



A lot of potential for non-TSMC ReRAM

Weebit Nano (ASX:WBT) has continued its push towards commercialisation of its ReRAM technology. Throughout CY23, we expect volume production and commercialisation of ReRAM to commence with customers of WBT's first major customer, US-listed semiconductor fab SkyWater (NASDAQ:SKYT). This should start once qualification of the demo chips is complete, which we expect in Q2 2023. WBT will also continue to further scale down the circuitry resolution and seek further commercial partners in addition to SkyWater.

Taping out at 22nm

An additional important step for the company was the tape-out of a 22nm demonstration chip integrating its ReRAM module in an advanced 22nm FD-SOI process technology, meaning it was released to manufacturing. This was announced to the market on 3 January and came barely 2 months after the first full technology qualification of ReRAM at 130nm. Although WBT will need to qualify ReRAM at 22nm, taping out is still a major step towards qualification and eventual commercialisation with this new prospect.

WBT is in the right place at the right time

Weebit Nano (ASX:WBT) is now well-positioned to enter the embedded Non-Volatile Memory (NVM) market segment in 2023. The embedded NVM market is expected to grow by 94% CAGR annually up over the next few years, reaching \$2.9bn by CY27. WBT is targeting the 33% market share for ReRAM, which represents a US\$957m opportunity for the manufacturing fabs that licence and use WBT's technology. WBT will then charge a certain percentage of that value in recurring royalties and a fixed, one-off license fee.

TSMC's ReRAM is a godsend for Weebit Nano

Ever since it became known in the industry that TSMC, the industry giant, is shipping ReRAM in certain products, including the iPhone 14, WBT has been getting a lot of traction with prospects, i.e. other foundries and chip manufacturers that won't be able to access TSMC's technology. This is the reason WBT is now engaging with the majority of the world's tier-1 fabs and doing evaluations with some of them. So, while TSMC has competing technology, it has actually opened up the floodgates for WBT, in our view.

Valuation upgraded to A\$6.10 per share

Our previous valuation for WBT was A\$4.75 per share as outlined in our report from 14 January 2021. This target has been reached and in light of the progress the company has made in recent months, we upgrade our valuation to \$6.10 per share. See page 8 for the valuation details and investment risks.

Share Price: \$5.00

ASX: WBT

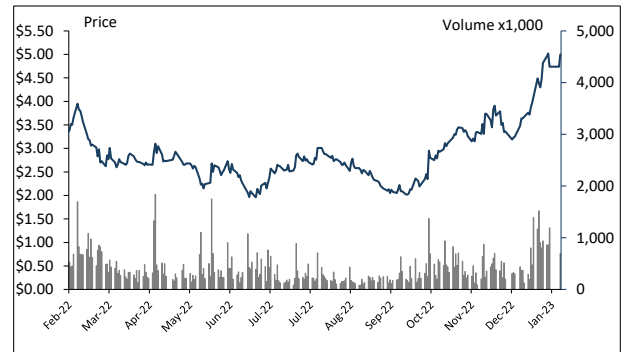
Sector: Technology Hardware and Equipment

3 February 2023

Market Cap. (A\$ m)	867.4
# Shares outstanding (m)	173.5
# Share fully diluted (m)	192.1
Market Cap Full. Dil. (A\$m)	960.3
Free Float	100%
12-month high/low (A\$)	\$5.10 / \$1.92
Avg. daily volume ('1000)	411.6
Website	www.weebit-nano.com

Source: Company, Pitt Street Research

Share price (A\$) and avg. daily volume (k, r.h.s.)



Source: Thomson Reuters, Pitt Street Research

Valuation metrics	
Valuation per share (A\$)	6.10

Source: Pitt Street Research

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Disclosure: Pitt Street Research directors own shares in Weebit Nano Ltd.



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The past 18 months have been a busy time for Weebit Nano (ASX:WBT) with the company taking several crucial steps towards commercialisation.

2023 has begun well for WBT

The past 18 months have been a busy time for Weebit Nano (ASX:WBT) with the company taking several crucial steps towards commercialisation. WBT entered its first commercial agreement with SkyWater Technologies, qualified its technology with CEA-Leti, received the first silicon wafers incorporating the company’s ReRAM module from SkyWater Technologies’ US production fab and demonstrated the maturity and suitability of its embedded ReRAM for volume production. See Appendix II for an outline on how WBT’s ReRAM technology works.

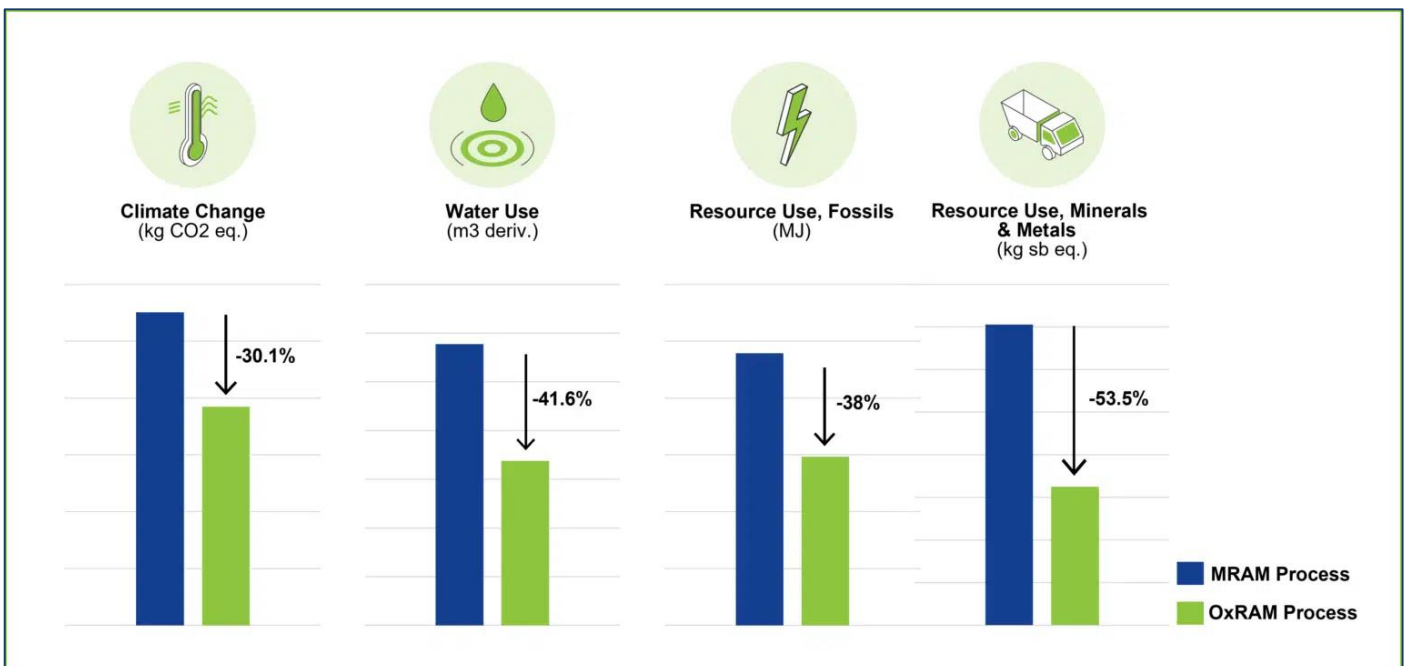
Taped out at 22nm

Since our last report, published on 10 November 2022, WBT taped-out its first 22m demonstration chip integrating an 8Mb ReRAM module in an advanced 22nm FD-SOI process technology, meaning it was released to manufacturing. This was the first tape-out of Weebit ReRAM in 22nm, one of the industry’s most common process nodes and a geometry where embedded flash is not viable.

ReRAM proven to be environmentally friendly

WBT has also undertaken a study in which it analysed the environmental impact of ReRAM compared to Magnetoresistive Random Access Memory (MRAM), which is the only other kind of emerging NVM that is commercially available at foundries. ReRAM demonstrated a superior greenhouse gases profile compared to MRAM (Figure 1), because it uses less critical raw materials, requires fewer manufacturing layers and masks and it doesn’t require exotic materials or special equipment. Beyond a smaller carbon footprint, the less intensive production method also translates to lower costs.

Figure 1: Results of ReRAM environmental impact study



Source: Company website



The global market for NVM is expected to grow from US\$74.6bn in 2022 to US\$124bn by 2027

The market opportunities for ReRAM

WBT has timed its run to market well. On one hand the addressable market is growing, but on the other hand, existing technologies are approaching their physical limits. As per data from MarketsandMarkets, the global market for NVM is expected to grow from US\$74.6bn in 2022 to US\$124.1bn by 2027, representing 10.7% CAGR.

Although WBT's ReRAM technology is suitable for both embedded and standalone memory, it is commercialising it on embedded applications first. Embedded applications allude to memory that is integrated into the chips (Systems on a Chip or SoCs) alongside the microcontroller.

Embedded memory typically performs better than a solution where the memory component is sitting next to the chip, specifically when it comes to speed and energy consumption, simply because data doesn't have to travel as far to get to the microcontroller.

Embedded memory is WBT's first target market

The dominant embedded NVM technology today is Flash memory, a technology that has reached its scaling limit. SoCs with embedded Flash memory tend to mostly be at 40nm or greater geometries, although 28nm is possible as well. Any smaller geometries lead to a leakage of current between adjacent memory cells, which would lose their value. This issue is commercially unviable (too expensive) to overcome.

The new generations of applications need embedded memory modules at process nodes of 28nm or below, a market need that is currently underserved and one that WBT hopes to penetrate. The Embedded emerging NVM market is expected to reach \$2.9bn by 2027 according to data from market researcher Yole. It is expected that ReRAM will capture a 33% market share, representing \$957m (Figure 2). This would represent 94% CAGR growth from 2021. We believe this 33% share is actually quite conservative given the benefits of ReRAM compared to other technologies.

Figure 2: Embedded ReRAM Market Size



Source: Company, Yole Emerging Non-Volatile Memory 2022.

Note: The embedded emerging NVM market size is evaluated based on assumptions of the average chip area occupied by a given memory technology

ReRAM has recently entered the NVM market.

Embedded ReRAM is entering the market

ReRAM technology has recently entered the NVM market. Taiwan Semiconductor Manufacturing Corp. (TSMC) has relatively new ReRAM technology. It is known there is a chip with TSMC's embedded ReRAM in the iPhone 14. Additionally, German semiconductor vendor Infineon has also announced it will use TSMC's ReRAM in its entire line of automotive MCUs starting this year.

During 2023, Weebit's ReRAM will be entering the market through SkyWater. In addition, we expect more commercial agreements to be signed between WBT and third-party manufacturers (fabs).

From 2024, we expect additional fabs to move towards using WBT's embedded ReRAM. WBT would license its IP to these fabs for a one-off license fee and receive royalties as a percentage of their sales. Potential applications include Mixed Signal, Analog and Power Integrated Circuits (IC's), IoT devices, Edge AI, Automotive/Industrial and Aerospace, and Defence (Figure 3). All of these represent significant opportunities for WBT, in our view.

Figure 3: Tentative timeline and Market Size of End-user segments for Weebit's embedded ReRAM

End-user segment	Timeline for entry (years)	Market size forecast (US\$)
Mixed Signal, Analog and Power ICs	1	83b (2022)
IoT devices	1	80b (2025)
Edge AI	2+	28b (2028)
Automotive/Industrial	4-5 (mostly due to regulation)	78b (2026)
Aerospace and Defence	1	8.6b (2027)

Sources: Investor Presentation – April 2022, Investors, Company website; 'The Future of Memory - The Time for ReRAM', Circuit Cellar

ReRAM can start to displace Flash in standalone applications

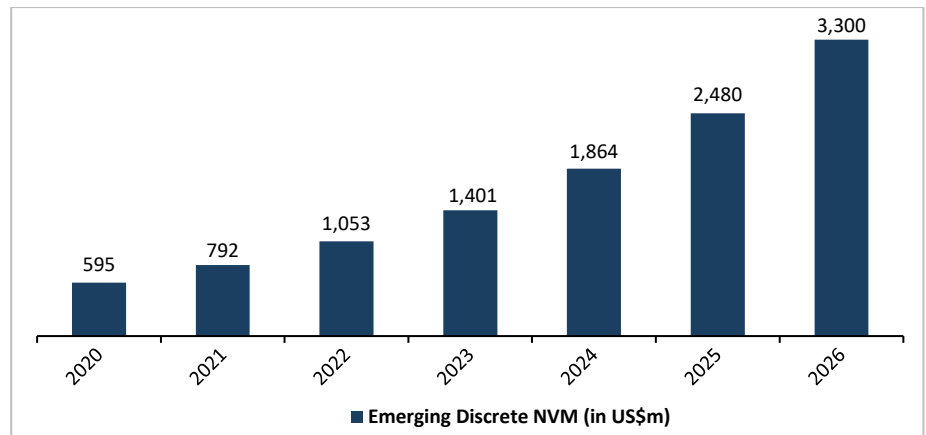
A big opportunity in Standalone / Discrete NVM

In the medium, we see potential for ReRAM to enter the standalone, or discrete, NVM segment. Discrete memory chips are used in low-cost, high-density on-device data storage applications, such as mobile phones, PCs, tablets, data centers, USB drives and Solid State Drives in PC's and laptops.

Similar to the market for embedded NVMs, the market for discrete NVMs is dominated by a particular type of Flash memory, notably NAND Flash.

The useful life Flash technology has been prolonged since it first hit its scaling limits in 2007, among other things by stacking layers of Flash memory on top of each other in what is known as 3D Flash. But to continue scaling Flash down, say towards 20nm, would require substantial capex investment to overcome the issue of crosstalk (current leakage), making it unfeasible for commercial applications. This will open up a market opportunity for emerging NVM technologies in the discrete NVM market worth US\$3.3bn by 2026 (Figure 4), according to i-MicroNews.

Figure 4: Emerging Discrete NVM market – Growth forecast (2020-2026)



Source: 'Emerging Non-Volatile Memory 2021', i-MicroNews

We think WBT could enter the market in 2024, starting with smaller size chips that do not require a selector, say memory sizes up to 512MB. Thereafter, ReRAM could integrate with larger chips.

In this case, WBT would sell memory chips itself.

Neuromorphic Computing is bound to be a massive market

Another long-term use case for ReRAM could be Neuromorphic Computing (NC). Simply put, neuromorphic computing systems analyse and process information in a way similar to how the human brain does it. Please see [our report on BrainChip \(ASX:BRN\)](#) for more background on neuromorphic processing. This technology is currently at an early stage, but could serve many end-user industries over time. BRN has made very substantial progress in this field and is currently commercialising its technology.

WBT's ReRAM has been proven to be able to work in a similar way as human synapses, as demonstrated at the Flash Memory Summit in 2019, using Spiking Neural Network (SNN) algorithms developed by CEA-Leti. The demonstration provided a proof-of-concept, highlighting the potential of ReRAM in NC. WBT intends to further explore and potentially develop this ReRAM application in the longer term to address a potential US\$35bn opportunity by 2035. Again, this is a long-term opportunity for WBT, but one that investors should be aware of nonetheless.

ReRAM has great potential in Neuromorphic Computing



Milestones in 2023

We expect WBT to achieve several more milestones in 2023.

SkyWater qualification of demo chips

The most important milestone is qualification of the SkyWater-manufactured demo chips.

The most important of these milestones, and the final step to commercialisation, is qualification of the SkyWater-manufactured demo chips that WBT is currently conducting. WBT has already completed a qualification process, based on JEDEC (Joint Electron Device Engineering Council) guidelines on chips that were manufactured by CEA-Leti, its French development partner. This provides confidence that WBT can achieve qualification with chips manufactured by SkyWater as well. Qualification of these chips is expected in 1HY23.

Given that WBT and SkyWater have begun engaging with prospective customers, we think volume production could ramp up within a year post-qualification. Indeed, the qualification has helped the company in its conversations with would-be customers.

Additional deals with foundries and potentially IDMs

We see the potential for more foundries to sign commercial partnerships with WBT to commercialise Embedded ReRAM.

As of late January 2023, SkyWater remains the only foundry that has become a commercial partner of Weebit. We see the potential for more foundries, as well as Integrated Device Manufacturers (IDM's) to sign commercial partnerships with WBT to bring ReRAM into volume production.

We think that any foundries competing with global leader TSMC and who are looking to integrate ReRAM into their offering, will require ReRAM technology of their own as they won't be able to access that of TSMC.

Since WBT's embedded ReRAM technology is practically the only other option on the market, the company should be able to benefit from this dynamic and partner with foundries around the world. Indeed, WBT is currently talking to the majority of top fabs.

A lot of potential for non-TSMC ReRAM

In addition to foundries, we would expect IDMs and fabless chip designers, such as Intel, NXP, Samsung, STM, NVIDIA and ARM to be interested in integrating non-TSMC ReRAM into their products as well.

Technical progress on embedded and standalone ReRAM

We also expect WBT to continue to develop its technology. Indeed, the recent news of initial tape-out of a 22nm FD-SOI demonstration chip signifies that WBT's R&D work is ongoing and will continue as ReRAM enters the market.

Specifically, WBT will continue to scale down its technology while improving its performance for the embedded ReRAM market.

Additionally, we expect further announcements on progress made in standalone/discrete memory applications.



Weebit's future revenue model

Non Recurring Engineering fees, one-off license fees and recurring royalties will form the basis of WBT's future revenues

As outlined in previous reports, WBT's business model is to license its Intellectual Property in the 'design' stage of production. Potential clients include foundries, fabless chip companies and IDMs.

WBT will generate revenue in the form of license fees (upfront and milestone payments), a per-unit royalty and Non Recurring Engineering (NRE) fees. The latter are costs incurred by WBT during design-in and testing on a customer's behalf. WBT simply gets reimbursed for these costs.

Based on industry standards, the royalty percentage on the customer's revenue could be anywhere between 1.5% and 3%, depending on the type of product, volumes etc.

An example

To illustrate how this might work, let's assume a foundry can make a chip that costs US\$10 per unit and includes WBT's technology. Let's also assume that WBT receives a royalty payment from this customer of 3% of the sales value of the chip with WBT's technology. If we assume WBT's customer sells 1m of these chips in a particular year, representing US\$10m in sales, WBT would receive US\$300,000 in royalties in that year from this customer for this product.

Adding new customers and new products with existing customers will drive revenue growth

As WBT builds its customer base, initially in embedded ReRAM and later on in discrete memory, we expect to see a gradual build-up of royalty revenues over time. This build-up will come from adding new customers to the stable, but also from existing customers expanding the use of WBT's ReRAM into other products. For each additional product that uses WBT's ReRAM, customers will have to enter into additional agreements.

Valuation for WBT of A\$6.10 per share

Our valuation for WBT was published in our research report from 14 January 2021. In that report, [available here](#), we valued the company at A\$4.75 per share, representing an enterprise value of \$750m. We derived this value using semiconductor industry M&A transactions, particularly deals completed by Intel, and parallels to ASX-listed peer BrainChip (ASX:BRN). Given the progress of the company, which has resulted in our valuation of \$4.75 being realised, it is time to update our valuation.

The deal we used to value WBT at was Intel's US\$2bn acquisition of Habana Labs for US\$2bn in 2019. We valued BRN at US\$2bn, because it was where Habana was two years before its acquisition.

We valued WBT at \$750m, taking into account our view that WBT was approximately 6 months behind BRN in terms of commercialisation at the time.

WBT has largely caught up with BRN in terms of commercialisation

Since then, not only has WBT made substantial progress, but the need for ReRAM has only become more prevalent.

In addition, we believe WBT has, to a large extent, caught up with BRN in terms commercialisation. We expect the company will be able to record its first license income in 2023 if and when SkyWater proceeds to take ReRAM into commercial production.

New valuation of \$6.10 per share

In other words, we believe WBT should be valued at least in line with BRN, which would imply a market capitalisation of \$1.17BN, of \$6.10 per share.

Key investment risks

- Alternative emerging memory technologies are being developed by WBT’s competitors. These technologies could potentially be superior in nature and/or could be commercialised sooner than WBT’s technology, which would inhibit the company’s future growth.

TSMC is currently already selling its own ReRAM technology commercially, but is essentially competing for business with all other foundries. Hence, these other foundries are all potential customers for WBT as they don’t have access to TSMC’s technology.

Other than that, apart from Crossbar, Adesto and 4DS (although all of these companies are behind WBT), we don’t see the other ReRAM players as potential competitors. Crossbar seems to have shifted focus to a niche end-user segment, while Adesto was acquired by Dialog Semiconductor for an EV of US\$500m (A\$758m at the time), specifically for its IP in the IoT space. Dialog was subsequently acquired by Renesas (2021).

- Although WBT seems adequately funded for the medium term, the company may need to raise further capital. That may be required, for instance, if its current development programs and technology transfer/qualification take longer than currently anticipated or multiple growth opportunities arise that require additional development capital. Future potential equity capital raises will result in dilution for existing shareholders (albeit at offer prices reflecting the company’s progress).



Appendix I – Analyst certification

Marc Kennis has been an equities analyst since 1996.

- Marc obtained an MSc in Economics from Tilburg University, Netherlands, in 1996 and a postgraduate degree in investment analysis in 2001.
- Since 1996, he has worked for various brokers and banks in the Netherlands, including ING and Rabobank, where his focus has been on the technology sector, including the semiconductor sector.
- After moving to Sydney in 2014, he worked for several Sydney-based brokers before setting up TMT Analytics Pty Ltd, an issuer-sponsored equity research firm.
- In July 2016, with Stuart Roberts, Marc co-founded Pitt Street Research Pty Ltd, which provides issuer-sponsored research on ASX-listed companies across the entire market, including technology companies.

Appendix II – ReRAM technology...how does it work

ReRAM technology: The right balance between Flash memory and DRAM

ReRAM is a fast, cost-effective and energy-efficient non-volatile memory (NVM) technology. It can be considered a hybrid memory technology, as it is non-volatile like Flash memory and nearly as fast as DRAM, which is volatile, i.e., a DRAM cell will lose the value (1 or 0) that is stored if the power is switched off. WBT is developing a ReRAM technology, which, in terms of performance metrics, sits right between Flash and DRAM.

How does it work?

Generally, in the case of NAND Flash memory, the values of 1 and 0 are attributed based on the trapped electrical charge present in the memory cell's floating gate. However, in the case of a ReRAM cell, the values (1 and 0) are attributed based on the resistance level of the cell material sandwiched between the two electrodes (Figure 1). A value of 1 is attributed to a state of low resistivity, while a value of 0 is attributed to a state of high resistivity.

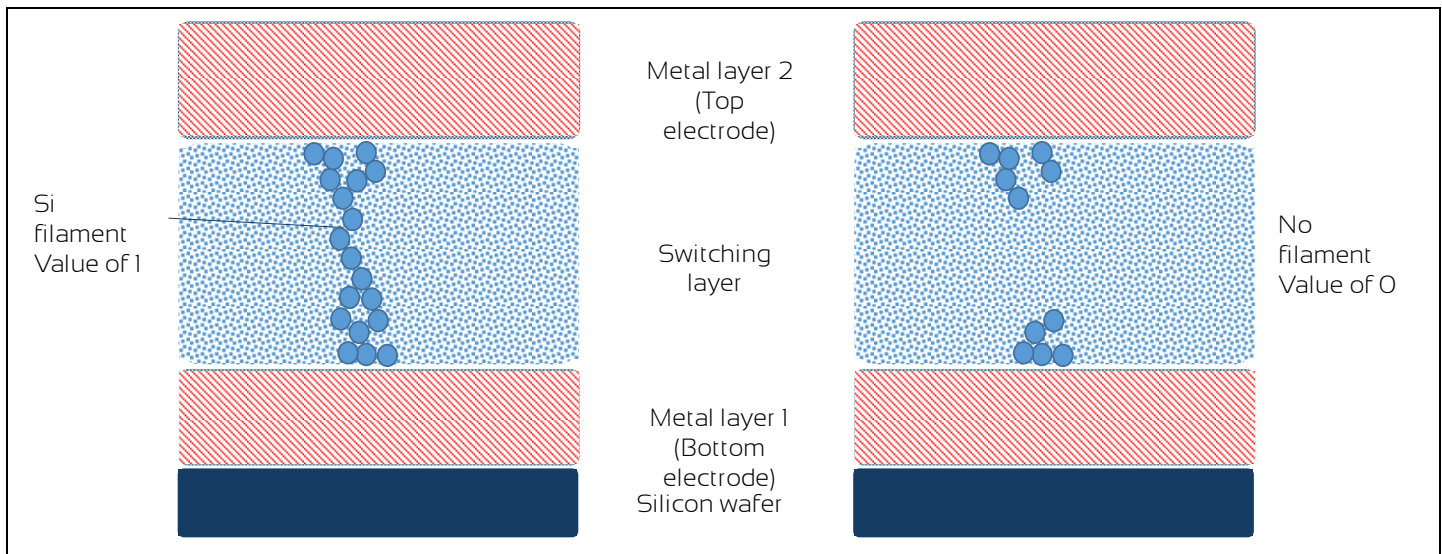
There are two ways of changing the resistance level of a ReRAM cell.

- Through interface switching, which changes the resistivity of the entire layer between the electrodes or
- By creating a filament that connects the two electrodes.

WBT uses the latter.

The technology WBT is developing is based on forming a conductive channel between the two metal electrodes of a ReRAM cell. These electrodes are typically made of metals, such as titanium, tungsten, aluminium or copper. The conductive channel is formed inside a non-conductive layer.

Figure 5: Cell switching by forming and breaking a filament in the switching layer



Source: Pitt Street Research

By applying a certain voltage to one of the electrodes, a switchable filament made of oxygen vacancies can be formed within the switching layer (Figure 5). In this high-conductivity, low resistance state, the cell value is 1. By subsequently applying a reverse voltage to the electrode, the filament can be broken down again, effectively switching the memory cell back to the original state of 0.

The actual filament is formed as the applied electrical voltage strips away some of the oxygen atoms in the switching layer, leaving the dielectric atoms to cluster and create a conductive pathway to the other electrode. The filament is ~5nm to 7nm in diameter.

Appendix III – Glossary

Access time: It refers to how long it takes to read data or write data to a memory cell.

BEOL: It refers to Back-End-Of-Line. It is the second portion of IC fabrication in which interconnecting layers are formed which connect transistors on the wafer.

CMOS: It refers to ‘Complementary Metal-Oxide Semiconductor’, a popular semiconductor technology used to manufacture most chips in the semiconductor industry.

Data retention: It refers to the amount of time the data stored in memory will retain its value without any power supply.

Discrete/Stand-alone NVM: It refers to a chip which contains only memory.

DMEA: It refers to Defence Microelectronics Activity, a provider of microelectronics to all branches of the U.S. government.

DRAM: It refers to Dynamic Random Access Memory, a type of volatile memory which is used in computer processors as the main memory

Embedded NVM: It refers to memory that is embedded on an SoC.



Endurance: It refers to the number of times a block of memory can be programmed and erased before the memory wears out and becomes unreliable.

Fabless: It refers to companies which design chips for customers.

FEOL: It refers to Front-End-Of-Line. It is the first portion of IC fabrication in which individual components are constructed and patterned inside the wafer substrate.

Fabs/Foundries: It refers to companies which manufacture chips for customers.

IC: It refers to Integrated Circuit, a set of semiconductor components connected on a single semiconductor wafer.

IDM: It refers to a company which designs and manufactures its own brand of chips.

OEM: It refers to Original Equipment Manufacturer, a company which produces equipment and parts which are sold by another company to their customers under their own brand name.

Scaling geometry: It refers to achieving a reduction in the size of a chip (measured in nanometres/nm) in the fab manufacturing process.

Neurons: It refers to fundamental units of the brain which carry information throughout the body.

nm: It refers to nanometre. It equals one billionth of a metre, or a millionth of a millimetre.

NVM: It refers to non-volatile memory, a type of memory which retains data even when the power supply is disconnected.

NRE: It refers to non-recurring engineering costs, a one-time cost which is incurred in the R&D and design phase of a product.

Rad-hard: It refers to radiation hardened, a term used to describe devices which can tolerate substantial amounts of radiation.

SNN: It refers to Spiking Neural Networks. They are artificial neural networks which mimics the brain's neural networks.

SoC: It refers to System-on-a-Chip, a chip which integrates a computer system on it.

SRAM: It refers to Static Random Access Memory, a type of volatile memory which is used to store local data and machine code.

Synapses: These refer to structures in the human body which facilitate communication between two neurons.

Wafer: It refers to a thin slice of semiconductor material.

zb: It refers to Zettabyte, a unit for measuring computing memory. It equals 10^{21} bytes. For reference, an mb equals 10^6 bytes.

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