

# China Technology

## Apple MR: Long-awaited next “iPhone moment”

**OUTPERFORM**  
(Maintain)

Apple is widely expected to launch its long-awaited MR headset in WWDC 2023 this week. We believe 2023 is set to be one of the best years in VR/AR ecosystem development as Apple’s first MR headset will set new standard for innovation. We expect technology upgrade to accelerate in displays, optics/sensors and tracking/interaction for enhancing user experience. In this report, we detail the key technologies and identify investment opportunities across the supply chain. Our analysis suggested major beneficiaries include Luxshare, Cowell, Everwin, Goertek, Zhaowin, Sunny Optical and Will Semi.

- **Why now?** Apple has been experimenting with AR/VR technologies for over 10 years based on patent filings and acquisitions, and it is widely expected to unveil its first MR device “Reality Pro” with “xrOS” at WWDC 2023, priced at US\$3,000 and targeted at prosumers/developers. We expect it to feature dual-chip (ISP+SoC), 3P Pancake lenses, 4K Micro-OLED, eye/gesture tracking, 15+ cameras/sensors, AR/VR digital switching and an external battery. We believe the use cases will focus on gaming, health & fitness, productivity and remote collaboration.
- **Apple MR headset: Start of a new era in AR/VR industry.** Apple’s sizeable 2bn active device installed base and its seamless integration of ecosystem will set its MR headset apart from other vendors. In near term, we estimate Apple’s first-gen MR device shipment will reach 200-300k unit in 2023, and ramp up multiple times to 10mn+ level by 2025-26 after more-affordable 2<sup>nd</sup>-gen model launch in 2H24-1H25E. We are positive on Apple MR headset’s TAM potential of 10-20mn units in next 2-3 years, compared to Meta/Pico 10mn, PS5/Xbox/Switch 20mn, iWatch/iPad/AirPods/iPhone 40/60/80/200mn.
- **Where are the opportunities?** We believe Apple MR headset will have a profound impact on VR/AR/MR market, setting new standards for innovation. In this report, we identify three major opportunities for supply chain players: **1) Display:** Micro-OLED is becoming mainstream; **2) Optics:** Pancake solution to replace Fresnel lenses; **3) Tracking/interaction:** 10+ cameras and sensors for eye tracking, gesture tracking and VST features.
- **Stock Picks:** We expect display, semis and memory to make up 50-60% of total BOM, and optical and camera/sensor are the key components in AR/VR experience. Major beneficiaries include Luxshare (OEM), Cowell (camera module), Everwin (casing), Zhaowei (IPD system), Goertek (acoustics/OEM), and Sunny Optical/Will Semi (optical lens/CIS).

### Valuation Table

Name	Ticker	Rating	Mkt Cap (USD mn)	Price (LC)	TP (LC)	Up/Down -side	P/E (x)		P/B (x)		ROE	
							FY23E	FY24E	FY23E	FY23E	FY23E	FY23E
Luxshare	002475 CH	Buy	28,402	28.35	48.0	69%	18.8	15.2	2.0	10.5		
Goertek	002241 CH	Buy	9,266	19.28	44.7	132%	9.8	13.2	1.7	17.8		
Sunny Optical	2382 HK	Hold	10,483	74.90	86.8	16%	22.9	19.8	3.1	9.8		
Cowell	1415 HK	NR	2,039	18.84	NA	NA	20.4	14.0	4.5	23.6		
Everwin	300115 CH	NR	2,364	14.01	NA	NA	32.4	17.0	2.7	8.9		
Zhaowei	003021 CH	NR	2,071	86.1	NA	NA	61.2	42.5	5.0	8.0		

Source: Company data, CMBIGM estimates

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## AR/VR Headset Supply chain

Fig.1: Overview of VR/AR hardware supply chain



Source: CMBIGM

## BOM cost breakdown for Apple MR headset

Fig.2: Overview of VR/AR hardware supply chain

Category	Component	Supplier	No.	ASP (USD)	Total (USD)
<b>SoC</b>	SoC	Apple M2 Series	1	100	100
<b>ISP</b>	ISP	Apple	1	60	60
<b>Memory</b>	ROM	Samsung, Kioxia	1	20	20
	RAM	SK Hynix, Samsung	1	30	30
<b>Inner Display</b>	Micro-OLED	Sony	2	300	600
<b>Outer Display</b>	AMOLED/OLED	LG	1	30	30
<b>Optics</b>	Pancake Lens	Genius, Young Optics	2	30	60
	Module	GIS	1	50	50
	6DoF tracking	Lens: Largan; Module Cowell	4	5	20
	VST RGB camera	Lens: Largan; Module Cowell	2	8	16
	Eye-tracking	Sony	2	12	24
	Face-tracking	Sony	2	12	24
	Body-tracking	Lens: Largan; Module: Cowell	2	5	10
	Gesture-tracking	Lens: Largan; Module: Foxconn	1	10	10
	ToF	Lens: Genius; Module: LG	1	10	10
	IMU	TDK	1	3	3
<b>Structural components</b>	Haptics		2	2	4
	Outer shield, frame	Everwin, Lingyi Itech	1	120	120
<b>Acoustics</b>	MIC	Merry	3	3	9
	SPK	Goertek	4	2	8
<b>PCB+FPC</b>	PCB+FPC	Avary, Dongshan Precision	1	55	55
<b>Headset battery</b>	Battery		1	3	3
<b>External battery</b>	Battery	Desay, Sunwoda	1	15	15
<b>OEM/ODM</b>	Assembly	Luxshare, Pegatron	1	130	130
<b>Others</b>	WiFi, PMIC, Thermal dissipation, waterproof		1	100	100
<b>Total BOM</b>					<b>1511</b>

Source: Wellsenn XR, CMBIGM

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Fig.3: Peers Comparison

Company	Ticker	Rating	Mkt Cap (US\$ mn)	Price (LC)	TP (LC)	Up/ Down -side	P/E (x)		P/B (x)		ROE (%)	
							FY23E	FY24E	FY23E	FY24E	FY23E	FY24E
<b>Optics</b>												
Sunny Optical	2382 HK	Hold	10,483	74.90	86.8	16%	22.9	19.8	3.1	2.8	13.4	14.1
Q Tech	1478 HK	Buy	490	3.24	5.2	60%	6.8	5.0	0.7	0.6	9.8	12.0
Truly	732 HK	NR	359	0.89	NA	NA	-	-	-	-	-	-
Cowell	1415 HK	NR	2,039	18.84	NA	NA	20.4	14.0	4.5	3.4	23.6	26.7
Largan	3008 TT	NR	9,951	2290	NA	NA	18.0	16.3	1.9	1.8	11.0	11.2
Genius	3406 TT	NR	1,547	422	NA	NA	18.0	16.3	2.3	2.0	13.3	13.7
Primax	4915 TT	NR	978	65.40	NA	NA	10.6	9.9	1.7	1.6	15.5	15.8
Lite-On	2301 TT	NR	7,383	96.00	NA	NA	17.0	14.2	2.7	2.5	15.8	18.6
O-Film	002456 CH	NR	2,298	5.02	NA	NA	-	-	6.9	6.9	(42.5)	(22.5)
Samsung Elec	009150 KS	NR	8,490	148400	NA	NA	16.4	11.5	1.4	1.3	9.0	11.7
Lg Innotek	011070 KS	NR	5,583	308000	NA	NA	9.8	7.5	1.5	1.3	16.2	18.4
Partron	091700 KS	NR	412	9140	NA	NA	10.4	9.2	1.0	0.9	10.0	10.4
<b>Average</b>							<b>15.0</b>	<b>12.4</b>	<b>2.5</b>	<b>2.3</b>	<b>8.7</b>	<b>11.8</b>
<b>Acoustics/Haptics</b>												
AAC Tech	2018 HK	Hold	2,456	16.06	15.6	-3%	14.7	13.2	0.8	0.8	5.2	5.7
Goertek	002241 CH	Buy	9,266	19.28	44.7	132%	9.8	13.2	1.7	1.7	17.8	13.1
Luxshare	002475 CH	Buy	28,402	28.35	48.0	69%	18.8	15.2	2.0	1.7	10.5	11.4
Sunway	300136 CH	NR	2,705	19.90	NA	NA	20.5	16.8	2.5	2.2	12.8	14.0
Merry	2439 TT	NR	647	91	NA	NA	15.1	14.0	1.5	1.5	10.4	11.2
Knowles	KN US	NR	1,593	17.43	NA	NA	17.0	13.2	-	-	-	-
Nidec	6594 JP	NR	31,462	7400	NA	NA	53.2	27.3	3.2	2.9	7.0	11.3
Alps Alpine	6770 JP	NR	1,942	1242	NA	NA	10.5	10.2	0.6	0.6	6.2	6.0
<b>Average</b>							<b>19.9</b>	<b>15.4</b>	<b>1.8</b>	<b>1.6</b>	<b>10.0</b>	<b>10.4</b>
<b>Connector</b>												
FIT Hon Teng	6088 HK	Buy	1,367	1.47	2.2	48%	9.2	7.4	0.5	0.5	5.6	6.7
Luxshare	002475 CH	Buy	28,402	28.35	48.0	69%	18.8	15.2	2.0	1.7	10.5	11.4
TE	TEL US	NR	39,790	126.27	NA	NA	19.2	16.8	3.5	3.2	18.6	20.0
Amphenol	APH US	NR	46,179	77.57	NA	NA	26.9	24.4	5.9	5.3	24.5	24.5
<b>Average</b>							<b>18.5</b>	<b>16.0</b>	<b>3.0</b>	<b>2.7</b>	<b>14.8</b>	<b>15.7</b>
<b>EMS/OEM</b>												
BYDE	285 HK	Hold	6,944	24.15	24.5	1%	16.5	13.5	1.7	1.5	10.4	11.4
Luxshare	002475 CH	Buy	28,402	28.35	48.0	69%	18.8	15.2	2.0	1.7	10.5	11.4
Hon Hai Precision	2317 TT	NR	48,521	107.50	NA	NA	12.1	9.5	0.9	0.9	8.2	9.8
Pegatron	4938 TT	NR	6,773	78.00	NA	NA	12.7	11.5	1.1	1.1	8.4	8.9
Wistron	3231 TT	NR	6,704	71.00	NA	NA	23.6	16.3	2.0	1.8	8.9	11.6
<b>Average</b>							<b>29.0</b>	<b>20.9</b>	<b>6.6</b>	<b>5.0</b>	<b>13.6</b>	<b>19.9</b>
<b>Casing</b>												
BYDE	285 HK	Hold	6,944	24.15	24.5	1%	16.5	13.5	1.7	1.5	10.4	11.4
Tongda	698 HK	Buy	122	0.10	0.2	104%	2.7	2.5	0.1	0.1	2.9	4.7
TK Group	2283 HK	Buy	158	1.49	3.4	127%	2.9	3.8	0.6	0.6	20.7	17.8
Ju Teng	3336 HK	NR	204	1.33	NA	NA	-	-	-	-	-	-
Everwin	300115 CH	NR	2,364	14.01	NA	NA	32.4	17.0	2.7	2.4	8.9	14.6
Lens Tech	300433 CH	NR	8,281	11.85	NA	NA	19.3	13.2	1.3	1.2	7.6	9.3
Chaozhou Three	300408 CH	NR	8,022	29.79	NA	NA	27.8	21.0	3.0	2.7	11.1	13.2
Catcher	2474 TT	NR	4,176	188.5	NA	NA	19.7	17.6	0.8	0.8	4.1	4.5
Jabil	JBL US	NR	12,243	92.27	NA	NA	11.0	10.2	4.0	3.3	40.8	36.3
<b>Average</b>							<b>16.5</b>	<b>12.3</b>	<b>1.8</b>	<b>1.6</b>	<b>13.3</b>	<b>14.0</b>

Source: Bloomberg, CMBIGM estimates

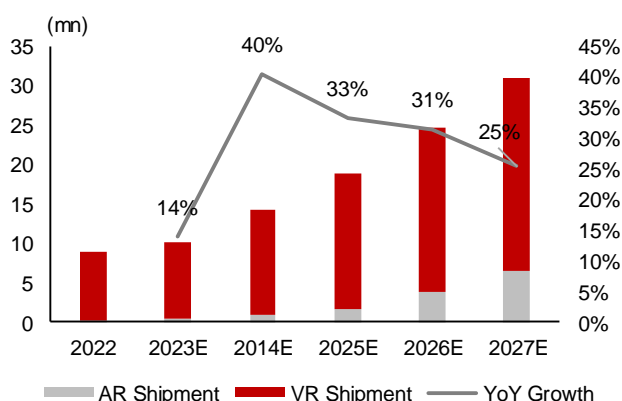
## AR/VR headset is the ticket to the Metaverse

Augmented reality/Virtual reality (AR/VR) have been one of the most overhyped technologies in recent years. While VR emphasizes the immersive experience in the virtual world, AR focuses on superimposing information in the real world, and mixed-reality (MR) is regarded as the integration of VR and AR, which emphasizes the interactive experience of real and virtual worlds. After a decade of advancement, we believe applications and technology of VR are more mature than AR, but AR will provide the main opportunities for growth in VR/AR market, and AR/MR will become the major trend in the market overall.

**2012-19: First AR/VR device launched in 2012; shipment ramp to 8.4mn in 2017.** Oculus launched the prototype headset 'Rift' in 2012, which is regarded as the first commercial AR/VR device, and the company was sequentially acquired by Facebook in 2014. Since then, Google, Sony and Samsung launched their AR/VR devices in 2014, and total shipment reached 8.4mn units in 2017, followed by decline to 6mn in 2018/19 due to lack of killer apps and slow upgrade of user experience.

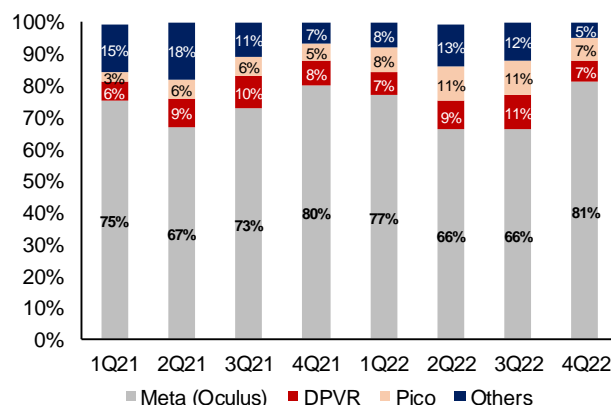
**2020-22: Meta Quest 2 first VR headset to cross 10mn shipments.** In 4Q20, Oculus launched Oculus Quest 2, which featured Qualcomm Snapdragon XR2, 6DoFs and fast-LCD with 503g. This was the turning point in AR/VR industry, as Meta has become the major driver for AR/VR headsets with 65%+ global market shares in 2021-22.

**Fig.4: Global AR/VR Headsets forecast (2022-27E)**



Source: IDC, CMBIGM

**Fig.5: Global AR/VR market Share (1Q21-4Q22)**



Source: Counterpoint, CMBIGM

**Fig.6: Specifications of the newest products by different brands**

Name	Apple MR 1st-Gen	Meta Quest 3	Meta Quest Pro	Meta Quest 2	Pico Neo 4/4 Pro	Sony PSVR2	HTC Vive XR Elite	DPVR E4
Type	Standalone	Standalone	Standalone	Standalone	Standalone	Tethered	Standalone	PC-Power
Release Date	Jun 2023 *	Jun 2023	Oct 2022	Oct 2020	Sep 2022	Feb 2023	Mar 2023	Feb 2023
Processor	Dual-Chip	Qualcomm XR2 Gen 2	Qualcomm XR2+	Qualcomm XR2	Qualcomm XR2	MediaTek	Qualcomm XR2	-
Storage	-	128GB	256GB	128GB/256 GB	128GB/256 GB	-	128GB	-
Display	Micro OLED	Mini-LED	Mini-LED	Fast-LCD	Fast-LCD	Fast-LCD	Fast-LCD	Fast-LCD
Resolution	4K	2064*2208	1800*1920	1832*1920	2160*2160	1280*1440	1920*1920	1832*1920
Refresh Rate	120	120Hz	90Hz	90Hz	90Hz	120Hz	90Hz	120Hz
Optical	Pancake	Pancake	Pancake	Fresnel	Pancake	Fresnel	Pancake	Fresnel
FOV (Deg)	120	-	106	100	104	110	110	95
Tracking	6DoF	6DoF	6DoF	6DoF	6DoF	6DoF	6DoF	6DoF
Weight	400g	-	722g	503g	586g	560g	625g	480g
Price (US\$)	\$3000	\$499	\$1499	\$299   \$399	RMB2499	\$399	\$1099	\$549

Source: Company, CMBIGM

## Apple MR: Long-awaited next “iPhone Moment”

**Apple’s first MR headset expected to launch in WWDC 2023.** Apple has been investing into AR/VR technologies for 10+ years based on patent filings and acquisitions, and it is widely expected to unveil its long-awaited MR device “Reality Pro” with “xrOS” at WWDC 2023. We believe Apple MR headset will start the new era for AR/VR hardware industry, and become Apple’s next most important device after iPhone, iPad, Mac and Watch.

Apple first MR device is expected to be priced at US\$3,000, mainly for high-end customers and developers, and the second-generation affordable version is expected to launch in 2H24/1H25E. While the first version will not be major shipment driver in our view, we believe Apple’s iterative innovation and improvement will have a profound impact on the AR/VR/MR market and reshape the hardware supply chain.

**Advanced optics/display/tracking/chipset as key focus areas.** Apple MR headset blends augmented and virtual reality. The VR features will be powered by a pair of 4K display inside the headset, while the AR functionality will be enabled by the video pass-through mode. In terms of optics, we expect Apple MR device will adopt 3P Pancake solution for shorter focal length and smaller size. For display, it will adopt 4K micro-OLED for near-eye display solution given its strong contrast ratio, color gamut, response time and high resolution. For tracking, we expect the device to equip 15+ cameras/sensors to support eye-tracking and gesture interactions. For chips, it is expected to adopt a dual-chip design (SoC + ISP) for enhanced computing power and graphical performance.

**Fig.7: Expected Apple MR Specs**

Spec	Technology details
Display	Dual 4K micro-OLED displays per eye; 120-degree FOV
Optics	3P Pancake lenses solution
Chipset	Dual-chip design (5nm), including a SoC (CPU, GPU, and memory) and an image signal processor (ISP).
Battery	Waist-mounted battery, connected via MagSafe-like power cable to headset’s headband. Two-hour max battery life.
Passthrough	ISP chip contains custom high-bandwidth memory for low latency color passthrough
Audio	H2 chip for ultra-low latency connection with AirPods Pro and future models.
Prescription Lenses	Magnetically attachable custom prescription lenses for glasses-wearers.
IPD Adjustment	Automatic, motorized adjustment to match wearer’s interpupillary distance.
Eye Tracking	More than one camera per-eye
Face/Body Tracking	More than 15 cameras/sensors for facial expressions and body movements
Room Tracking	LiDAR scanners to map surfaces and distances in 3D.

Source: CMBIGM

**Apple’s AR/VR technology roadmap.** After 10+ years of acquisitions in AR/VR space, Apple has built an established AR/VR technology roadmap. For instance, **1) for software**, Apple acquired Metaio (AR software), and Flyby Media (SLAM technology) in 2015 for AR vision, 3D positioning and navigation areas. **2) for hardware**, Apple acquired SensoMotoric (eye-tracking R&D) and Vrvana (AR headset) in 2017, and then acquired Aknoia Holographics (holographic storage) in 2018, for interactive hardware, AR HD displays, and headset display technology. **3) for interaction tracking**, Apple acquired PolarRose (facial recognition) in 2010 and PrimeSense (Israeli 3D sensing) in 2013, Faceshift in 2015, and Emotient in 2016, for interactive games and facial expression AI technology. **4) for content**, Apple spent US\$100mn to acquire Next VR (VR sports live broadcast) in 2020 for VR live broadcast and VR video conferencing.

Fig.8: Apple's acquisitions of AR/VR technology in recent years

Tech categories	Time	Descriptions
Processors	Nov-2013	<b>Acquired</b> PrimseSense for USD 345 million, which developed 3D machine vision and made chips
	Nov-2020	<b>Developed</b> M1 series Chip. M1 series chip consist of Apple M1, M1 Pro and M1 Pro Max. Apple Glass' processor is rumoured to be similar to the specifications of Apple M1 Chips.
Display	May-2014	<b>Acquired</b> LuxVue Technology, a firm specialising in Micro LED display technology
	Aug-2018	<b>Acquired</b> Akonia, a company specialising in waveguide tech with a portfolio of 200 IPs
	Mar-2020	<b>Developed</b> and registered a patent that embedds fingerprint & touch sensing in its micro-LED display
	Feb-2021	<b>Developed</b> and registered a micro-LED patent to effectively detect and identify the quality of display during the manufacturing process
Refractive waveguide	Nov-2013	<b>Acquired</b> PrimeSense, an Israeli Structured-light 3D scanners manufacturer
Sensors	Nov-2017	<b>Acquired</b> Invisage Technolgoes, an image sensors manufacturer that improves the quality of digital photographs taken with a cell phone camera
	Dec-2021	<b>Invested</b> USD 411 million into production of LIDAR sensor to provide a more vivid AR experience
Human-machine interaction	May-2015	<b>Acquired</b> Faceshift, a company developing motion capture technology
	Jan-2016	<b>Acquired</b> FLY by Media, an company that developed technology for mapping spaces using smartphones
	Jan-2016	<b>Acquired</b> Emotient, a comnpny building tools for facial expression recognition
	Feb-2017	<b>Acquired</b> RealFace, an Israeli company speciliasing in facial recognition tech
	Jun-2017	<b>Acquired</b> SensoMotoric Instruments, a firm specialising in eye tracking software & hardware
	Sep-2017	<b>Acquired</b> Regaind, a leading facial recognition tech company, to enhance analysis of facial recognition.
	Oct-2019	<b>Acquired</b> Ikinema, a UK-based 3D animation company developing motion capture technology
	Oct-2020	<b>Developed</b> and registered a patent of "Spatial Audio", which enabled 3D sound effect emitted from headphones
	Oct-2021	<b>Developed</b> and registered a patent of 3D audio rendering to incorporate audio features in the graphical framework
Audio	May-2015	<b>Acquired</b> Metaio, a specialising in AR software maker
	May-2020	<b>Acquired</b> NextVR for USD 100 million, which develops applications for livestreaming and on-demand VR content
Software	Aug-2020	<b>Acquired</b> Spaces, a VR software maker for themed and location-based virtual environemnt
	Aug-2020	<b>Acquired</b> Camerai, a platform developer that allowed apps and developers to easily create AR and image processing graphics without much technical knowledge
VR/AR hardware manufacturer	Sep-2017	<b>Acquired</b> Vrvana for USD 30 million, a VR/AR headset developer that launched Totem virtual reality headset (it was never shipped, but Vrvana distributed early hands-on to some consumers)

Source: Company, CMBIGM

## Apple MR Headset: Technology evolution to accelerate

### Optics: Pancake solution to replace Fresnel lenses

We expect Apple MR headset to adopt 3D Pancake solution. AR/VR optics technology evolves on upgrade trend of "non-Spherical lens-Fresnel lens-Pancake". In recent years, Pancake solution gradually becomes the mainstream optical solution, compared to Fresnel lens previously (Quest 2, PicoNeo3, and iQiyi 3). 60% of new VR products were equipped with Pancake solution in 2022, such as Skyworth Pancake 1, Pico 4 and Quest Pro.

Overall, Pancake solution has these key advantages: **1) Lighter and thinner:** Pancake's multi-lens folding optical path design can effectively reduce thickness of lens and shorter focal length. Thickness and weight is reduced by is 50% and 30%+, compared to Fresnel lens. **2) Improve edge imaging quality and image distortion;** **3) Diopter adjustment support (0-700°)**, which cannot be achieved by single-lens Fresnel and aspheric solutions.

Fig.9: Comparison of optical solutions for major VR/AR products

Release Date	Product name	Optical Lens	FOV	Weight
Sep 2020	Meta Quest 2	Fresnel	100	503g
Feb 2023	Sony PSVR2	Fresnel	110	560g
Sep 2022	Pico 4	Pancake	104	586g
Mar 2023	HTC Vive XR Lite	Pancake	110	625g
Oct 2022	Meta Quest Pro	Pancake	106	722g
Jun 2023	Apple MR	Pancake	120	400g

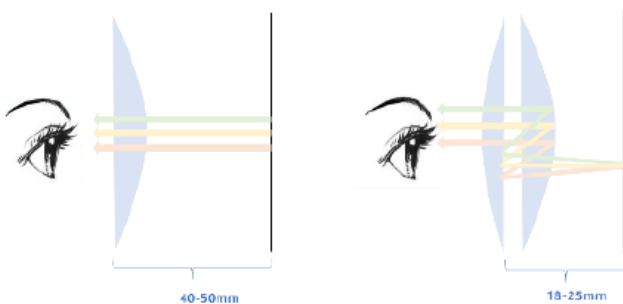
Source: VR-compare, CMBIGM

Fig.10: Specifications of different optics

	Non-Spherical	Fresnel	Pancake	Folded Freeform
FOV	90°-180°	90°-120°	70°-100°	80°-100°
TTL	40-50mm	40-50mm	15-20mm	40-45mm
Image Quality	Edge image is good	Prone to artifacts and distortion	Edge image quality is good but prone to artifacts	Prone to distortion
Advantage	Low cost	Thin, low cost	Thin, good quality	Eye movement
Cost	RMB5-10	RMB 15-20	RMB 120-180	RMB 50-100
Stage	Fade out	Mainstream	Mass adoption	Niche market
Products	VR box, PSVR	Meta quest 2, Pico neo3	HW VR Glass, Apple MR	Lynx

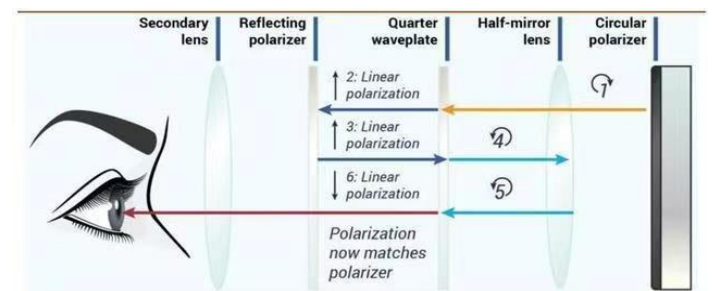
Source: Wellsenn XR, CMBIGM

Fig.11: Fresnel solution vs Pancake solution



Source: Wellsenn XR, CMBIGM

Fig.12: Principles of Pancake Optics



Source: Wellsenn XR, CMBIGM

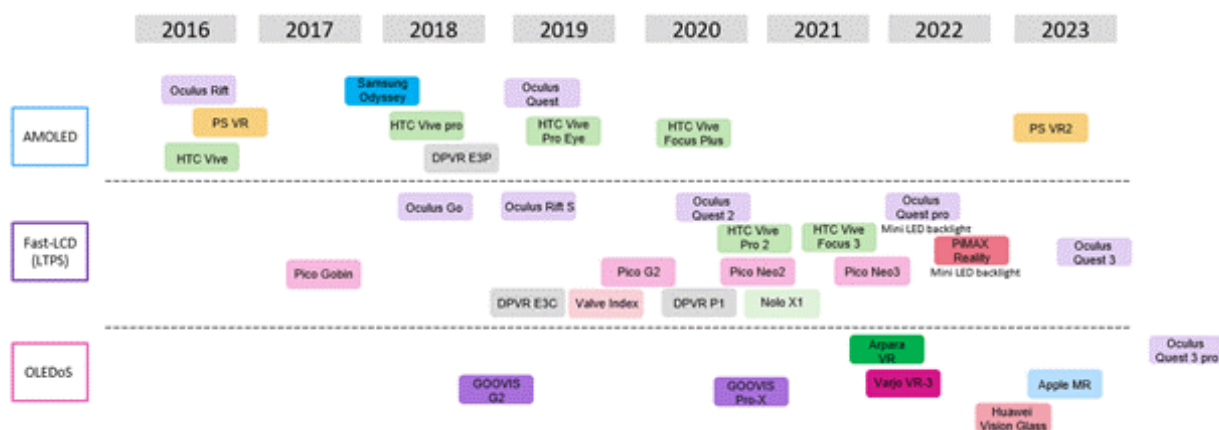


## Display: Micro-OLED to become mainstream after Apple MR launch

**Fast-LCD panel with Mini-LED backlight has been popular since 2018.** In 2016, all major AR/VR products (e.g. Oculus, Sony, HTC) adopted OLED solutions, given its high refresh rate and low latency. Starting from 2018, since fast-LCD technology became mature, OLED has been gradually replaced by fast-LCD solution, and fast-LCD with LED-backlight was the mainstream spec in 2022 (e.g. Quest pro/3, Pico).

**Micro-OLED as emerging solution with significant advantages.** The threshold for a high-quality VR experience is to have a display with at least 2500 PPI, which can reduce screen door effect on VR devices. Therefore, Micro-OLED's high 3000+ PPI is one major advantage over fast-LCD 1000-1500 PPI. In addition, Micro-OLED also has other advantages, which make it an ideal solution for AR/VR display. **1) Short response time:** OLED is self-emitting while LCD requires backlight, leading to shorter response time and higher refresh rate. **2) Large FOV:** Micro-OLED allows lights to spread to wider angles than fast-LCD as backlight need to pass through multiple polarizer and TFT layers on fast-LCD. **3) Light weight:** Micro-OLED has fewer components than fast-LCD (e.g. polarizer, TFT layers) and thus lighter weight. **4) High Contrast:** OLED produces more vivid dark colors than fast-LCD display with backlight and polarizer layers.

**Fig.13: Trends in AR/VR display technology adoption**



Source: Omdia, CMBIGM

**Fig.14: Comparison of AR/VR display technology solution**

Display Type	Fast-LCD	Mini LED	OLED	Micro OLED	Micro LED
Technology	LED-backlight	LED-backlight	Self-emitting	Self-emitting	Self-emitting
Brightness(nit)	500	1000-6000	500	1000-6000	100000
Color Gamut	75%NTSC	>110%NTSC	124%NTSC	>100%NTSC	140%NTSC
Contrast	5000 : 1	10000 : 1	10000 : 1	10000 : 1	100000 : 1
Lifespan (Hour)	60k	80-100k	20-30k	<100k	100k
Response Time	ms	nm	ms	ms	nm
Temperature°C	-40°C-100°C	-100°C-120°C	-30°C-85°C	-50°C-70°C	-100°C-120°C
Power consumption	High	Low	60-80% of LCD	30-40% of LCD	10% of LCD
Driver solution	Driver IC	Driver IC	Driver IC	TFT/CMOS	TFT/CMOS
Thickness	Thick	Think	Relatively thin	Thin	Thin
Cost	Low	High	Medium	High	High
Development Stage	Mass production	Mass production	Mature	Mass Production	R&D Stage
Products	Quest 2, Pancake 1, PICO Neo3	Pancake 1 pro, Quest Pro	Quest 1, HTC Vive, PS VR2	Apple MR	--

Source: CMBIGM

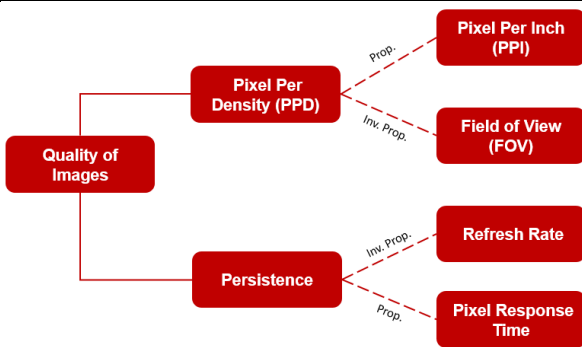
**Apple MR launch and capacity expansion; Micro-OLED adoption set to accelerate.**

Given the advantages of Micro-OLED display, we expect Apple MR launch and panel capacity expansion will boost Micro-OLED adoption to accelerate in the next 2-3 years.

**1) Apple MR launch:** Apple MR is expected to come with a Micro-OLED display, and we believe other brands such as Meta, Pico, and Sony will follow and adopt high-end Micro-OLED display in their next-gen products.

**2) Panel capacity expansion to drive cost reduction:** Sony is now the major supplier of Micro-OLED for commercial XR headsets (incl. Apple MR), and other panel suppliers are also actively expanding Micro-OLD capacity, which will drive cost reduction further in next few years. For instance, Samsung’s Micro-OLED production line will start mass production in 2024, and LG is also cooperating with Meta and Hynix to develop Micro-OLED panels for Meta XR products. In China, BOE’s Phase 2 production line will commence production in 2024, and CSOT’s new capacity can supply 624k XR devices per year after mass production. Overall, we expect cost of Micro-OLED will start to decline gradually after 2024, boosting penetration of Micro-OLED in AR/VR products.

**Fig.15: Key factors for VR display quality**



Source: CMBIGM

**Fig. 16: Major display panel suppliers**

Display Technology	Panel Suppliers
LCD	JDI, Sharp, BOE, AUO
OLED	Samsung Display, BOE
Micro-OLED	Sony, eMagin, LG Display, APS, BOE, TCL CSOT
Micro-LED	PlayNitride, AUO, TCL CSOT, Jade Bird Display, Charm Engineering

Source: CMBIGM

## Tracking/interaction: Eye/gesture tracking and VST to enable AR/VR experience

**Apple MR headset to support video see-through (VST).** To allow users seamlessly switch between VR and AR, we expect Apple MR headset to adopt video see-through (VST) by using 15+ cameras/sensors and a digital crown-like switch. Our analysis suggested that most product launches in 2H22 (e.g. Pancake 1 Pro, Pico 4, Quest Pro) started to adopt RGB see-through, compared to B&W see-through for earlier products (e.g. Quest 2, Pico Neo 3). We also expect Apple MR headset to equip VST technology by using 15+ cameras/sensors and a digital crown to switch between AR and VR modes.

**Advanced eye and gesture tracking with no controllers.** We expect advanced eye and gesture tracking to be key differentiators to set Apple MR headset apart from its peers. Unlike current mainstream VR headsets, Apple MR headset is expected to detect human interaction through eye movement and gesture tracking at the same time, and no controllers are required. Based on patents filing and acquisitions, Apple and other AR/VR players have extensive research and development in eye/gesture tracking technology, and we believe eye/hand tracking capabilities will be a major selling point for Apple MR device.

**Fig.17: Comparison of tracking features and cameras for major AR/VR products**

Release Date	Brand	Model	# of Camera	R&W See-through	RGB See-through	Eye-tracking	Gesture tracking
Jun-23	Apple	MR	15		Y	Y	Y
Feb-23	Sony	PSVR2	6	Y		Y	Y
Mar-23	HTC	Vive XR	6		Y		
Oct-22	META	Quest Pro	10		Y	Y	Y
Sep-22	Pico	PICO 4 pro	8		Y	Y	Y
Sep-22	Pico	PICO 4	7		Y		
Jul-22	Skyworth	PANCAKE 1 Pro	6		Y	Y	Y
Jul-22	Skyworth	PANCAKE 1	4				
May-21	PICO	Neo 3	4	Y			
Sep-22	META	Quest 2	4	Y			

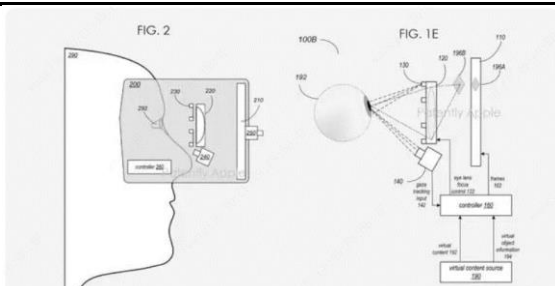
Source: Company, CMBIGM

**Fig.18: Major AR/VR players' acquisitions of eye-tracking technology companies**

Company	Year	Details
Apple	2017	<b>Acquired</b> SensoMotoric Instrument, a German eye-tracking technology company
Meta	2017	<b>Acquired</b> The Eye Tribe, a Denmark eye-tracking technology company Considered acquiring Adhawk, an eye-tracking technology startup
Google	2016	<b>Acquired</b> Eyefluence, a US eye-tracking technology company
Microsoft	2014	<b>Acquired</b> FOVE, a Japanese eye-tracking hardware/software startup

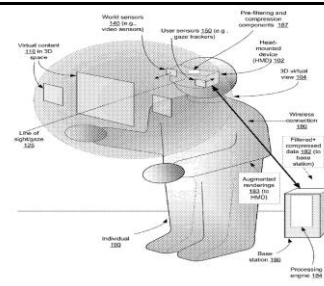
Source: Company, CMBIGM

**Fig.19: Apple's eye tracking patent**



Source: Patently Apple, CMBIGM

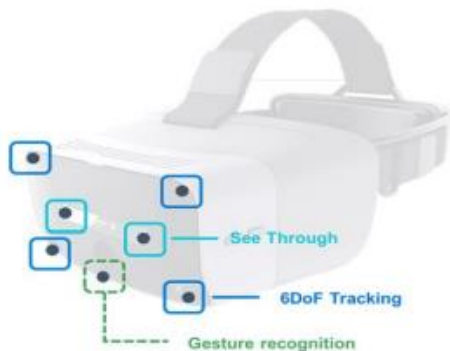
**Fig.20: Apple's gesture tracking patent**



Source: Patently Apple, CMBIGM

**8-15 camera/sensors to become mainstream spec.** We believe VR manufacturers will embed more built-in cameras to enhance immersive experience with advanced eye/gesture tracking technology. For instance, Pico Neo 3 and Meta Quest 2 launched in 2021/22 adopted 6DoF with 4 tracking cameras to achieve better perception interaction experience, while for the latest products launched in late 2022/2023 (e.g. Pico 4 Pro, Quest Pro), they are equipped with 8-10 cameras, including RGB VST cameras, IR cameras and 6DoF tracking cameras.

**Fig.21: Meta’s headset cameras for gesture tracking**



Source: Sunny Optical

**Fig.22: Meta’s headset cameras for gesture tracking**



Source: Meta, UploadVR

## Chipset: dual-chip design (SoC+ISP) to enhance computing power

**Apple’s self-developed dual-chip to boost computing power.** Apple has excellent track record to develop customized chips for new product categories, such as A-series chips for smartphones, W-series chips for watches, H-series chips for Airpods, and M-series chips for PCs. Given huge demand for computing power of MR devices, we believe Apple will develop a customized chip for MR (Staten), which is a modified version of M2 chip. In addition, we expect Apple to design a separate ISP chip (Bora) and a wireless chip (Golay) for MR devices, which are used for internal display and data transmission.

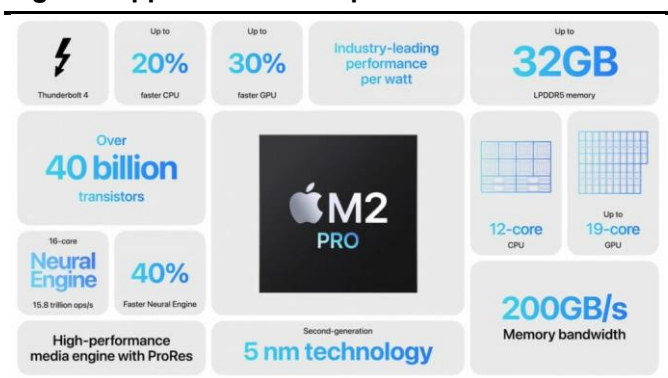
**Fig.23: Comparison of tracking features and cameras for major AR/VR products**

Categories	Chip	Launch Date	Device
Watch	W3	3Q18	Watch 4, Watch 5, Watch 6, Watch SE
Smart Home	S5	3Q19	HomePod Mini
TWS	H1	1Q19	AirPods (2nd Gen), Powerbeats Pro, Beats Solo Pro, AirPods Pro, Powerbeats (2020), AirPods Max
	H2	3Q22	AirPods Pro 2
Smartphone	A13 Bionic	3Q19	iPhone 11, iPhone 11 Pro/Max, iPhone SE (2 <sup>nd</sup> gen), iPad(9 <sup>th</sup> gen), Studio Display
	A14 Bionic	3Q20	iPhone 12, iPad Air (4 <sup>th</sup> gen), iPad (10 <sup>th</sup> gen)
	A15 Bionic	3Q21	iPhone 13 mini, iPhone 13, iPhone 13 Pro/Max, iPhone SE (3 <sup>rd</sup> gen), iPhone 14, iPhone 14 Plus, iPad mini (6 <sup>th</sup> gen)
	A16 Bionic	3Q22	iPhone14 Pro/Max
PC	M1	4Q20	iMac 2021, MacBook Air (M1, 2020), MacBook Pro (M1, 2020), Mac mini 2020, iPad Pro (2021) , iPad Air (5 <sup>th</sup> gen)
	M2	2Q22	MacBook Pro (M2, 2022), MacBook Air (M2, 2022), Mac mini 2023, iPad Pro (2022)

Source: Company, CMBIGM

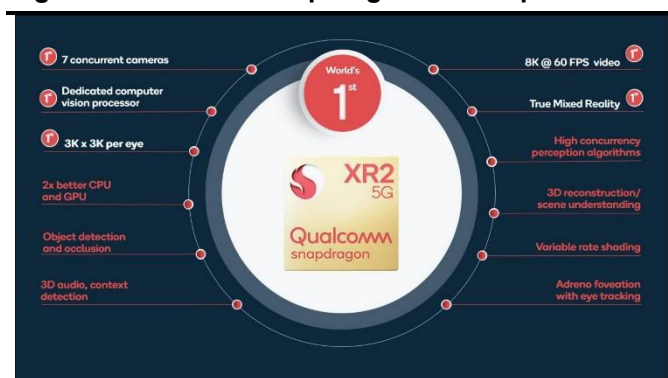
**Snapdragon XR2 is mainstream XR chipset.** Since launch in 2019, Qualcomm Snapdragon XR2 has been adopted by mainstream VR/AR products, such as Meta, Pico, and HTC. In Oct 2022, Qualcomm launched XR2+Gen 1 upgrade version, which achieved 50% increase in battery life and 30% increase in heat dissipation, as well as supporting head/gesture/controller tracking and low-latency VST. XR2+Gen1 is adopted by Quest Pro after launch, and we expect other high-end AR/VR products will follow.

**Fig.24: Apple’s M2 Pro chipset**



Source: Company, CMBIGM

**Fig.25: Qualcomm Snapdragon XR2 chipset**



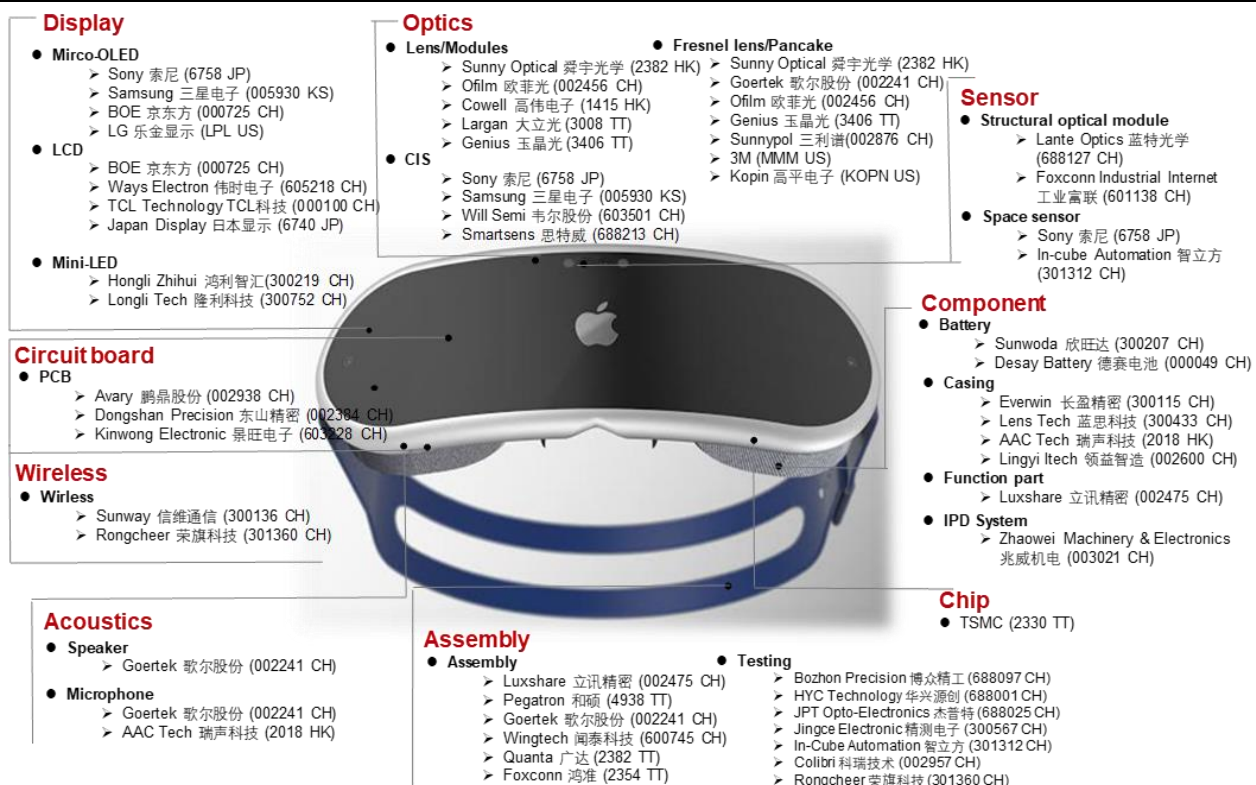
Source: Company, CMBIGM

## Who are best positioned in hardware/semiconductor?

We expect display, semis and memory to make up 50-60% of total BOM for AR/VR headset, and optical and camera/sensor are the key components in AR/VR experience. Below are the major beneficiaries in AR/VR hardware/semi supply chain.

- **Luxshare (002475 CH, BUY):** Luxshare is the major assembler of Apple's AirPods, and it is well-positioned for assembly of Apple MR products. Luxshare also invested in AR/VR industry, with 11% share in AR start-up company, XLONG Technology.
- **Cowell (1415 HK, NR):** Cowell is the major front-cam supplier for Apple's iPhone/iPad. Leveraging Luxshare's strong partnership with Apple, Cowell is well placed to supply camera modules for Apple MR headset in 2023E.
- **Everwin (300115 CH, NR):** Everwin is the casing supplier for Apple's MacBook/watch/iPhone. Everwin announced to raise new proceed of RMB2.2bn for AR/VR projects. We expect Everwin to secure orders in AR/VR structural components.
- **Zhaowei Electronics (003021 CH, NR):** Zhaowei is the domestic leader in IPD electric focus adjustment drive system, and we expect it to supply IPD adjustment components to Apple MR headset in 2023E.
- **Goertek (002241 CH, BUY):** Goertek is the major assembler for Meta/Pico's AR/VR products. It is the industry leader for key AR/VR technologies, including optical and acoustics components, which we expect to benefit from rapid growth in AR/VR industry.
- **Sunny Optical (2382 HK, HOLD):** Sunny Optical is a global leading optical company, and it currently provides optical lens (Fresnel, Pancake) for Meta/HTC AR/VR products. We expect it to continue to benefit from rapid growth of AR/VR industry.
- **Will Semi (603501 CH, HOLD):** Will Semi is the CIS supplier for Meta headset. Will Semi also bought Aurora and supplied LCoS displays to MagicLeap AR. We expect it will benefit from strong demand for camera/sensors in AR/VR devices.

Fig.26: Overview of VR/AR hardware supply chain



Source: CMBIGM

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