4DS Memory

# Investor Update

May 2016

4DS Memory Limited
ABN: 43 145 590 110

## We are

A Silicon Valley memory technology developer with high tech management

## We make

Non-filamentary ReRAM for next generation gigabyte silicon storage

## We own

16 patents with US$10m invested in development

## We have

A strategic partnership with HGST, a global storage leader

# Contents

# Letter From The Chairman

## Welcome to the first edition of the 4DS Investor Update for 2016.

Throughout the year, you can expect to look forward to updates about our progress, learn about our key development initiatives, hear about 4DS in the news and view enhancements to our website. Next month expect the release of a video which will help to explain the more complex aspects of our unique technology.

In this edition you will learn more about our Chief Executive Officer and Managing Director, Guido Arnout, the critical milestones we need to achieve to become a commercially viable technology for gigabyte **(GB)** silicon storage and some of the emerging trends shaping this market.

### Significant Progress Achieved

It is my pleasure to report on a period of strong progress for 4DS and the continued improvements to the core intellectual property of our memory cell technology, MOHJO™.

Last month our IP portfolio was strengthened by the addition of our 16th US patent providing further protection for our non-filamentary ReRAM technology. The most recent patent granted is essential for the commercialisation of 3D stacked ReRAMs and offers patent protection to 2029.

In addition to this, 4DS has achieved a ground breaking milestone demonstrating a scalable non-filamentary ReRAM cell at a 50 nanometre **(nm)** lithography which is approaching production geometries.

**This makes 4DS the most advanced non-filamentary ReRAM technology.**

With this critical 50nm milestone and together with our patent portfolio, 4DS is positioned to be a pivotal technology for the fast-growing GB silicon storage market, estimated to be around US$40 billion.

### The Next 6 Months

Our development program is currently on schedule and within budget. We are now working towards demonstrating viable scalability below 50nm, with the objective in the next six months on measuring cell endurance yield for these small geometries.

In May, 4DS will have dedicated equipment that has the ability to collect endurance yield data across a large number of cells on multiple wafers, significantly expediting the testing process.

Following this, 4DS will concentrate on refinements to the fabrication process to further optimise cycling endurance, data retention and access speed, and to demonstrate the viability of its technology for GB silicon storage.

### Global Memory Specialists

We have a dedicated team of industry respected engineers and scientists with extensive knowledge of every type of commercial memory technology.

Guido Arnout is highly accomplished with over 30 years' experience in founding and building multiple Silicon Valley high-tech companies. Within six months of commencing his role with 4DS, he successfully established a joint development agreement **(JDA)** with HGST, a strategic and valuable partnership that provides resources and technical expertise to accelerate our development. This is testament to our high tech expertise and to our unique ReRAM technology.

The JDA with HGST started in mid-2014 with the goal of optimising the 4DS memory technology for the storage market. 4DS and HGST are currently discussing renewal terms of the JDA around a new scope of work which is due to commence in July 2016.

### Our Strategy

**We are targeting a growing multi-billion dollar market.**

We own extraordinary patented IP that has lower power consumption, increased reliability and improved performance potential when compared to traditional data storage technologies.

Our business strategy is to prove the value of this technology to memory makers and create significant shareholder return. This is the point where all major technical hurdles have been achieved and it is just a matter of time and money to commercialise the technology.

### Marketing

Over the last three months, investor marketing has concentrated on Australia, Hong Kong, Japan and the UK. 4DS also has plans to market to the US later this year. The Board has every expectation of increasing institutional demand for 4DS as we progress through to the planned renewal of our JDA and achieve the next goal of measuring endurance.

It is common practice for companies developing disruptive technology to provide limited or no information with regards to schedules, specific development stages and the creation of new IP until commercial arrangements and suitable patent protection have been finalised. However, we will provide updates in the next quarter as 4DS continues to hit key strategic and technical milestones.

Kind regards,

Jim Dorrian
Chairman

# 4DS Roadmap

## 2007 to 2013
**Core IP Patented**

- ReRAM building blocks in place
- Proof of concept in affordable geometries - basic memory cell works well
- Patented filament-less ReRAM memory cell based on oxygen vacancies
- Patented low-temperature deposition of essential memory material

## 2014
**Strategic Partnership Established**

- JDA established with leading storage company, HGST
- Allows both parties to investigate the viability of 4DS ReRAM cells scaling to high density for memory applications

## 2015
**Scalable Non-Filamentary ReRam Cells Developed**

- Developed functional and high yield lot-to-lot consistency for ReRAM cells smaller than 250nm
- Significant progress for non- filamentary ReRAM development

## 2016
**Breakthrough in Non-Filamentary ReRam Achieved**

- Demonstrated scalability, consistency and behaviour of memory cells with high yield at 50nm
- This 50nm geometry parallels current 3D Flash, the most dominant non-volatile memory technology

## Future Steps
**Demonstrate Viability for GB Silicon Storage Required for Mobile and Cloud**

- Demonstrate viable scalability below 50nm
- Meet the performance shares milestone criteria for measuring cycling endurance[1]
- Refine the fabrication process to further optimise endurance, retention and access speed

1. Per the performance shares milestone criteria in Section 14.2 of the Prospectus. In summary, 90% of cells with sizes from 50nm to 150nm in 2 blocks on 2 "process of record" wafers – that are different from the wafer that defines the "process of record" – need to survive either 400 consecutive writes where the written state is verified after each write or survive 10,000 write cycles when the written state is verified 17 times along the way.

# Employee Showcase

## Meet Guido Arnout, Chief Executive Officer and Managing Director

**What attracted you to 4DS?**

> 4DS has a unique core technology to address a clear need for change in an endless market.

These are the three ingredients for a great opportunity.

The replacement of spinning hard drives with fast solid state drives for storage in mobile personal computing is virtually complete now. Silicon storage offers a faster user experience and enables lighter mobile devices with longer battery life. In our daily life, spinning hard drives are now mostly used for out-of-sight backup storage. The same process is happening now in cloud storage, which in contrast with the mobile market is endless and not limited by the population.

So far NAND **(Flash)** has been the technology of choice for silicon storage but it will become more and more challenging to produce higher capacity and higher density charge-based devices. Hence the significant market interest in new memory technologies.

> Industry experts cite ReRAM as the leading emerging memory candidate to replace Flash.

**How will your experience benefit 4DS?**

I have founded and managed several high tech start-ups that created either a new industry (tools for chip design), introduced a new design methodology (hardware-software co-design), or that helped software engineers develop higher performance algorithms that use less power precisely by optimising memory access. In the process, I have raised funding, orchestrated technology partnerships, industry alliances and exits for investors.

**Most enjoyable aspect of your current role?**

Making the smart choices that maximise progress on an industry-critical technology within a limited budget by leveraging my technology vision and business experience and understanding of key industry trends.

**What are the major challenges facing 4DS and do we have expertise to solve them?**

No breakthrough technology ever got to market without having to overcome some technical hurdles but our team combines world-class memory specialists, material scientists, semiconductor manufacturing experts and test engineers. We try to anticipate what these potential hurdles may be and analyse them wherever possible through dedicated experiments or simulation.

> Our team combines world-class memory specialists, material scientists, semiconductor manufacturing experts and test engineers.

**Where do you see 4DS in 12 months?**

We are working on viable scalability below 50nm and expect to be able to complete the performance milestone which relates to cycling endurance. In addition, as we reach certain milestones and continue our global investor relations strategy we would expect to see a significant re-rating of the company's value.

**What is the benefit of working with HGST?**

Our engagement with HGST enables us to demonstrate the necessary data to prove the value of our IP and the viability of our technology for GB silicon storage without incurring the expense of fabricating fully functional GB ReRAM prototypes.

**Your greatest achievement?**

Doing what was at the time considered "impossible" I found and corrected the design errors in the first ABS (anti-lock braking system) for passenger cars by developing a simulation model. I have the satisfaction that it has saved countless lives in the past 40 years.

**Most admired CEO, why?**

Past (Steve Jobs, Apple founder) and present (Elon Musk, Tesla founder). Both with a clear vision, undeterred by the technological challenges to make their vision a reality, ignored everyone who told them that it was impossible, resisted introducing products prematurely and dramatically changed the world of mobile computing (Jobs) and electric transportation (Musk).

# Emerging Data Trends Shaping Silicon Storage

Consumers spend over **US$2 trillion** on content, devices and services every year

Apple is the **biggest buyer of Flash** in the world

Household digital content is forecast to grow by **150%** in the next 5 years

Microsoft **trialled an underwater data centre** for 90 days to test its cooling benefits

The world is home to **7.2 billion** mobile devices, and they're multiplying five times faster than we are

Data centre space will grow to almost **200 million square metres** in 2018

# Every 24 Hours

**250 billion**
emails are sent

**700 million**
tweets are posted

**1.3 billion**
photos are uploaded

**1 million**
video hours are uploaded

**Amazon Web Services**
the world's largest cloud provider, adds more server capacity, than Amazon.com had a decade ago

# Development of Viable ReRam Technology

4DS is a developer of non-filamentary resistive random access memory **(ReRAM)**, pioneering a unique solution for next generation silicon storage for mobile and cloud. Established in 2007, 4DS owns a patented IP portfolio developed in house through an US$10 million R&D program.

4DS is focused on continuous improvements of its core IP and manufacturing process optimisation to create the smallest cell geometries that can be reliably fabricated. The strength of 4DS' proprietary technology and materials deposition process is underpinned by 16 US patents and represents a breakthrough in ReRAM functionality.

Specifically, the formation of filaments is a common approach in ReRAM cell research and development today. Filamentary mechanisms may work well at relatively large cell geometries but pose significant current density, retention, endurance, access and control problems when trying to achieve gigabyte **(GB)** range memories.

**The filament-less switching mechanism positions 4DS as a promising alternative to NAND Flash with improved scalability, lower power consumption, higher speed and better endurance.**

4DS has demonstrated non-filamentary ReRAM cells at a 50 nanometre **(nm)** lithography, achieving wafer to wafer and lot to lot consistency using memory cells of varying sizes, representing significant progress in scalability and yield.

### Why our progress is commercially significant

This 50nm geometry, demonstrated by 4DS, parallels the latest generation of 3D Flash — the most dominant non-volatile memory technology used in billions of mobile devices, cloud servers and data centres.

## Development Goals

### In the next 6 months:

1. Demonstrate viable scalability below 50nm;
2. Measure cycling endurance yield for these small geometries; and
3. Continue fabrication refinements to further optimise endurance, retention and access speed.

### Next steps:

- Demonstrate consistent scalability and functional cell behaviour at a high yield;
- Reaching this goal requires:
  - a process of simultaneous and continuous improvements of the memory cell architecture and fabrication; coupled with
  - yield analysis to derive the functional specifications that can be guaranteed.
- Achieving this goal will demonstrate commercial production viability for GB silicon storage.

# Development of Viable ReRam Technology

In the next six months, in conjunction with continuous fabrication refinements, the development goals are to:

1. **Demonstrate viable scalability below 50nm; and**
2. **Measure cycling endurance yield for these small geometries.**

**What are the next steps?**

To demonstrate that production of a commercial memory is viable for GB silicon storage, 4DS must develop consistent scalability and functional cell behaviour.

**What is involved to demonstrate viability?**

This requires a process of simultaneous and continuous improvements of the memory cell architecture and the fabrication process, complemented with semi-automated test procedures to monitor the progress of **yield analysis on** the properties of **cell behaviour, cycling endurance, data retention and access speed**.

Every time changes are made to the cell architecture, cell size, materials composition, material thickness or the fabrication process, 4DS has to re-confirm that the changes have the desired effects.

Specifically, with each process, the yield of the following **properties** has to be revalidated:

### Behaviour
The fundamental behaviour of a cell

### Endurance
The guaranteed number of times the state of cells can be changed without failure

### Retention
The guaranteed duration cells retain their state ("0" or "1")

### Access speed
The guaranteed time in which the state of cells can be read or written

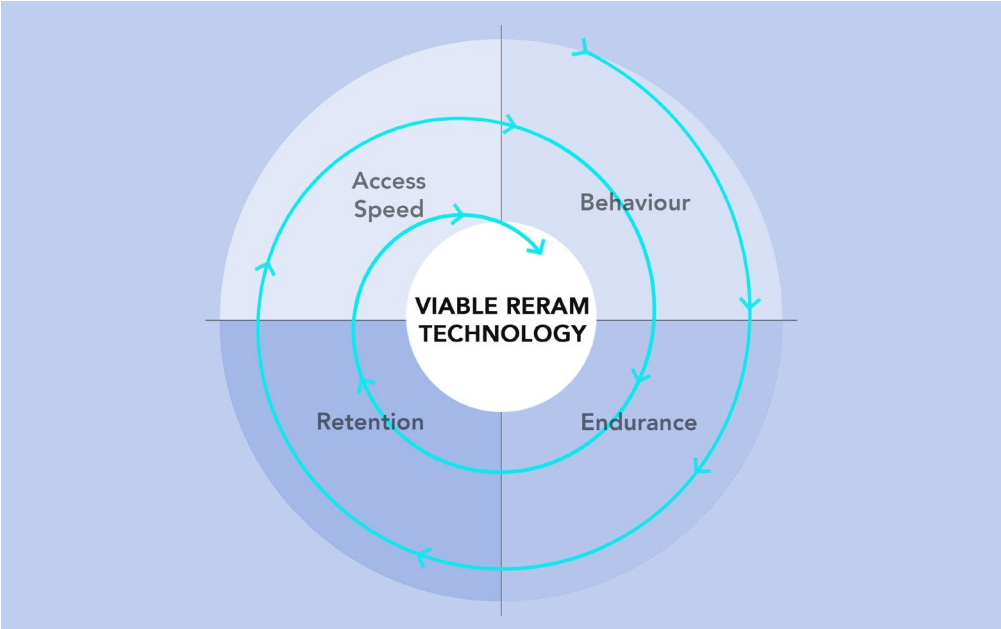
**What is our objective?**

The objective is not just to measure cycling endurance, data retention and access speed but to measure these metrics on a statistically significant number of cells across different wafers in different wafer lots and then to perform statistical yield analysis on the data collected from all measurements to **derive the functional specifications that can be guaranteed**.

### What do memory buyers require?

For functional GB silicon storage, memory buyers require an extremely high yield across a very large number of cells. That makes the achievement of competitive functional specifications of cycling endurance, data retention and access speed the important reportable events to shareholders and to memory makers.

# Yield Analysis Testing Cycle



# Why No Filament?

The earliest approach to developing ReRAM relies on the formation of a conducting filament of atoms/ions to form the "on" state or "1", and the destruction of this filament to form the "off" state or "0".

4DS believes that this create and destruct switching mechanism has a number of significant limitations for GB silicon storage and therefore developed a way of controlling the overall resistance of the memory cells using the diffusion of oxygen atoms across the interface. The 4DS technology does not use filaments.

A filament is a short circuit from one electrode to the other and has been described as a lightning strike at a micro scale. 4DS considers it unlikely that what is essentially a failure mechanism can be used to reliably control GB memory intended for large-scale storage.

Part of what makes the 4DS ReRAM cell unique and ground-breaking is the use of PCMO – a perovskite material. Perovskites, hold the promise of revolutionising many fields of electronics, such as solar cells where the use of silicon is starting to show limitations.

| | FILAMENTARY ReRAM | 4DS NON-FILAMENTARY ReRAM |
|---|---|---|
| Switching Currents | **High** and don't scale with cell size | **Low** and scale with cell size |
| On-Off Current Ratios | **Must be high** due to widely fluctuation currents | **Can be low** due to much more stable currents |
| Scalability to Smaller Geometries | **Limited** by wire current densities due to constant switching currents | **Not limited** by wire current densities |
| Cycling Endurance | Constant filament formation and destruction results in **eventual cell breakdown** | Does not rely on a destruction mechanism thereby **increasing reliability** |
| Data Retention | **High switching currents** needed for long data retention | **Low switching currents** help data retention |
| Market Sweet Spot | **Low density:**<br>IoT devices, small embedded memories | **High density:**<br>GB silicon storage for mobile and cloud |

# Glossary

### Switching
The action of increasing or decreasing resistance – and thus defining the "set" or "reset" (1 or 0 ) state of the cell.

### Memory Window
The difference between the "set" and "reset" currents.

### Switching Ratio
The ratio of the "set" and "reset" currents.
The memory window or switching ratio required depends on the statistical variation of the "set" and "reset" currents. Large current variations require big switching ratios but switching ratios can be much smaller when "set" and "reset" currents are stable.

### Endurance
A measure of the number of write cycles before a memory cell is expected to fail (e.g. the memory window collapses).

### ReRAM
Resistive Random Access Memory.

### Retention
A guide of how long the memory cell can hold data before it begins to degrade. In Flash, this is caused by charge leakage, in most ReRAM, it is caused by breakdown of filaments over time.

### Electrodes
The positive and negative poles at each end of the memory cell. ReRAM electrodes are often arranged as perpendicular crossbar arrays with the memory cells sandwiched between them.

### Filament
A technique used by the earliest ReRAM developers where after a voltage is applied, conducting atoms/ions move to form a conducting filament.

### Flash (NAND Flash)
The most common type of non-volatile memory in use today. Industry consensus is that it will be more and more challenging to produce higher capacity and higher density charge-based Flash chips. Hence the significant market interest in new memory technologies.

# Board of Directors

**Jim Dorrian**
Chairman

Served as CEO and director of several Silicon Valley companies with in depth experience in M&A and IPOs gained through founding and managing successful technology exits. Partner at Crosspoint Venture Partners, venture capital firm for early stage companies.

**Dr Guido Arnout**
CEO and Managing Director

Over 30 years' experience with specific expertise in commercialising electronics technology from concept to product including Power-Escape, CoWare, CrossCheck Technology and Silvar-Lisco.

**Howard Digby**
Non-Executive Director

Over 25 years' experience managing technology related businesses in the Asia Pacific region. Including former senior roles at IBM, Adobe, Gartner and the Economist Group. Director of Estrella Resources (ASX:ESR).

**David McAuliffe**
Non-Executive Director

Experienced company director and entrepreneur. Involved in numerous capital raisings and in-licensing of technologies and founder of several companies in Australia, France and the UK, many of which are now publicly listed.

# Capital Structure[1]

| | | |
|---|---|---|
| **Market Capitalisation** | $21.7 million | Fully diluted |
| **Ordinary Shares on Issue** | 659.2 million | Including 113.4 million escrowed shares[2,3] |
| **Escrowed Performance Shares** | 67.6 million | Expiry 31/12/18 |
| **Unlisted Options** | 106.2 million | |
| **Top 20 Share Holders** | 50.0 % | |
| **Cash** | $1.8 million | At 31 March 2016 |

1. At 29 April 2016.
2. 7.8 million shares escrowed for 12 months from re-listing to Dec 2016.
3. 105.6 million shares escrowed for 24 months from re-listing to Dec 2017.

**FURTHER INFORMATION**

4DS Memory Limited (ASX:4DS), with research and development facilities located in Silicon Valley, is a developer of non-volatile memory technology, pioneering non-filamentary ReRAM for next generation storage in mobile and cloud. Established in 2007, 4DS owns a patented IP portfolio developed in house to create gigabyte silicon storage.

For further information, visit **www.4dsmemory.com** or contact Mel Buffier at **mel.buffier@4dsmemory.com**