

## The home stretch

4DS Memory (ASX:4DS) is moving closer to potentially delivering a fully functional megabit chip, having received favourable wafer testing results in June 2020. The results showed superior speed (near DRAM speed) and endurance metrics vis-à-vis previous tests. This has laid the groundwork for development plans for the next six months, which are expected to lead to the delivery of a megabit chip and/or a corporate transaction in 2021. Additionally, 4DS was granted three more US patents for its Interface Switching ReRAM technology, which further strengthens its intellectual property portfolio (26 patents, all 100% owned).

### Sufficiently funded to execute development plans

4DS recently raised approximately A\$7.6m in capital, via a A\$4.5m private placement and a A\$3.1m share purchase plan. In our view, this inflow of funds, coupled with the cash balance of A\$2.5m as of 30 June 2020, should allow the company to achieve its development objective of delivering a megabit chip collaborating with imec and HGST (part of storage giant Western Digital, NASDAQ:WDC).

### Investment case further de-risked

With the memory cell optimisation work now largely complete, we believe 4DS has taken a significant step in de-risking its investment case, i.e. readying its technology for a strategic sale to a memory manufacturer, design house or foundry. Producing a fully functional megabit array on imec's off-the-shelf memory platform for 300mm wafers is the last step in this process. However, development risks remain and we'd like to refer investors to our elaborate research coverage of 4DS on <http://www.pittstreetresearch.com> for more detail about investment risks for 4DS Memory.

### Valuation of A\$0.103 per share

An outright acquisition of the company has been management's stated goal for the last few years. M&A activity in the semiconductor industry suggests an average transaction value of A\$135m for semiconductor IP companies, which would translate into an equivalent value of A\$0.103 per 4DS share (fully diluted). However, in the right hands, we believe the value of 4DS' IP may be substantially higher, especially if we take the applicability of Interface Switching ReRAM in neuromorphic processing into account.

Share Price: A\$0.062

ASX: 4DS

Sector: Semiconductors & Semiconductor Equipment

23 September 2020

Market Cap. (A\$ m)	81.2
# shares outstanding (m)	1,309.7
# share fully diluted	1,380.3
Market Cap Ful. Dil. (A\$ m)	85.6
Free Float	95%
52-week high/low (A\$)	\$0.09 / \$0.03
Average daily volume (x1,000)	3,316.4
Website	<a href="http://www.4dsmemory.com/">www.4dsmemory.com/</a>

Source: Company, Pitt Street Research

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



Source: Refinitiv, Pitt Street Research

Disclosure: Director(s) of Pitt Street Research own stock in 4DS Memory.

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## Major milestone achieved during lockdown

In June 2020, 4DS shared a key update on the status of the development of its Interface Switching ReRAM technology. It announced that it had made significant technical progress with regard to the analysis of the wafers it received from its collaboration partner imec, coupled with technical inputs from HGST – Western Digital’s wholly owned subsidiary.

The company highlighted that it had measured the highest speed and endurance ever recorded in the Additional Wafers Lot. Notably, it achieved the best recorded speed at near DRAM speed, exceeding storage class memory (SCM) requirements, coupled with endurance levels, which were two to three times better than previously reported.

Further, it also completed analysis on its Initial Platform Lot of 300mm wafers, which combine 4DS’ memory cell arrays with imec’s megabit platform. The integration of the two technologies is a very important step in development of the end product.

Testing revealed 4DS also achieved read/write speeds comparable to DRAM, which will be beneficial for SCM applications. The company also tested data retention in its memory cells, another key performance metric, but indicated additional studies need to be completed in order to assess the upper limits. The analyses have helped the company identify process steps that need to be refined further to benefit future platform iterations.

Based on the wafer testing results and identification of further iterative improvement steps, we believe that 4DS has moved a step closer towards its goal of delivering a megabit chip.

## Results from the upcoming wafer lots to drive future

Based on the analysis of the Additional Wafers and Initial Platform Lot, 4DS has devised its development strategies for the next six months. It began the fabrication of two sets of wafers in 3Q20 on imec production equipment. Imec, 4DS’ development partner, will manufacture one lot of 23 Non-Platform Wafers (Second Non-Platform Lot) and one lot of 12 Platform Wafers (Second Platform Lot).

The company is defining the process conditions for each of the 23 Non-Platform Wafers which are less complex and easier to test than Platform Wafers. We believe this will also lead to crucial inputs on process conditions leading to significant improvement in speed, endurance and retention. The Second Non-Platform wafers are expected to be available for analysis in second half of 4Q20.

While the Initial Platform Lot was to test the integration of dense memory arrays without transistors, the Second Platform Lot will contain dense memory arrays with transistors, enabling the selection of memory cells, a crucial aspect of a memory cell. The wafers from the Second Platform Lot are expected to be available for testing in 1Q21. More importantly, based on the results of this Second Platform Lot, 4DS would be able to fabricate wafers with integrated circuits that can potentially operate as fully functional megabit memory modules.

Thus, the results from both wafer lots will enable the company to deliver a megabit chip and/or a corporate transaction in 2021. With sufficient data in hand, 4DS would be positioned to demonstrate commercial viability to potential licensees or acquirers.

*The company measured the highest speed, near DRAM speed, in the Additional Wafers Lot*

*During Q3 2020, fabrication of two sets of wafers commenced on imec production equipment*

*Second Platform Lot to include selectors*



## Megabit array may be enough for a trade sale

While 4DS is aiming to produce a megabit array using Interface Switching ReRAM technology, we believe the memory market requires gigabit arrays for SCM applications. In other words, more development work will be needed to get to a market-ready product (gigabit ReRAM chips).

However, it has been the company's stated goal to find a potential acquirer for its technology, rather than develop the technology to maturity itself and license it out to chip manufacturers. Furthermore, building a gigabit array is relatively straightforward once a megabit array has been produced.

Therefore, we believe that even if 4DS only develops the technology to the point of having a megabit Interface Switching ReRAM module, that in itself may be sufficient for potential acquirers to consider a take-over offer. The acquirer would then need to take the technology to the gigabit level to be able to address the SCM market.

## Robust patent portfolio

In August 2020, 4DS was granted three additional patents in the US, specifically related to the operation of its Interface Switching ReRAM technology required for high-speed SCM. The latest three patents pertained to 'Resistive Memory Device Having a Template Layer', 'Resistive Memory Device having Ohmic Contacts', and 'Resistive Memory Device having Side Barriers'.

This is a significant milestone, and complements the recent favourable results achieved in the wafer tests conducted with imec. These additional three patents will strengthen 4DS' intellectual property portfolio as the company now owns an IP portfolio comprising 26 granted US patents. Notably, all the patents have been developed in-house and are 100% owned by the company. Further, it has also filed another six US patent applications in the same domain.

*4DS memory now owns an IP portfolio comprising 26 granted US patents*

## Secured funding for its development plans

4DS Memory recently raised ~A\$7.6m through a combination of an institutional placement of A\$4.5m and a A\$3.1m share purchase plan (SPP). Notably, the SPP was oversubscribed from the original offer size of A\$2.5m. The offer price for the institutional placement was A\$0.045 per share, which was a 15.1% discount on the closing price on 22 June 2020 and 17.6% to 15 day volume weighted average price (VWAP).

The funds raised will primarily accelerate the development of a megabit chip with imec and HGST. The company also plans to utilise part of the proceeds for filing additional patents and general working capital purposes.

We believe this latest fundraising activity will play a crucial role in supporting the development objectives of the company until the end of 2021.

*The company raised A\$7.6m through a combination of private placement and SPP*

## Long standing relationships with its partners HGST and imec

In May 2020, 4DS announced that it had successfully renewed its joint development agreement with HGST. It is the seventh consecutive renewal with this global storage leader and has a term of 12 months. In our view, this evidences the value potential that HGST, and Western Digital for that matter, continue to see in working with 4DS and its technology. In our view, Western



Digital is still the most obvious candidate to acquire 4DS if it came to an acquisition scenario.

Previously, in October 2019, 4DS had extended its collaboration agreement with imec to the end of 2020. We consider this a major plus for 4DS, given the important role imec has played so far in advancing the technology. In our view, the extensive work history that the three partners share should help underpin the execution of the development strategies currently in place for the megabit chip.

## Investor sentiment turns positive for Artificial Intelligence (AI) stocks

In February 2020, the ASX introduced a new index – the S&P/ASX All-Technology Index (XTX) – in partnership with S&P Dow Jones Indices. This index complements the existing S&P/ASX Information Technology Index (XIJ) as it includes the relevant subindustries that get excluded from the XIJ, such as consumer electronics, internet and direct marketing retail, interactive media and services and health care technology.

Moreover, there is no restriction on the number of stocks that can be included in the new index, which is rebalanced each quarter. This translates to enhanced scope for other tech stocks to join this index as they gain investor attention.

One such company is BrainChip Holding (ASX:BRN), which witnessed a tremendous increase in its share price since the beginning of the year. BrainChip is an AI focused technology firm, which developed a Spiking Neural Network named Akida. A large part of the uptick was driven by an announcement made by BRN on 2 September 2020 regarding the collaboration with VORAGO Technologies. This collaboration is intended to support the Phase I of a NASA program for a neuromorphic processor that meets spaceflight requirements. Akida's incremental learning and ultra-low power performance supports the criteria. BrainChip also partnered with Magik Eye, developer of 3D sensors, to incorporate its neuromorphic processor in Magik Eye's Invertible Light 3D depth sensing technology.

Two days later, on 4 September 2020, S&P/ASX All Technology Index announced the addition of BrainChip Holding to the index as part of its upcoming quarterly rebalancing. Per 21 September 2020, BRN is part of the XTX.

## Potential beyond storage

We believe the success story of BRN will likely lead to retail investors seeking out similar stocks, e.g. in the semiconductor development space. We believe that 4DS is currently undervalued as it is. But we believe there's more potential for ReRAM technology beyond storage alone.

As per a study by IBM Research-Almaden,<sup>1</sup> PCMO ReRAM has demonstrated competitive performance for the on-chip acceleration of training of large-scale artificial neural networks. In our view, with the potential for use of non-filamentary ReRAM in neuromorphic processing, 4DS has substantial upside potential for re-rating. Moreover, the overarching theme of digital transformation has led many entities to rethink their business model, especially in the COVID-19 era. Firms offering digitisation solutions, whether

*ReRAM has applications in neuromorphic processing as well*

<sup>1</sup> Severin Sidler, et al. "Large-scale neural networks implemented with non-volatile memory as the synaptic weight element: impact of conductance response"; IBM Research–Almaden; 2016



they are Network-as-Service providers like Megaport (ASX:MP1) or software companies like WiseTech Global (ASX:WTC), have witnessed positive share price movements – with MP1 gaining 45% YTD and WTC gaining 164% since March 2020. But more noticeable is the attention that firms which employ AI are receiving. For instance, Appen Ltd (ASX:APX), which provides and improves data used for development of machine learning and AI products, saw a 41% uptick in its share price, on YTD basis. In our view, as more ASX investors shift their attention to AI and semiconductor developers, the upside potential for companies like 4DS could be significant.

## Valuation of A\$ 0.103 per share

Our current valuation for 4DS of A\$0.103 per share (was A\$0.11 prior to the dilution from the most recent capital raise) is based on the average value of M&A transactions in the semiconductor IP space in the last four years. In that period, transaction values ranged from A\$29m to A\$541m with an average of A\$135m.

We believe the actual value of 4DS in a potential M&A deal (if and when that happens) could prove to be substantially higher to the right acquirer, though. To illustrate this point, we've looked at sales of 3D XPoint, an emerging non-volatile memory technology developed jointly by Intel and Micron Technology.

Both companies have only started selling 3D XPoint in its current iteration in 2019 with Micron reportedly having achieved US\$119M in 3D XPoint revenues in its 2Q20, which ended in February 2020, so roughly US\$480m on an annualised basis. Total revenues for 3D XPoint are expected to reach US\$3BN by 2023 and US\$16BN by 2029.

In other words, Interface Switching ReRAM, which is technologically superior to 3D XPoint mainly due to better read/write speeds, would present a very substantial revenue opportunity in the right hands, i.e. existing players or challengers in the SCM space. This potential should be expressed in any potential take-over bid for 4DS, in our view.

Adding the potential of neuromorphic computing to the equation could lead to a substantially higher valuation for 4DS still. Intel paid around A\$600M for both Movidius and Nervana Systems in 2016 to get its hands on the IP these companies developed around neuromorphic computing. However, a lot more development work on the part of 4DS will be required to unlock that potential, in our view.

In summary, we see A\$0.103 per share is a near-term, minimum valuation for 4DS. The actual value in a take over scenario, if and when it comes to that, is potentially substantially higher.

## Poised for a re-rating:

- Recent share price movements of semiconductor peers, such as BrainChip, have highlighted the upside potential for 4DS. Given that the company's latest wafer testing reported superior speed and endurance results, we believe the market is undervaluing the stock.
- The robust state of M&A activity witnessed in the semiconductor IP industry underpins the potential for 4DS to gain an attractive price for its ReRAM technology. In our view, if the company is able to successfully deliver a megabit Interface Switching ReRAM module, this should lead in a significant re-rating of the stock.

*Emerging NVM 3D XPoint is expected to generate at least US\$3BN in revenues by 2023*

*Intel paid A\$600M each for two acquisitions in the neuromorphic computing space in 2016*



Please see [www.pittstreetresearch.com/4ds-memory](http://www.pittstreetresearch.com/4ds-memory) for our initiating coverage of 4DS. Risk factors for 4DS include, but are not limited to, slower than anticipated development of its technology, limited industry interest in the company's memory technology, which would limit the value in a potential take-over scenario and the emergence of competing memory technologies that would potentially make 4DS' technology outdated or potentially obsolete.

### **Analyst certification**

Marc Kennis, lead analyst on this report, has been covering the Semiconductor sector as an analyst since 1997.

- Marc obtained an MSc in Economics from Tilburg University, Netherlands, in 1996 and a post graduate degree in investment analysis in 2001.
- Since 1996, he has worked for a variety of brokers and banks in the Netherlands, including ING and Rabobank, where his main 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 equities 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.

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