

Presented at:  
MEPTEC - IMAPS  
Semiconductor Industry Speaker Series  
July 15, 2020

# Market Growth Drivers: Key Developments in Advanced Packaging

- TRACK INNOVATION
- IDENTIFY TRENDS
- ANALYZE GROWTH
- INFLUENCE DECISIONS

RELEVANT, ACCURATE, TIMELY

**E. Jan Vardaman**  
**President and Founder**

# Economic Issues Resulting from Covid-19 Pandemic

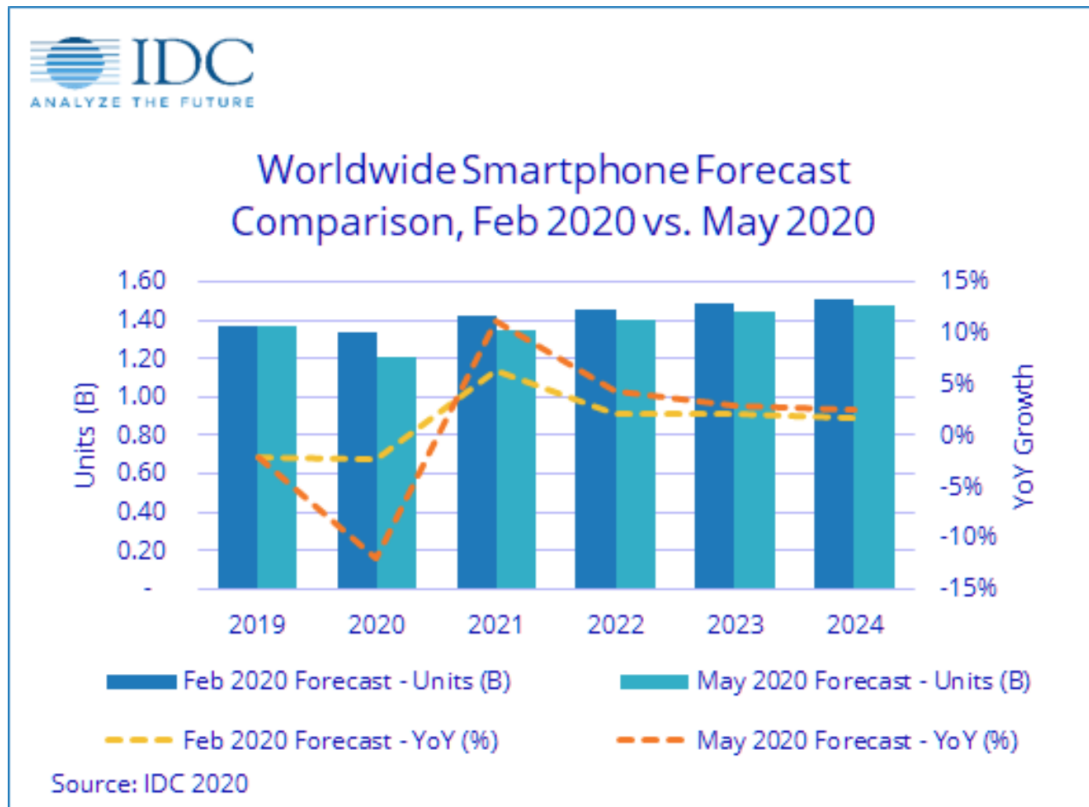
- **IMF is predicting a 4.9% decline in the global economy for 2020**
  - 90% of countries experiencing lower per capita income
  - Prolonged pandemic will worsen economic conditions
- **Countries around the globe increase spending to dampen negative impact**
  - U.S. spending \$3 trillion
  - Germany and France have proposed a \$545 billion in a recovery fund
  - China spending \$205 billion on projects (5G, rail, power grid)
- **Consumer purchases account for 70% of U.S. economic activity**
  - Impacts smartphone and consumer product sales
  - Some out-of-cycle purchases of laptops, tablets, and game systems



Source: Dreamstime.com

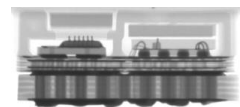
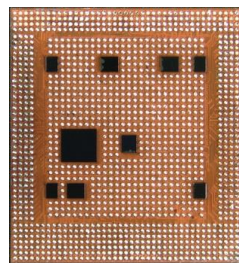
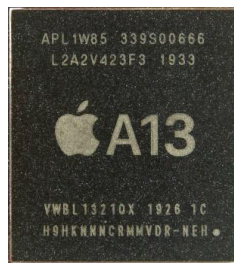
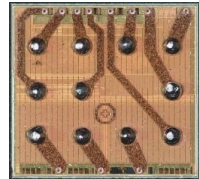
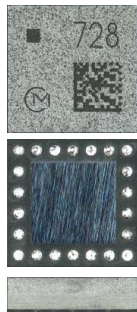
# Smartphone Sales Projected to Decline in 2020

- **IDC projects smartphone shipments will decline 11.9% this year, but return to growth in Q1 2021**
  - Huawei and Samsung seeing smartphone sales declines
  - China-based smartphone shipments were down ~26% in Q1 year-over-year
- **Impacts unit shipments for CSPs**



# Apple iPhone 11 Pro Max

- **123 packages on the board**
  - 89 WLPs (either on board or inside another package)
  - More WLPs than any other smartphone
  - Application processor in TSMC's InFO with memory package on top (InFO PoP)
  - Many packages are underfilled
- **>30 chip suppliers**



# 5G Still Key to Smartphone Sales

- **Qualcomm predicts 5G smartphone shipments of 175 to 225 million units in 2020**
  - Most will be sub-6 GHz
  - Apple is expected to launch 5G smartphone, but may have some delay
- **IDC projects 5G smartphones will account for ~28% of sales by 2023**
- **Drives CSP growth**
- **Drives WLP growth**



Source: Digitized.

# 5G Phone = Package Count Increase: RF, Baseband, WLPs



**S10 5G  
package area  
569 mm<sup>2</sup>**

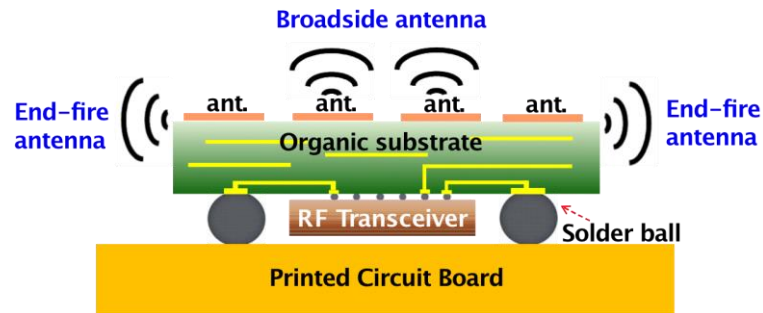
**S10  
package area  
383 mm<sup>2</sup>**

	S10 5G	S10/S10+
<b>Total WLP Count</b>	<b>41</b>	<b>33</b>

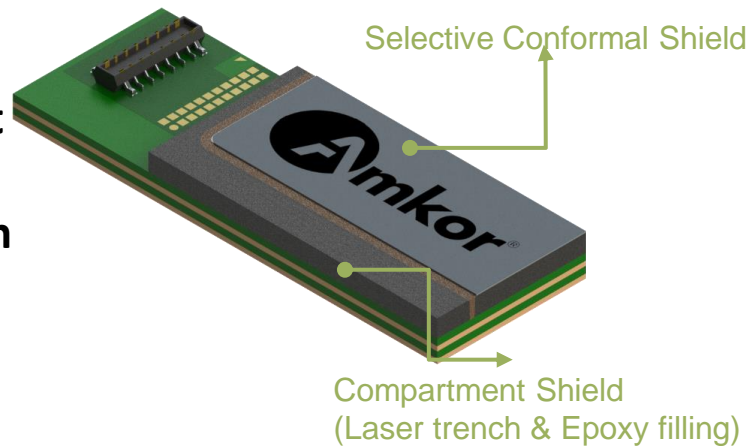
- **Compared to S10, the S10 5G has 1.8x more of RF/BB packages with 49% greater total package area**
  - 5G phones have stand alone baseband
- **More filters**
- **More WLPs**

# 5G mmWave = Changes in Package Design and Construction

- **5G potentially means new radios, new modems, new PA, and new FEM**
  - System-in-package designs with fully integrated antenna (so antenna design capabilities are important)
  - Thermal and electrical modeling become more critical
  - Electromagnetic compatibility and EMI shielding become more important
- **Antenna for sub-6 GHz can be on PCB, but mmWave needs RF IC closer to antenna, therefore antenna-in-package (AiP) design critical**



Source: ASE.



Source: Amkor Technology.

# 5G Infrastructure Rollout

- **5G infrastructure rollout**

- Expansion in China with up to 600,000 base stations to be installed this year (sub-6 GHz, mmWave in 2 years)
  - Drives demand for RF modules
  - System-in-Package
- China build 198,000 base stations nationwide by March 2020
- Rollout continues in U.S. (mmWave)
- Rollout in Europe slows (spectrum auctions delayed because of Covid-19)

- **Drives demand for complex SiPs**

- Laminate substrates with AiP



Source: techhq.com.

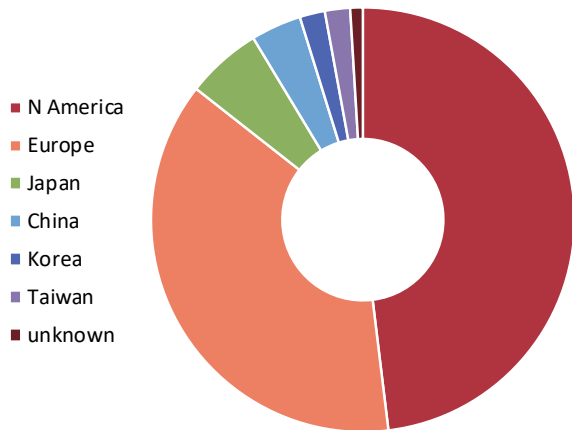


Source: JCET.

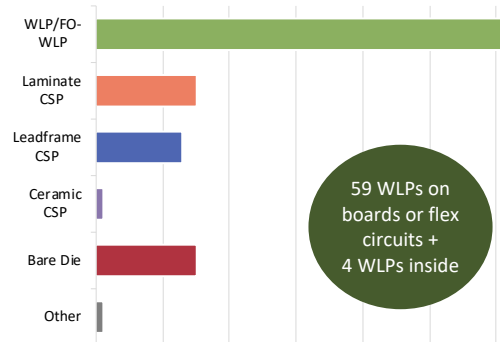


# Apple Watch Series 5 with LTE Teardown

## Package Quantity by Chip Supplier HQ Location



## Package Quantity by Package Type

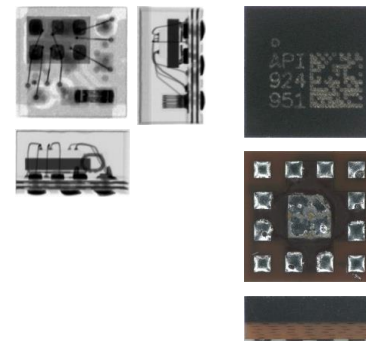
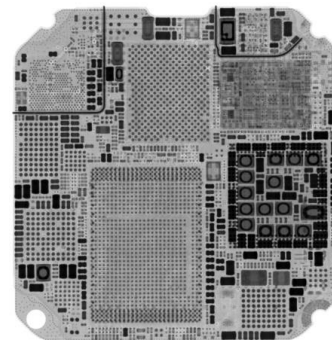


59 WLPs on boards or flex circuits + 4 WLPs inside



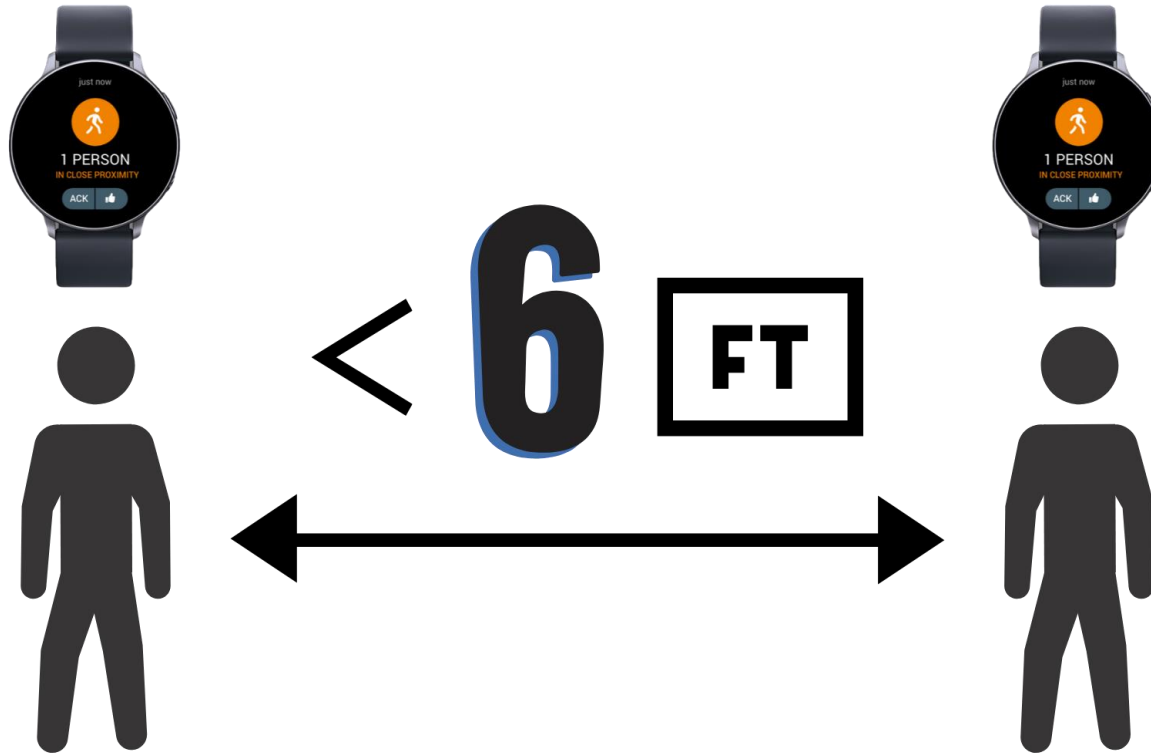
## Smartwatches

- 12% growth in Q1 year-over-year
- Apple Watch top sales (55% market share)
- **104 board-level packages (many WLPs)**
- **>25 chip suppliers**



Source: TechSearch International, Inc.

# Automated Social Distancing Management by Radiant



Source: Radiant.

- **Workers at Ford are using Samsung wrist device that vibrates with another devices is within 6 feet**
  - Uses Bluetooth and RFID application software developed by Radiant

# Increased Implementation of Telemedicine

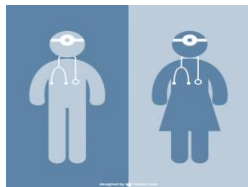


>6K

An estimated 6,146  
hospitals in USA in  
2020

>1M

Active Physicians  
in the USA



- Physicians across the U.S. tasked with launching telemedicine in MAR/APR and the market demographic is taking shape
- Key *influencers* for Telemedicine include hospitals, doctors, and American Medical Association
- Recent case study of two MDs uncovered need to immediately buy new laptops for compatibility plus Netgear Orbi System

## AMA

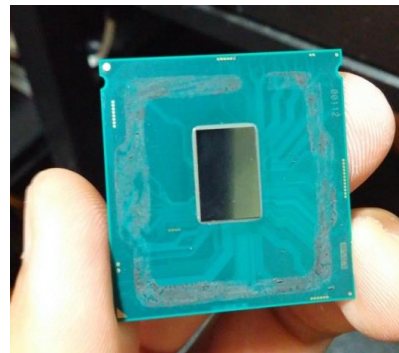
Telemedicine Requirements by AMA

- ✓ High Quality Video Streaming
- ✓ Uninterrupted Coverage
- ✓ Compatibility with E.H.S.
- ✓ Security Against Cyber Attacks

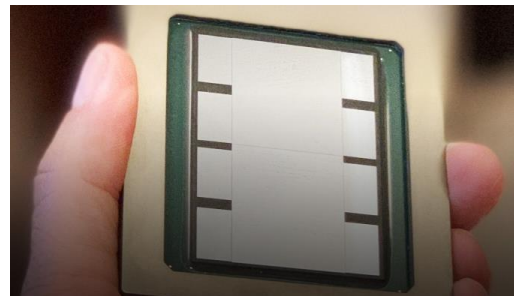
Netgear Orbi RBK50 System  
Using FBGAs, QFNs, WLPs

# Growth Areas Despite Covid-19

- **Increase in laptop and tablet sales driven by work from home and educational demand**
  - Out-of-cycle demand
  - Potential for increase demand as schools remain closed this fall
- **Increased use of Telemedicine**
- **Demand increasing for networking**
- **Datacenter and cloud computing expansion**
- **Server volumes increased in Q1, some increase in Q2**
  - Driving FC-BGA substrate capacity expansion
  - Drives demand for DIMMs
- **AI accelerator demand increasing**
  - TSMC reports CoWoS production line at full capacity for Q2 2020
  - Future designs with FO on substrate such as ASE's FOCoS, Amkor's Substrate-SWIFT®, and TSMC InFO\_MS



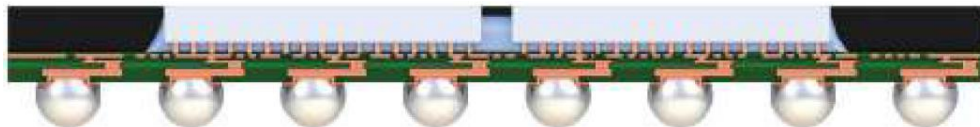
Source: Anandtech.com



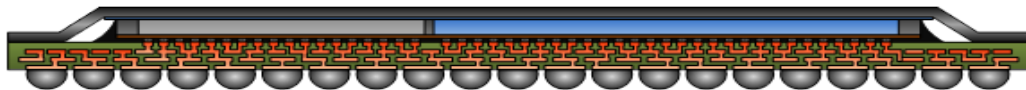
Source: TSMC.

# Fan-out on Substrate

- **ASE's Fan-Out Chip on Substrate (FOCoS)**
  - RDL with 2/2 $\mu$ m L/S
  - Up to 3 RDLs plus UBM
  - High I/O (>1,000)
  - Production with chip first since 2016 (Hi-Silicon Network Switch)
  - Chip last qualified
- **TSMC Integrated Fan-Out on Substrate (InFO\_oS) and InFO\_MS**
  - RDL with 2/2 $\mu$ m L/S
  - Up to 3 RDLs plus UBM
- **Amkor's Substrate Silicon Wafer Integrated Fan-out Technology (Substrate-SWIFT<sup>®</sup>)**
  - RDL with 2/2 $\mu$ m L/S
  - Up to 3 RDLs plus UBM



Source: Amkor.



FOCoS – Fan Out Chip on Substrate (FO FCBGA)

Source: ASE.

# TSMC's InFO\_oS: Homogeneous Integration



- **Homogeneous Integration (split die) for MediaTek**
  - 67.5 mm x 67.5 mm
  - Three RDLs
  - 2 $\mu$ m L/S
  - No  $\mu$ bump (uses C4 bump), no TSV
  - Cost is slightly less than using a Si interposer
  - Offers better electrical performance because RDLs instead of silicon (dielectric constant better with RDL than silicon)



# Growth in Datacenters and AI Accelerators

- **Datacenters, cloud computing, and AI accelerator growth drivers**
  - Large amounts of data such as commercialization of 5G services, smart factory (Industry 4.0)
  - Remote working and online meetings driving demand
  - Internet shopping malls and movie streaming services
  - IBM CEO says pandemic will dramatically accelerate adoption of AI and cloud computing
- **Major cloud computing service providers**
  - Amazon, Microsoft with Azure, Google, Facebook, Baidu, Alibaba, Tencent, ByteDance, and others



Source: Google.

# IC Package Substrate Expansion

- **IC substrate suppliers expanding capacity for build-up substrates**
  - Ajinomoto build-up material used exclusively, adding capacity
  - Servers and networking equipment driving demand
  - New GPU and CPU offerings
  - ABF substrates used with silicon interposers, FO on Substrate, and active silicon interposers
- **Larger body sizes and higher layer counts require increased capacity**
- **Substrate suppliers including Unimicron, Ibiden, Shinko Electronic, Kinsus, Nan Ya PCB increasing capacity**



Source: Intel.

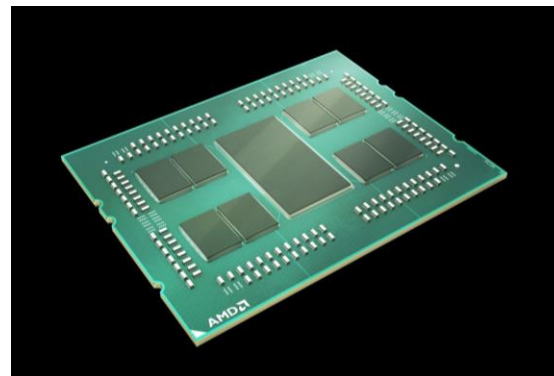


# Chiplets: Key Enabler for Next 10-20 Years

- **Chiplet demand driven by:**

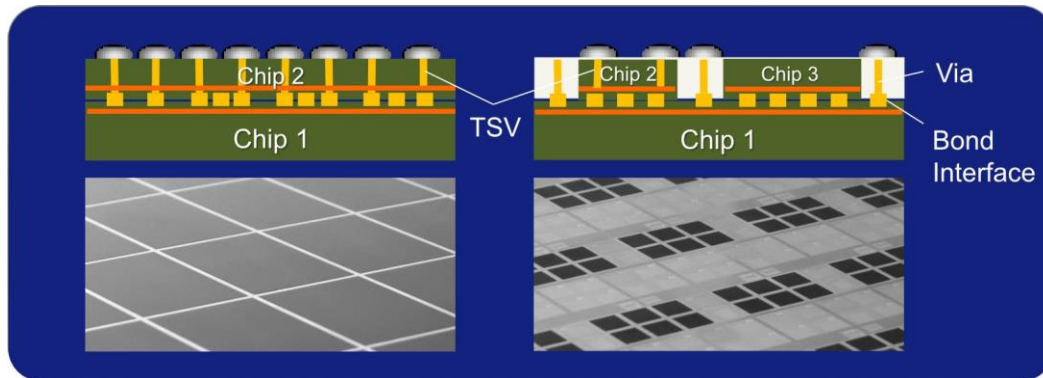
- Need for a more cost-effective solution given the economic challenging of continued silicon scaling
- Desire to reuse IP
- New test flows
- Improved electrical performance
- Reduced power consumption
- Faster time-to-market

AMD's Chiplet design  
on organic substrate



Source: Wired.com.

TSMC's SoIC  
Using active Si interposer



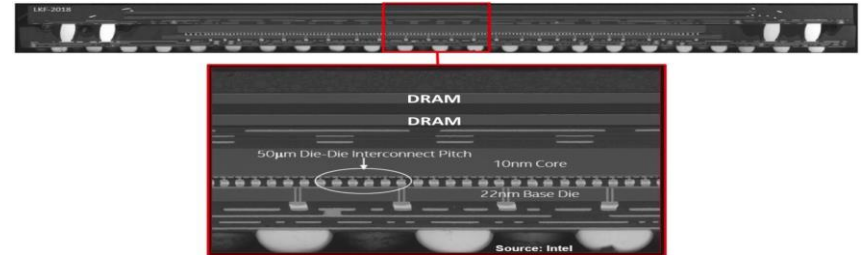
Source: TSMC.

# Intel's Foveros in Production

- **In production for Samsung's Galaxy Book 5**
  - Longer battery life
  - Very thin
  - No fan
- **Active interposers can include power management features, voltage regulators, DC/DC converters**
- **Benefits include**
  - Reduced voltage drop
  - Power efficiency
  - More immediate power delivery to the CPU cores
  - Elimination of passives on substrate
  - System-wide communication across multiple chiplets/dice vs. the limited die-to-die communication capability enabled by passive Si interposers

## Intel's Lakefield CPU

- 10nm CPU
- 22nm Active Si Interposer



Source: Intel.

# Summary

- **Continued growth in advanced packaging driven by many applications**
  - OSATs benefit from this growth
- **Consumer and smartphone expected to see negative impact in 2020 from pandemic-induced economic downturn**
  - Growth in smartphones, driven by 5G, expected to drive growth in 2021 and beyond
- **5G infrastructure expansion with drive growth, especially in China**
- **Growth in datacenters and cloud computing driving growth in servers and AI accelerators**
  - Drives growth in high-performance packaging
  - Drives growth for laminate substrates
  - Drives growth for memory

# Thank you!

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