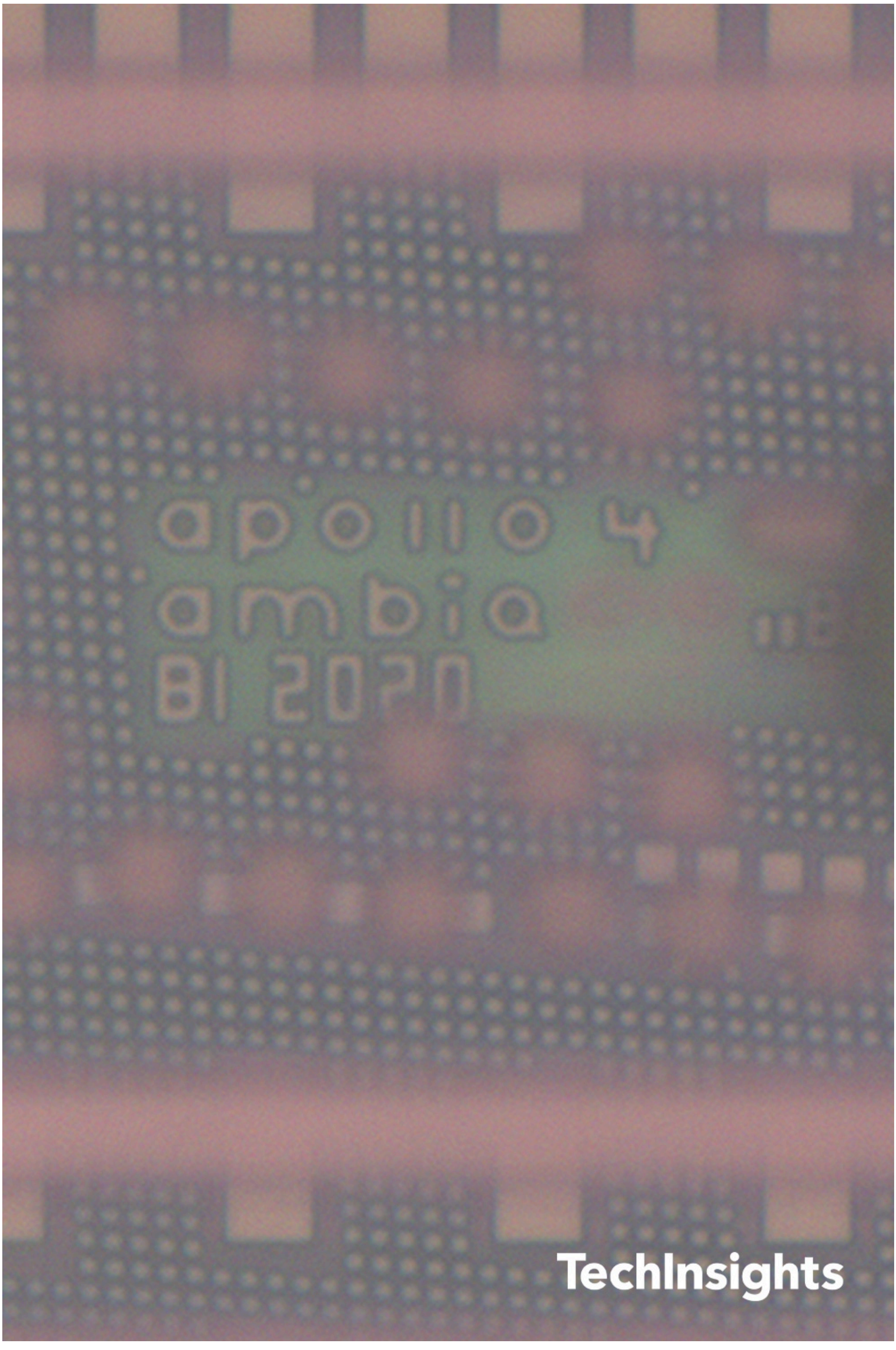
TSMC 22ULL eMRAM Die removed from Ambiq™ Apollo4

Another Disruptive Technology on Embedded Memory!

Another disruptive product on embedded Memory (eMemory) has been arrived and quickly reviewed! TSMC has successfully developed and commercialized 22 nm eMRAM products with STT-MRAM technology and device integration. TechInsights removed TSMC eMRAM die from Ambiq™ Apollo4 Blue MCU (Parent Product: Fitbit Luxe Fitness Band). The Apollo4 SoC (Package Markings: 2M AMA4B) is the 4th generation system processor solution built upon Ambiq's proprietary Subthreshold Power-Optimized Technology (SPOT) platform.

TSMC-1022
U.S. Patent 8,884,373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TechInsights' Emerging and Embedded Memory experts agree that the TSMC 22ULL eMRAM shows expansive system design applications such as:

- IoT (internet of things) Devices
- Battery-powered endpoint devices
- Wearable Devices
- Efficient non-volatile memory for code and data
- Automotive
- MCU (microprocessor)
- Server
- Analog Controllers
- Sensor Hubs

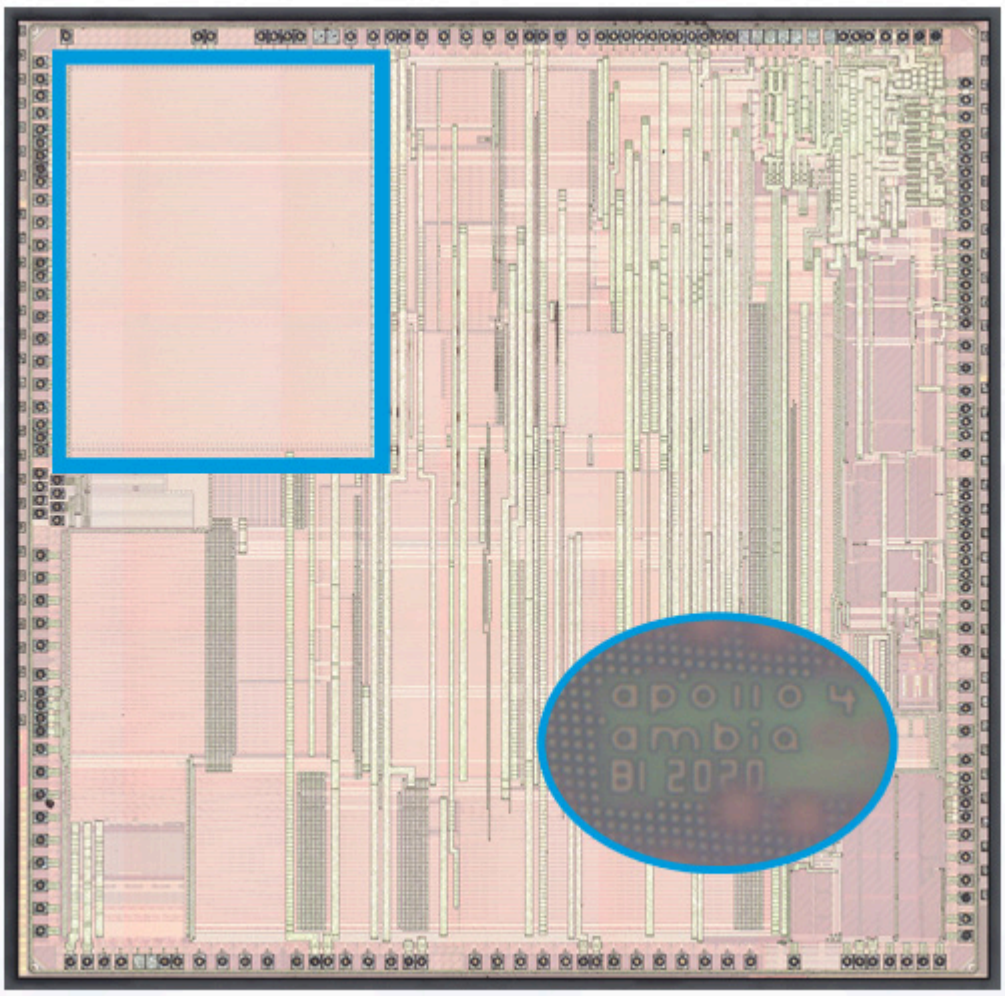
Ambiq™ Apollo4 and TSMC 22ULL Process Enabling High-Intelligence Without Sacrificing Battery Life on Cutting Edge IOT Devices

(https://www.techinsights.com/sites/default/files/2021-08/tsmc-22ull-1.jpg)

Figure 1. Fitbit Luxe fitness band packaging

(https://www.techinsights.com/sites/default/files/2021-08/tsmc-22ull-2.jpg)

Figure 2. Ambiq™ Apollo4 Blue MCU package

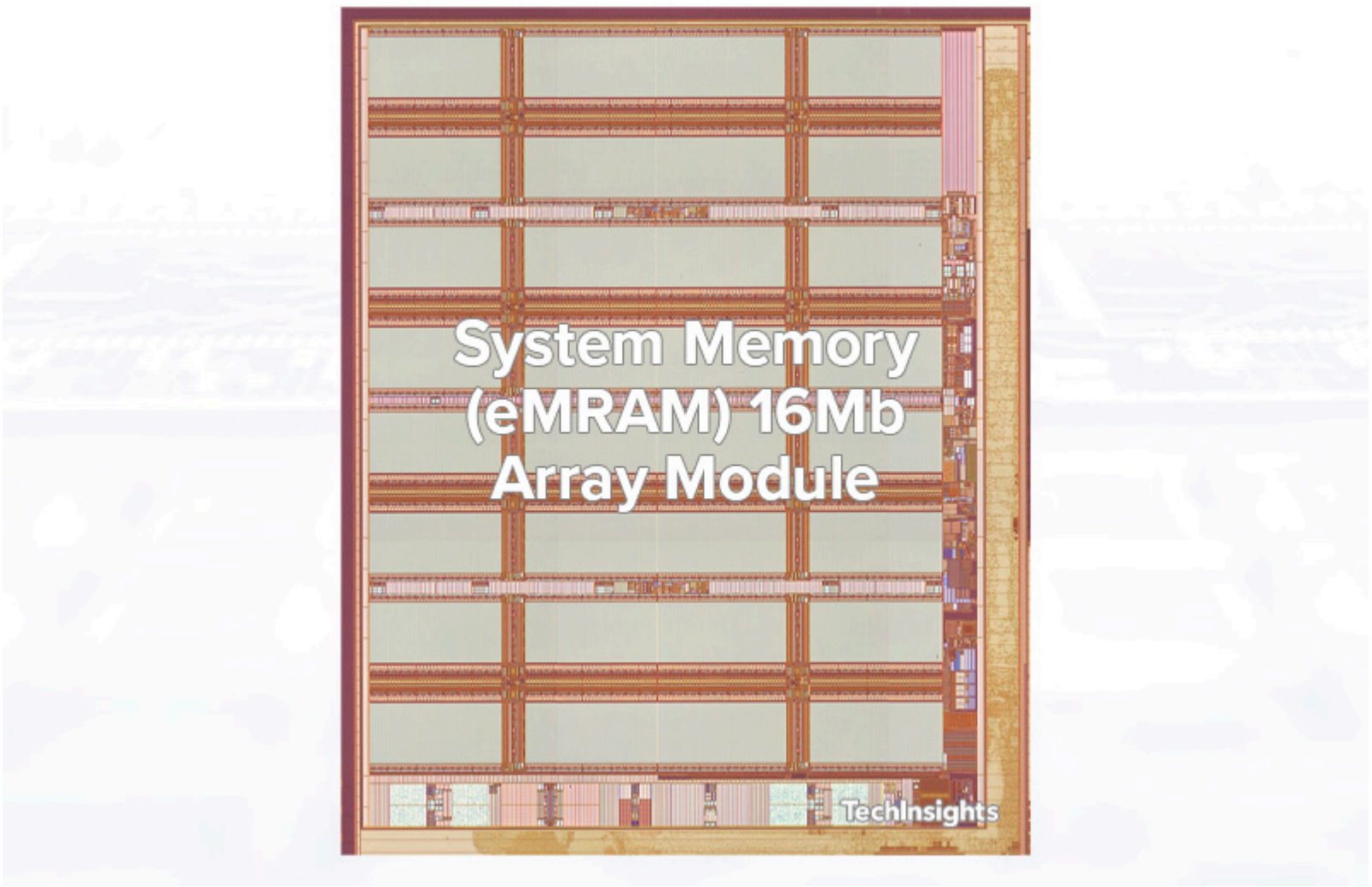


(https://www.techinsights.com/sites/default/files/2021-08/tsmc-22ull-3.jpg)

Figure 3. Ambiq™ Apollo4 Blue MCU die photo

The Apollo4 SoC is implemented on the TSMC 22 nm Ultra-Low-Leakage (22ULL) HKMG Gate-last process and based on a 32-bit Arm Cortex-M4 processor with FPU and Arm Artisan physical IP, achieving 3 µA/MHz from MRAM with low deep sleep current modes. TSMC 22ULL eSTT-MRAM is essential to support on-chip code storage for MCU functions to achieve industry-leading power performance, comparing with previous Apollo2 (10 µA/MHz, eFLASH) and Apollo-3 (6 µA/MHz, eFLASH). Figures 1, 2 and 3 show the Ambiq™ Apollo4 Blue MCU package and die removed from Fitbit Luxe fitness band. Die markings and a description of the eMRAM array blocks (blue colored box) are added on the die image.

The Low-Power eMRAM Provides a Very Large, Efficient Non-Volatile Memory for Code and Data



(https://www.techinsights.com/sites/default/files/2021-08/tsmc-22ull-4.jpg)

Figure 4. A 16Mb eMRAM array module with TSMC 22ULL process on Ambiq™ Apollo4 Blue MCU die

The Apollo4 MCU employs 2 MB (16 Mb) of MRAM on the 15.56 mm^2 MCUdie. Figure 4 shows a 16Mb eMRAM array module with TSMC 22ULL process on Ambiq™ Apollo4 Blue MCU die. Previous Apollo2 (AMAPH) and Apollo3 (AMA3B) SoC products used TSMC 40nm eFLASH process (40ULP) and 2D NOR ESF3 cell structure, the 3rd generation split gate Embedded SuperFlash which consists of EG (Erase Gate), CG (Control Gate), FG (Floating Gate), and WL SG (Select Gate). The low-power eMRAM provides a very large, efficient non-volatile memory for code and data. MRAM doesn't suffer from the write wear incurred by flash memory.

Download High Resolution Ambiq™ Apollo4 Blue MCU Die

SEM X-Section and Bevel Top-View Imaging of eMRAM Cell MTJ

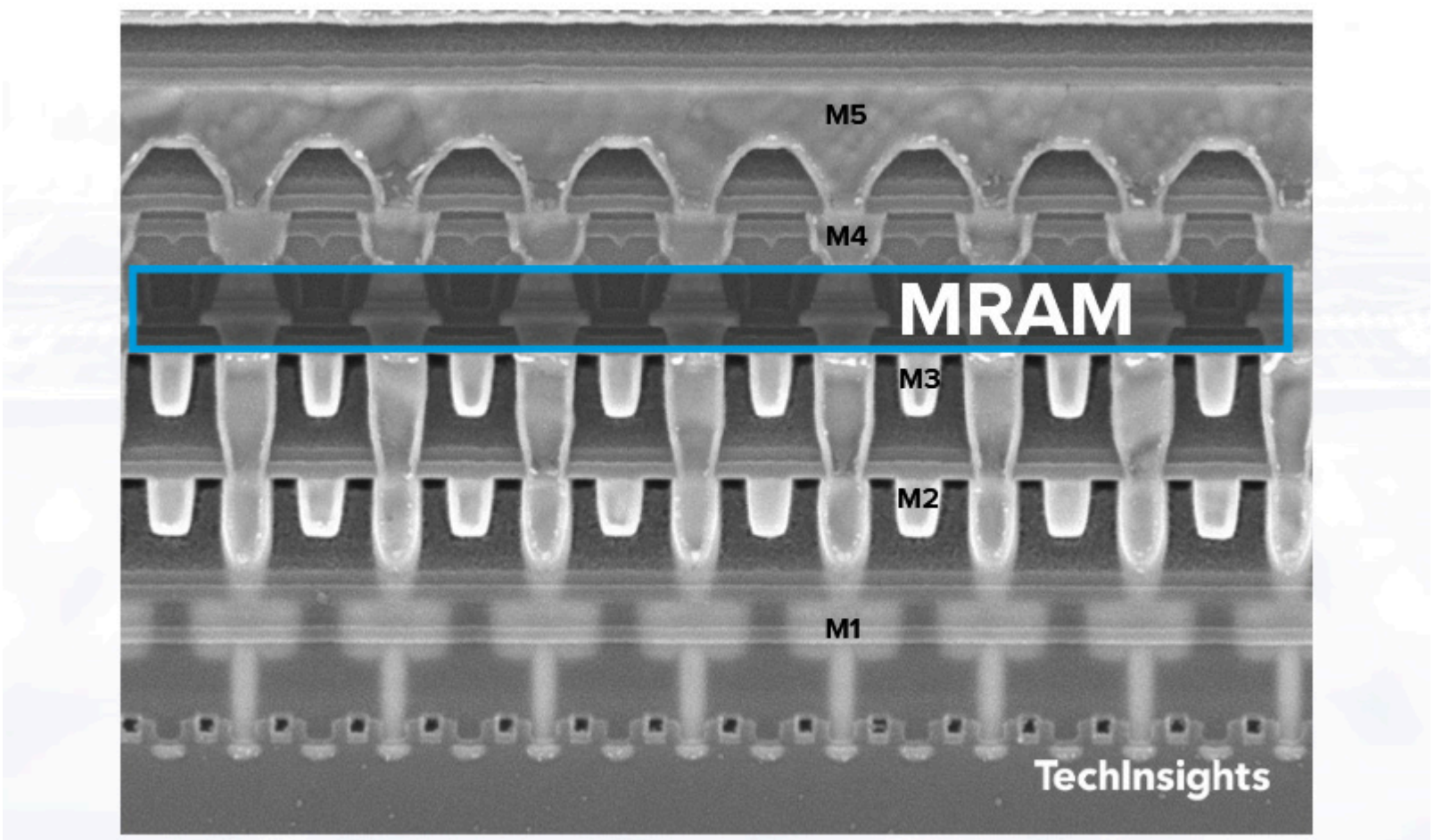


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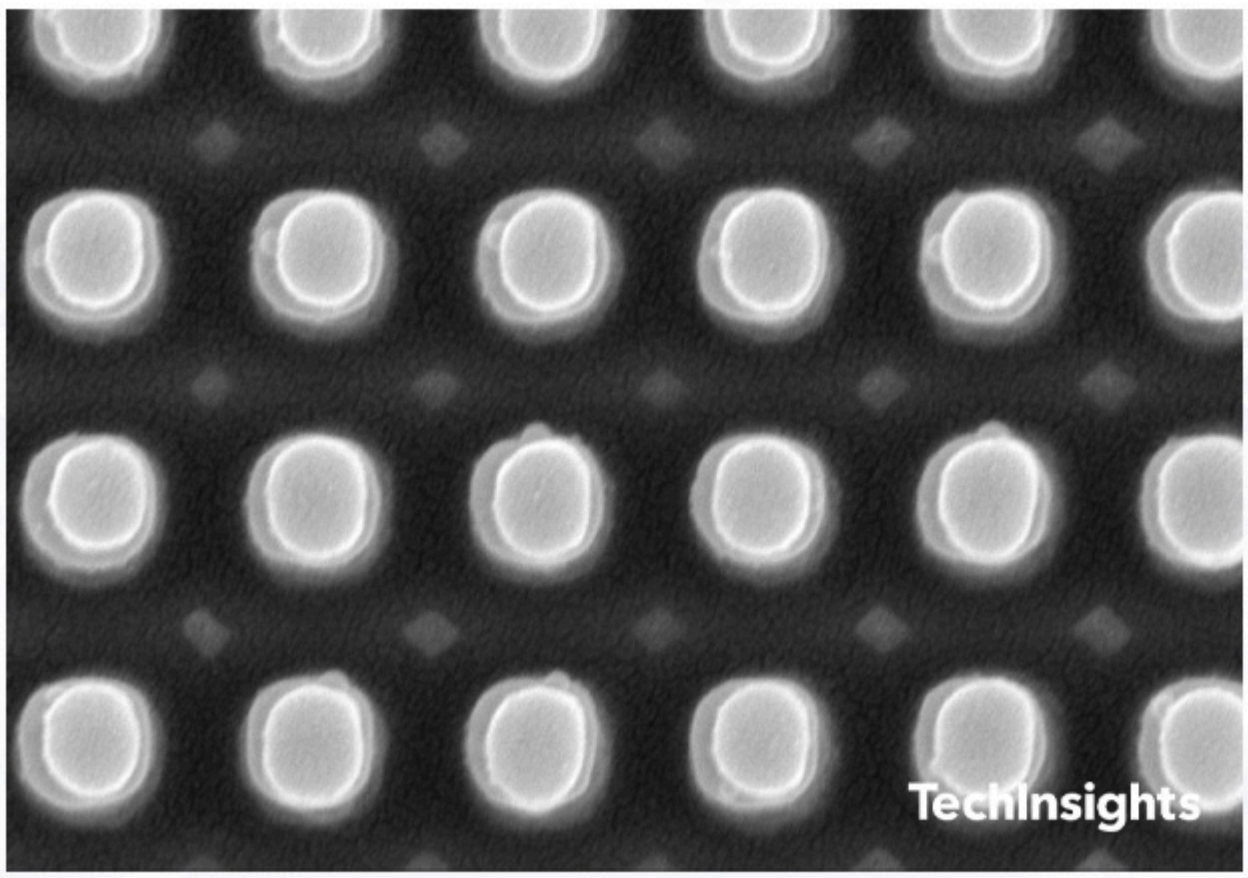
Figure 5. SEM x-section image of TSMC 22ULL eMRAM cell MTJ layer



(https://www.techinsights.com/sites/default/files/2021-08/tsmc-22ull-6.jpg)

Figure 6. Bevel top-view images of TSMC 22ULL eMRAM cell MTJ layer

Last year, TechInsights did analyses on some recent eMRAM products such as Sony's GPS SoCs manufactured by Samsung (28 nm FDSOI) and used in Huawei's smartwatches, as well as Everspin/GlobalFoundries (GF) 28 nm 1 Gb stand-alone DDR4 STT-MRAM and Avalanche/Renesas 40 nm eSTT-MRAM ICs. However, TSMC 22ULL eSTT-MRAM is the most advanced technology node ever to date. The eMRAM 1-bit cell size is 0.046

μm^2 which is similar with Everspin/GF's 28 nm STT-MRAM cell (0.041 μm^2). Module area for 2 MB eMRAM on the die measures 1.90 mm^2 with sixteen sub-array blocks, and eMRAM sub-array block size is 46,800 μm^2 with 220 nm WL pitch and 210 nm BL pitch.

MRAM/MTJ layers are embedded between metal-3 (M3) and metal-4 (M4), circle-typed patterns with 77˚etch-angle (x-section). Figures 5 and 6 show the SEM x-section and bevel top-view images of eMRAM cell MTJ layer. In comparison with Apollo3, peripheral and eMemory gate pitches (min.) have been decreased, 170 nm to 120 nm (for peripheral gate), and 230 nm to 110 nm (for eMRAM array) for each.

Download High Resolution TSMC 22ULL eMRAM SEM X-Section and Bevel Top-view

Ambiq Apollo Blue MCU (microprocessor): Comparative Product Specifications

A comparison of Ambiq™ Apollo Blue MCU series is shown in Table 1 with Apollo2, Apollo3, and Apollo4. Ambiq's low-power Apollo4 MCUs manufacturing by TSMC on 22ULL process will be comparable with GlobalFoundries' eMRAM (22 nm FDSOI) which is used for GreenWave's AI processors, for example. TSMC's eMRAM is being taken on to 16 nm FinFET platform and will be volume produced in 2022.

Device	Ambiq™ Apollo2 Blue MCU	Ambiq™ Apollo3 Blue MCU	Ambiq™ Apollo4 Blue MCU
Product Example	Huawei ERS-B29 Band 2 Pro	Huawei TER-B19 Band 3 Pro	Fitbit Luxe (Fitness Band)
Package Markings	AMAPH	AMA3B	AMA4B
Supply Current	10 µA/MHz (eFLASH)	6 µA/MHz (eFLASH)	3 µA/MHz (eFLASH)
Die Markings	Apollo 2 Ambiq Micro 2016	Apollo 3 Ambiq Micro 2017	Apollo 4 Ambiq Micro 2020
Die Size (Seal)	6.43 mm^2 (2.55 mm x 2.52 mm)	10.72 mm^2 (3.21 mm x 3.34 mm)	15.56 mm^2 (3.95 mm x 3.94 mm)
CMOS Process	40 ULP	40 ULP	20 ULL
Foundry	TSMC	TSMC	TSMC
Number of Metals	8 (7 Cu, 1 Al)	9 (8 Cu, 1 Al)	10 (9 Cu, 1 Al)
Logic Gate Pitch	170 nm	170 nm	120 nm (HKMG)
Embedded Memory	eFLASH (2D NOR ESF3)	eFLASH (2D NOR ESF3)	eMRAM
eMemory Gate Pitch	250 nm	230 nm	110 nm
eMemory Bit Cell Size	0.068 μm^2	0.068 μm^2	0.046 μm^2
eMemory Area Portion & Capacity	14%, 8 Mb	9%, 8 Mb	10.4%, 16 Mb

Table 1. A comparison table of Ambiq™ Apollo Blue MCU series; Apollo2, Apollo3, and Apollo4

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