dielectric), which are the materials that make functional electronics.

Nano Dimension's AME 3D inkjet printing machines are thereby able to concurrently integrate electronics parts such as capacitors, antennas, coils, transformers and electromechanical components in situ. They can, therefore, rapidly prototype and produce complex, highly efficient electronics. This makes them much more versatile and efficient than PCB manufacturing based on layering, patterning, drilling and compression of typically FR-4 (glass-reinforced epoxy laminate) material, and copper sheets.

OPENING UP THE POSSIBILITIES

Using its unique 3D printing technologies, Nano Dimension aims to serve the growing demand for electronic devices that require increasingly sophisticated features. Demand for circuitry, including PCBs - which are at the heart of every electronic device - covers a diverse range of industries. These include consumer electronics, medical devices, defense, aerospace, automotive, IoT and telecom. These sectors can all benefit from products and services that can enable rapid prototyping and short-run manufacturing.

When it comes to the sorts of precision electronic products 3D printing can conjure up, such as High-Performance Electronic Devices (Hi-PEDs™) and complex multilayer PCBs, things can get really interesting.

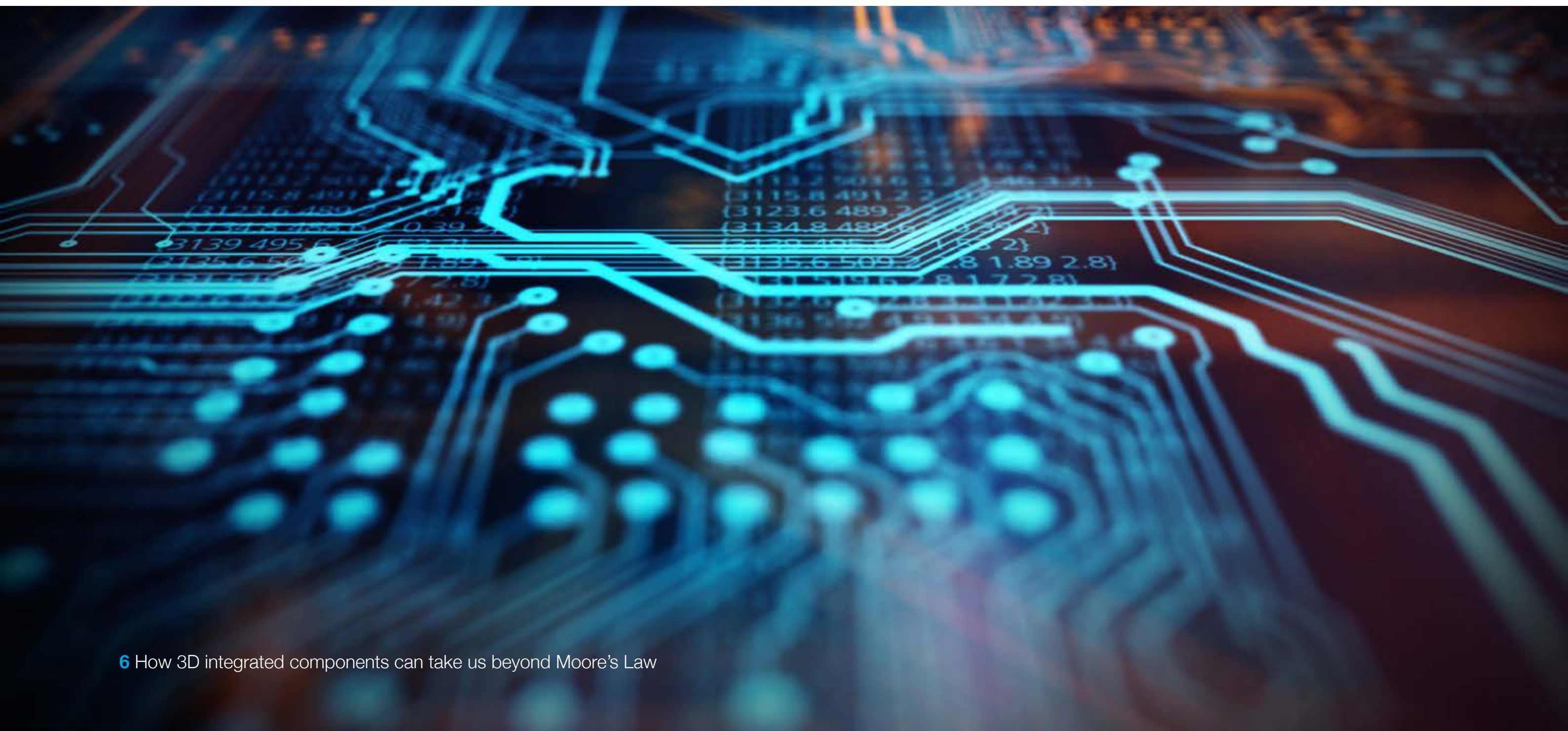
Vertically-stacked integrated circuits are a great example of Hi-PEDs™, which is a term coined by Nano Dimension. The new freedom to create interconnects and vias without traditional manufacturing limitations is key to the heterogenous integration.

Stacked ICs have a higher circuitry density than traditional PCBs by allowing ICs to be mounted and interconnected on top of each other. This creates opportunities to produce highly compact, highly complex electronics. Multilayer PCBs also present a promising area of innovation and can currently combine up to 50 layers easily.

Hi-PEDs™ and multilayer PCBs can combine elements such as sensors, capacitors and transformers into unique geometries and complex devices. They can also feature more advanced elements like lowpass filters, compact 3D printed coils and inductors, 3D-MIDs (molded interconnect devices), RF antennae, IoT access points, electronic circuits with side-mounted components, and vertically stacked ICs.

Indeed, electronics professionals are currently experimenting with 3D AME technology and embedding components, and integrating optoelectronic elements, biochemical sensors, radiofrequency radar systems, and piezoelectric sensors into new packaging solutions.

Another promising area for 3D AME heterogeneous integration is packaging for Micro-Electro-Mechanical Systems (MEMS). The technology essentially miniaturizes mechanical and electro-mechanical elements, such as devices and structures, using the techniques of microfabrication. This enables multiple devices to be put on a single chip - features such as solar power sensors, infrared cameras, accelerometers, motion sensors, or pico-projectors. 3D AME can help to extend this technology, again by playing a complementary role.



NEW DESIGNS WITH NON-PLANAR ELECTRONICS

Modern electronics designs demand improved performance and functionality and increased miniaturization. This creates the need for curved surfaces and 3D printed layers that are not flat or of uniform thickness. The challenge is to produce optimized electronic prototypes, embedding the electronics in any shape, in order to authenticate new product designs.

This is where additive manufacturing can offer brand new mechanical and form factor advantages due to its versatility. So, for example, Nano Dimension's Dragonfly LDM allows for the heterogeneous integration of ICs, sensors, circuitry and special shapes very easily.

The printing of non-planar geometries and non-traditional layer parts, in particular, creates immense design flexibility. It paves the way for new and exciting electronic circuits and devices that could feature curved surfaces and varying thicknesses, and offer better performance in smaller form factors - such as a 3D cube.

Instead of producing electronic circuits through subtractive chemical processes, products are built up additively. This makes it possible to build up a 3D shape with bespoke cavities, holes and shapes, because the additive process allows for the selective deposition of the material at specific X, Y or Z coordinates. It also means you can have interconnects exactly where you want them, without having to drill through or link using wire bonding.

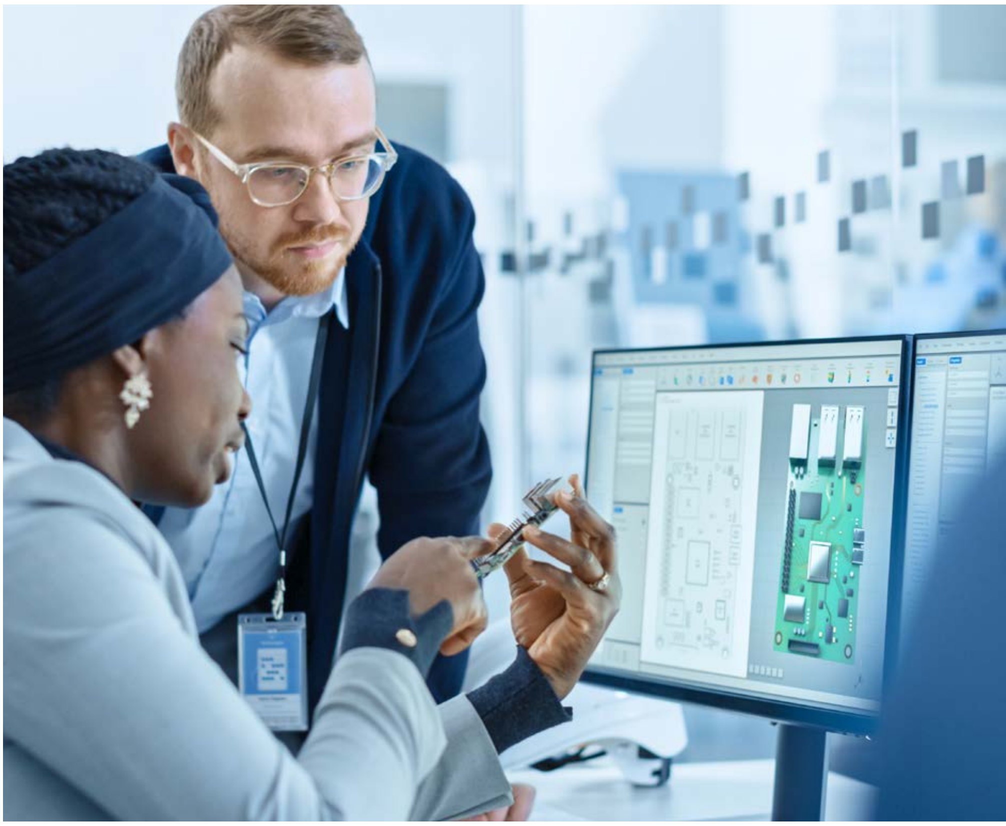
In terms of mechanical innovation, additive manufacturing can produce a board that combines multiple properties, such as rigid areas, cavities for components, and thinner, more flexible parts that can replace the need for interconnects, without adding to the bulkiness or weight of the board.

One component that illustrates the beauty of the free-form geometry that 3D additive manufacturing can achieve is the coil. Coils are at the heart of many applications in the electronic engineer's toolkit, and using the Dragonfly LDM, it's possible to produce a continuous conductive spiral which, for example, allows the part to function as an electromagnet.

Using the same build process, it is also feasible to build motors or explore inductance, and other electrical components such as sensors, components and RF antennas. So, the ability to print non-planar electronics and circuitry facilitates the printing of electrical functions, which can otherwise be very difficult and costly if not inefficient to make.

3D PRINTING AND SUSTAINABILITY

As mentioned above, 3D printing offers a way to transform traditional electronic design and manufacture whilst complementing and extending Moore's Law by increasing functionality and efficiency at all levels including the package level. It also has profound sustainability advantages.



Traditional electronic circuit (EC) manufacturing hasn't changed its methods of production for decades. This has culminated in significant chemicals and materials waste, through processes such as machining, image etching, laminating and limiting functionality.

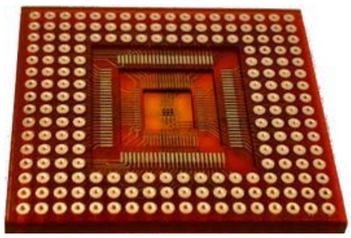
Studies have found that in general, the composition of waste water from EC production contains significant amounts of hazardous waste. This is down to the high amounts of harmful substances used in the EC production process, such as nitric acids, ferric chloride, glycol ethers, and formaldehyde. Furthermore, waste water solutions consist of etching chemicals and metal particles. And there are very few ways to recycle these solid and liquid waste materials.

Considering the high volume of electronic equipment entering the market each year, it's become increasingly important to develop new ways to produce sustainably manufactured goods in the years to come.

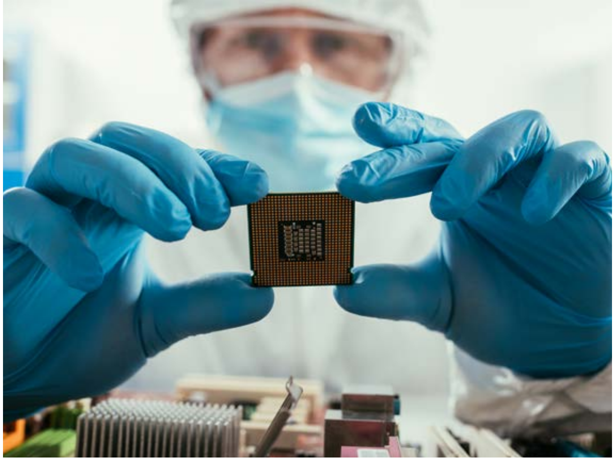
Full additive manufacturing of electronics with inkjet AME technology offers a reduction in waste of 65-80% compared with traditional PCB manufacturing. In comparison with chemicals-based EC production, the water waste of AME inkjet technologies consists of a solvent with only three materials: conductive ink, dielectric ink and washing liquid.

Indeed, 3D printing AME is considered one of the most promising next-generation green manufacturing processes. Additive manufacturing of electronics offers the industry lower material and energy costs and faster production speeds, and these represent huge saving factors in comparison to traditional PCB and IC packaging.

Another way 3D AME can improve sustainability is by reducing the carbon footprint of transportation and travel. Having an advanced AME platform in-house eliminates the round-trip required for development in Asian fabs, which is the traditional route for PCB prototyping and manufacture. Instead, organizations can print on demand at the point of need, minimizing transportation.



THE ROLE OF SOFTWARE IN DEVELOPING NEW FUNCTIONALITIES

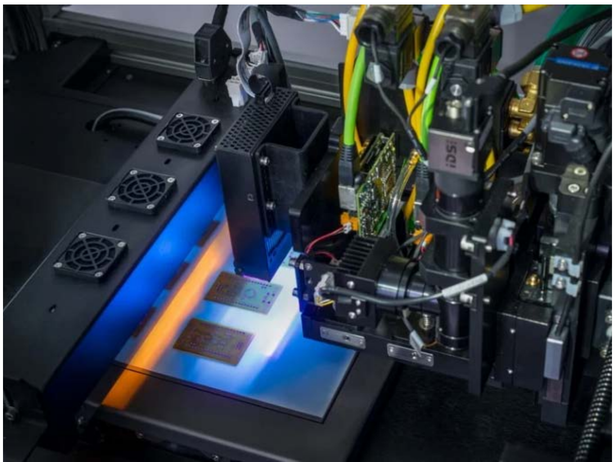


An important aspect of modern 3D printing is the software it uses. Nano Dimension's Dragonfly LDM gives electronics professionals an easy and straightforward user experience that translates into speed, innovation, time to market and competitive edge.

The software, SWITCH® Hub seamlessly integrates with all the popular Electronic Design Automation (EDA) software products on the market. It can be used to create many different types of AME files, drill guides and mechanical cut files. And it works with all EDA and mechanical CAD software programs automatically to create three-dimensional shapes at the push of a button.

The next version of the software, SWITCH® Hub, takes things up a level by allowing users to merge EDA layouts into 3D form factors. The ultimate goal is to move to a cloud-based application for greater flexibility, so a designer in one location can take a standard EDA or CAD tool, push a button, convert it to a go file, and print to a 3D Dragonfly LDM® machine at another location.

The software-centric nature of 3D AME also means that organizations can build up a digital inventory of 3D electronic components and designs, and move to a world where they no longer have to send physical products around the world. Instead, it will be possible to send a digital file or access it via the cloud, and print a product remotely.



INDUSTRIES AND INTELLECTUAL PROPERTY

AME has applications for a diverse range of industries that can benefit from rapid prototyping and low volume, high-mix manufacturing. Among these are consumer electronics, a fast-moving and highly competitive market and healthcare which has an increasing requirement for wearable and in-body devices. Defense and military are also key sectors that benefit greatly from AME, for devices that range from drones to satellites. There is also a lot of scope to innovate products in automotive, telecoms, research and aerospace, to name a few.

Importantly, having in-house 3D AME capabilities enables organizations to protect their intellectual property by not having to rely on suppliers in Asia, where prototypes and designs are potentially vulnerable to IP Theft. Additionally, businesses can gain supply chain security by bringing it closer to home, or even in-house.

Precision AME machines like the Dragonfly LDM also help to bring the electronics industry back to continental Europe and North America, which has shifted east over the past decades. This has mainly been because the East is where the high level of skills, specialist materials and cost-effective labor are in greater supply. But times are changing.

3D AME takes a digitally-driven approach and puts the power and capability back into the hands of electronics professionals. And by taking a file optimized for 3D printing, they can press a button and print out complex, highly efficient electronics in Austin, New York, London, Paris, Munich or wherever it's required, in just a matter of hours.