Flash Memory Summit

ReRAM: The Next NVM is Here

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Outline

- Embedded ReRAM market
- Weebit Nano overview
- ReRAM module
- Qualification results
- Summary

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Embedded ReRAM market – Approaching the tipping point

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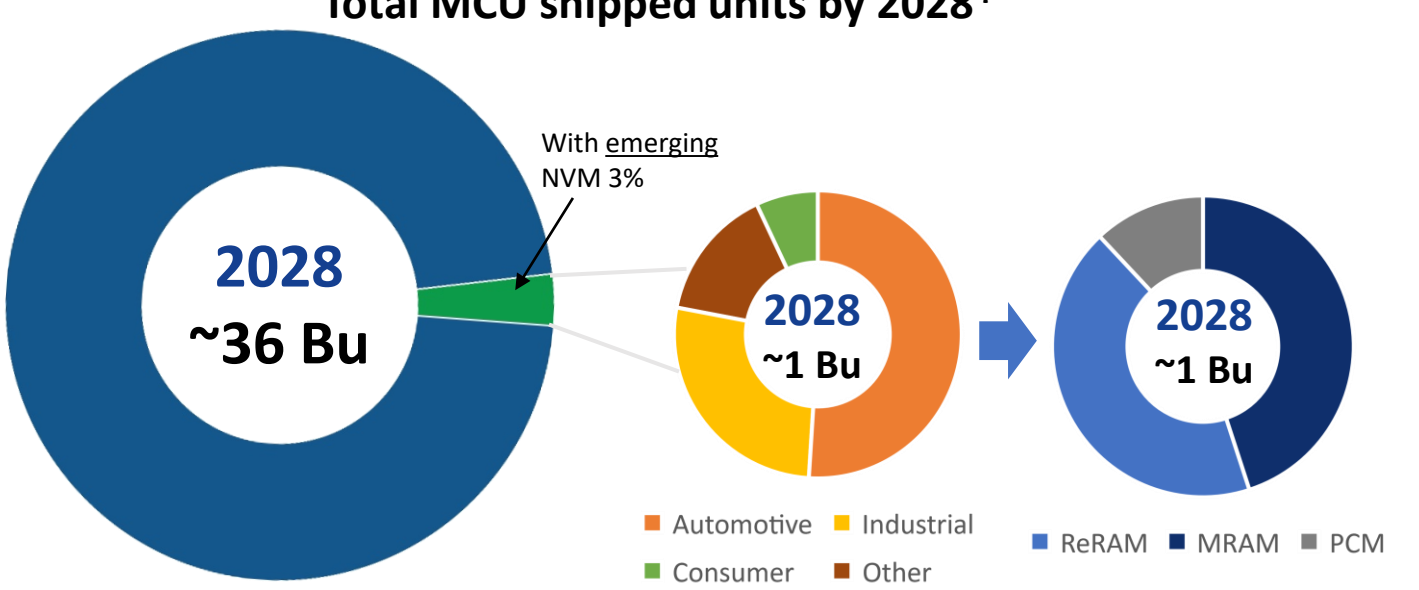
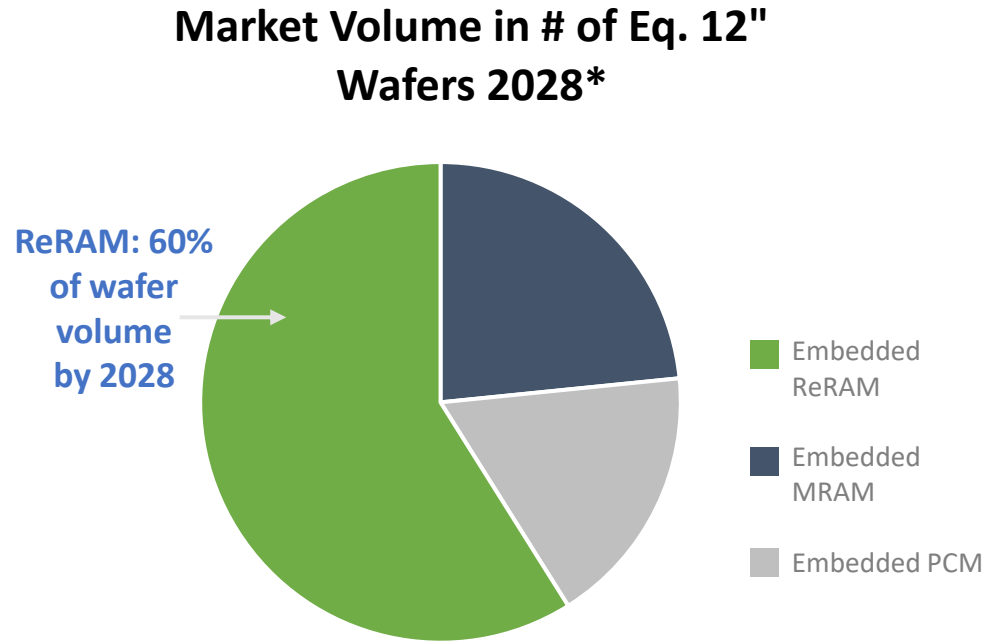
The embedded emerging NVM market is expected to reach $2.7B by 2028, with ReRAM expected to represent 37%*





* Source: Emerging Non-Volatile Memory report, Yole Intelligence, 2023

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Who is Weebit Nano?

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Leading developer of advanced memory technology – Weebit ReRAM – for the global semiconductor industry

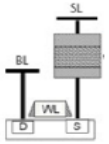
Founded: 2015
Israel & France 50 personnel*
(90% engineers/scientists)

R&D Partner: CEA-Leti
Leveraging years of research experience in NVM

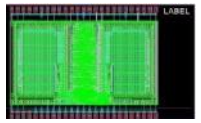
Current Business Model:
IP licensing to semiconductor companies & fabs

Silicon-Proven Technology
Mbit arrays avail @ 28-130nm
Volume production 2024

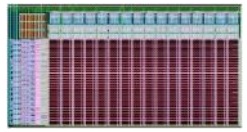
2017 — 1T1R



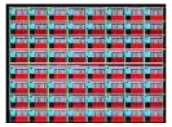
Q1 2018 — 4Kb



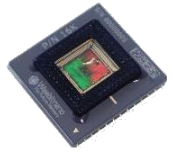
Q2 2018 — 16Kb



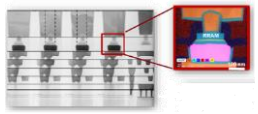
Q4 2018 — 1Mb



Q3 2019 — FMS AI Demo



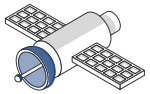
Q4 2021 — Successfully Scaled to 28nm



Q2 2022 — IP Module Live Demonstration

Q3 2022 — Full qual with CEA-Leti

Q1 2023 — Research: Weebit ReRAM radiation tolerant



Q1 2023 — Tapeout in GlobalFoundries 22FDX™

Q2 2023 — Full qual in SkyWater S130

*Includes employees and permanent contractors.

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Weebit ReRAM module design

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Integrating a ReRAM array in a complete module in 130nm technology

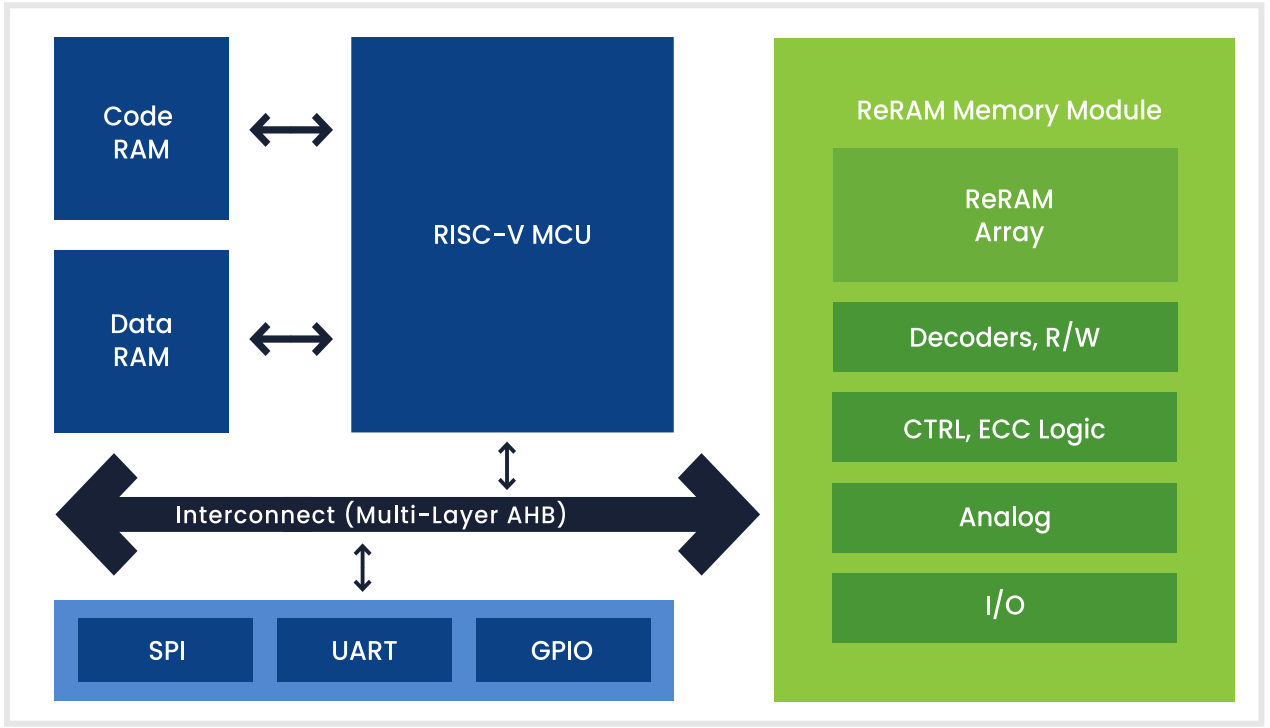
Module includes:

- All analog circuitry
- Smart algorithms (read, set/reset, forming)
- Control logic and data manipulation
- Redundancy, ECC

The ReRAM module is further integrated into a complete subsystem

- Based on a RISC-V processor

Silicon is fully functional and qualified



Embedded ReRAM Demo-Chip

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Successfully completed ReRAM module qualification

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Major milestone using Weebit's ReRAM memory module produced at SkyWater

Qualified wafers to industry standards JEDEC

- Endurance
- Industrial robustness

Results driving interest from foundries and customers

- Repeatability
- Uniformity
- Maturity of Weebit's embedded ReRAM

Commercial Traction

Based on results, Weebit ReRAM is **being evaluated by several SkyWater customers**

Weebit is now **qualifying ReRAM** modules at higher temperatures and endurance levels – **for advanced applications**

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ReRAM qualification process

- Weebit has now qualified its 2nd ReRAM module
- Qualification process (unlike technology demonstration) requires meeting industry standards (JEDEC, AEC, MIL) to show technology maturity

Stress	Test Item	Reference	Stress Conditions	Test Conditions / Acceptance Criteria	Sample Size	Comments
NVCE	**Endurance**	**JESD22-A117 JEDEC 47**	25°C and 85°C V=Vcc max	**Datasheet Spec**/ 0 Fails	3 Lots/ 77 units	Test all the array bits to 100% Max spec
UCHTDR	**Data Retention**	**JESD22- A117 JESD47**	**Tstress – 125°C**	**1000** hrs/ 0 Fail	3 Lots/ 77 units	Readout at 25°C and 85°C
PCHTDR	**Post Cycle Data Retention**	**JESD22- A117**	**Tstress = 125°C 100% spec**	**10** hrs/ 0 Fail	3 Lots/ 39 units	Readout at 25°C and 85°C
SMT	**SMT Reflow**	ESD22 - A113	Tc 260 °C	3 cycles/ 0 fails	3 Lots/ 25 units	Pb-Free Assembly Profile

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Qualification results – SkyWater 256Kb, 85°C

Test Description & Conditions	Qual Lot 1	Qual Lot 2	Qual Lot 3	Results
JEDEC NVM Qual tests (85°C):				
NVCE: Cycling endurance @ Room	**0/38**	**0/38**	**0/38**	**10K cycles @ 25°C**
NVCE: Cycling endurance @ 85°C	**0/39**	**0/39**	**0/39**	**10K cycles @ 85°C**
UCHTDR: Uncycled data retention (T_{Bake}=130°C, 1000h)*	**0/77**	**0/77**	**0/77**	**10 years @ 85°C**
PCHTDR: Post-cycle (10k @ 85°C) data retention (T_{Bake}=130°C, 10h)	**0/39**	**0/39**	**0/39**	**10 years @ 85°C (RAC)**
SMT: Solder Reflow Test (T_{Peak}= 260°C)	**0/25**	**0/25**	**0/25**	**Passed 3x SMT**
Extended Qual tests (85°C):				
UCHTDR: Uncycled data retention (T_{Bake}=130°C, **Lot1 2000h, Lot2 1500h, Lot3 1500h**)	**0/77**	**0/77**	**0/77**	**15-20 years @ 85°C**
PCHTDR: Post-cycle (10k* @ 85°C) data retention (T_{Bake}=130°C, **168h**)**	**0/39**	**0/39**	**0/39**	**>1 year End of life @ 85°C (RAC)**

*PCHTDR reached more than 3500h bake to show 1st failure points on our 1ST MODULE

** UCHTDR – reached 5000h with no failures, continue to 10,000h on our 1ST MODULE

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Qualification results – ST/Leti 128Kb, 125°C

Test Description & Conditions	Qual Lot 1	Qual Lot 2	Qual Lot 3	Results
JEDEC NVM Qual tests (125°C):				
NVCE: Cycling endurance 10k* @ 125°C	**0/39**	**0/39**	**0/39**	**Cycling @ 125°C**
UCHTDR: Uncycled data retention (T_{Bake}=175°C, 1000h) 3rd lot 168h, in progress	**0/77**	**0/77**	**0/77**	**Retention @ 125°C**
PCHTDR: Post-cycle (10k* @ 125°C) data retention (T_{Bake}=175°C, 10h) 3rd lot on going)	**0/39**	**0/39**	**0/39**	**10 years @ 125°C (RAC)**
Extended Qual test (bake time):				
UCHTDR: Uncycled extended data retention (T_{Bake}=175°C, **2000h**)	**0/77**	**0/77**	**0/77**	**Extended Retention @ 125°C**

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Weebit ReRAM scaling to advanced nodes

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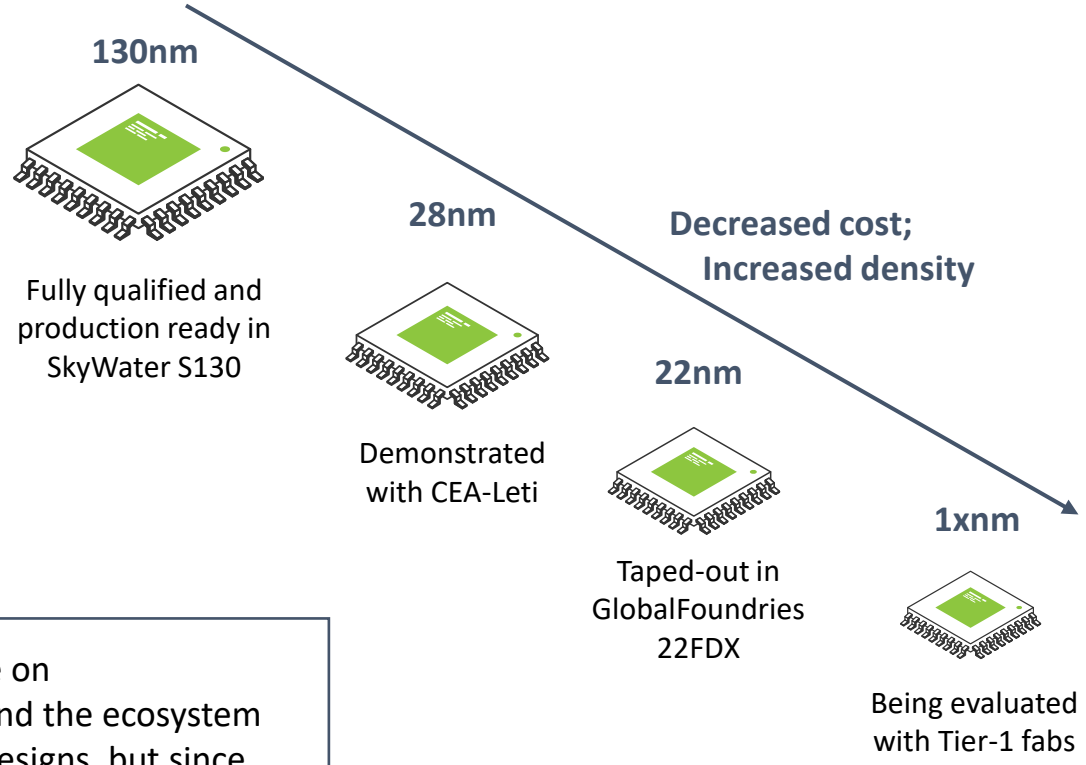
Clear opportunities for NVM at 22nm and below

- Existing embedded flash technology is not a viable option
- Serving various applications including IoT, 5G and AI

Recent development: taped-out ReRAM IP module in GlobalFoundries' 22FDX™ FD-SOI (fully depleted silicon on insulator) platform

- Weebit ReRAM + FD-SOI is ideal for low-power embedded devices



"The work Weebit and CEA-Leti are doing to make Weebit ReRAM available on GlobalFoundries' 22FDX is a welcome development as we continue to expand the ecosystem around this platform. Embedded NVM is a key element of our customers' designs, but since embedded flash is difficult to scale below 28nm, many customers are looking to NVM solutions such as embedded ReRAM." – Mike Hogan, Chief Business Officer GlobalFoundries

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ReRAM is inherently radiation tolerant

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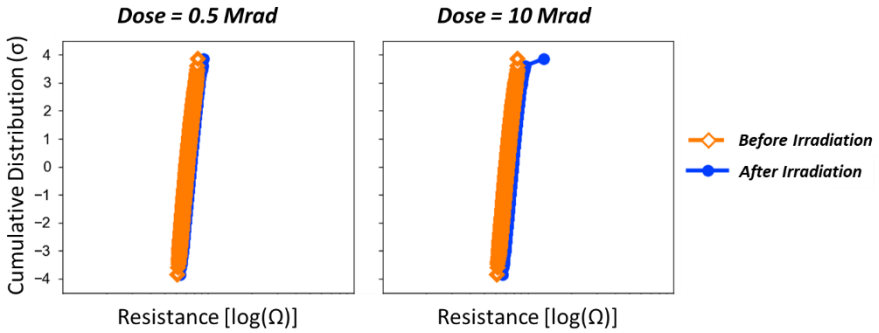
ReRAM cell stores data within dielectric stack in back-end-of-line (BEOL) process, so various types of radiation do not affect it

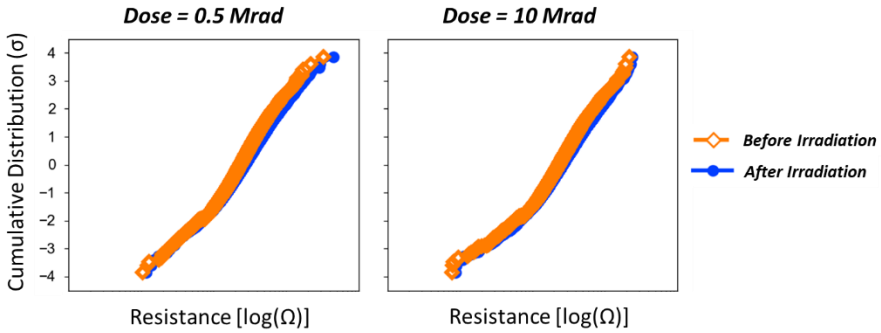
- Does not use charge trap like flash
- Radiation mostly affects front-end-of-line (FEOL) – CMOS
- Access circuitry must be hardened using standard methods

Weebit is partnering with University of Florida's Nino Research Group to test ReRAM structures under radiation

- Initial study irradiated pre-cycled 130nm 16Kb 1T1R arrays in 0.5Mrad-10Mrad in UF training reactor



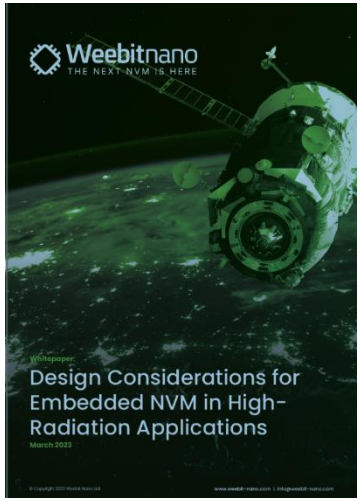
Low Resistance State (LRS) distribution before and after different radiation doses



High Resistance State (HRS) distribution before and after various radiation doses

Note: The scale of these two diagrams is not the same.

Results confirm that Weebit ReRAM preserves data and can be fully reprogrammed after high doses of irradiation



New whitepaper available

https://tinyurl.com/dbk2nmwv

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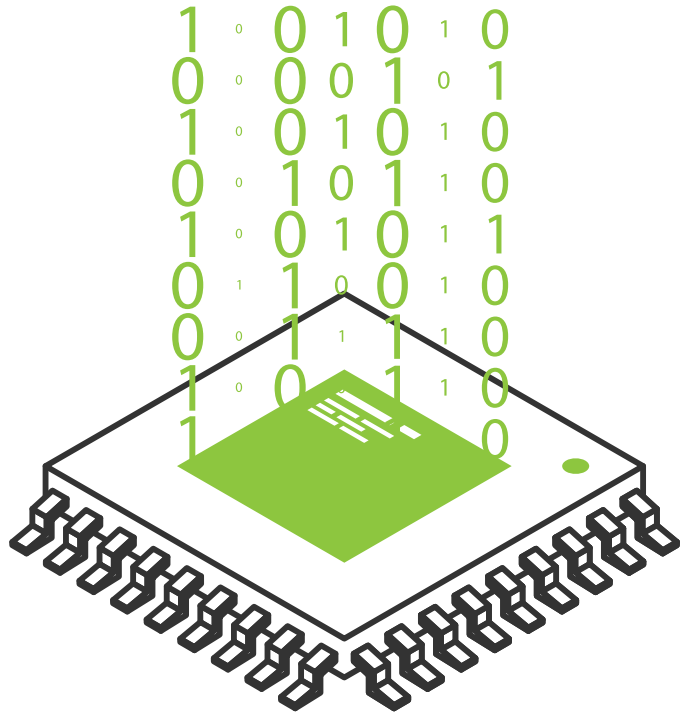
Conclusions

Weebit ReRAM was ported successfully to a commercial foundry (SkyWater)

- Is fully functional within one year, and qualified

Weebit has functional ReRAM modules fully qualified in SkyWater at 85°C and 125°C

Weebit continue developing and scaling ReRAM technology towards 22FDX™ FD-SOI and beyond



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