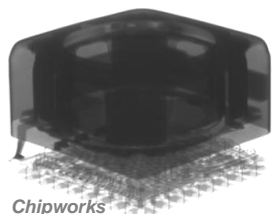


Report
SAMPLE

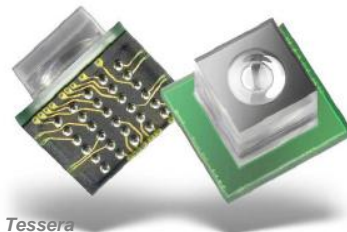
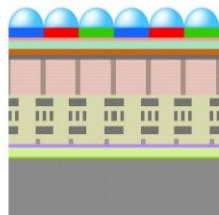
CMOS Image Sensors

Technologies & Markets - 2010 Report

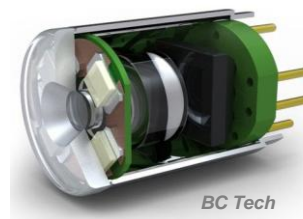
Disruptive technologies are paving the way
to the future of digital imaging industry !



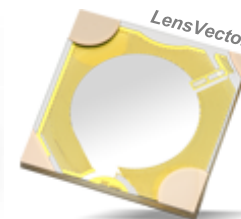
Chipworks



Tessera



BC Tech



LensVector



YOLE DÉVELOPPEMENT

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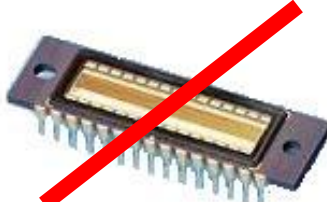
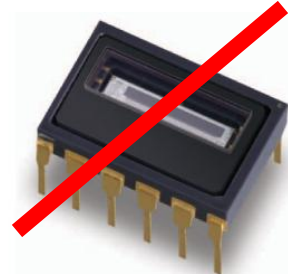
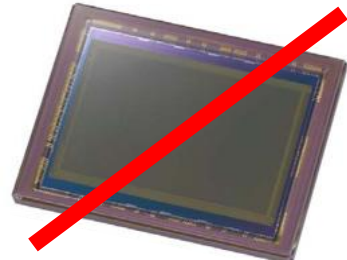
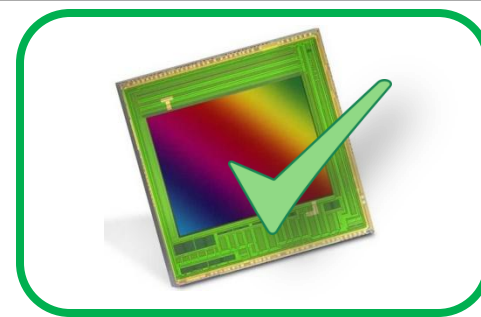
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Objectives of the Report

- This is the first report on CMOS image sensors technologies and markets from Yole Développement.
- As a market research company leader in MEMS & Sensors markets since 1998, it was a quite logical for our company to extend our investigations to the area of CMOS image sensors.
- The objectives of this first report are the followings:
 - To provide **market data on CIS key market metrics & dynamics**:
 - CMOS image sensor unit shipments, revenues and wafer production per application
 - Market shares with detailed breakdown for each player
 - Application focus on key areas of growth for CMOS image sensor (handsets, DSC/SLR, medical, automotive, security & surveillance, etc ...)
 - To provide **key technical insight about future technology trends & challenges**:
 - From BSI (Backside illuminated sensor) and other front-end technologies evolution (Pixel isolation, color filters, micro-lenses...) to WLC (Wafer Level Cameras) realization with wafer level optics, Packaging / Assembly & Test (Wafer Level Packaging and 3D TSV interconnects), WDR (Wide dynamic Range) sensor technologies, Image stabilization & Auto-focus technologies (eDoF, Piezo, other mechanical AF, MEMS based or liquid lenses)
 - To provide a deep understanding of **CIS value chain, infrastructure & players**:
 - Who are the CMOS image sensor players (IDMs, foundries, design houses) and how are they related?
 - What are the key suppliers and emerging infrastructure for BSI, Wafer Level Cameras, and future optical camera module technologies?

Scope of the Study

- There are various kind of image sensors:
 - CMOS versus CCD image sensors. Array versus Linear image sensors.

	CCD image sensors	CMOS image sensors
<u>Linear</u> image sensors		
<u>Array</u> image sensors		

→ Through this report, we will primarily focus on Array type of CMOS image sensors

Who Should be Interested in this Report?

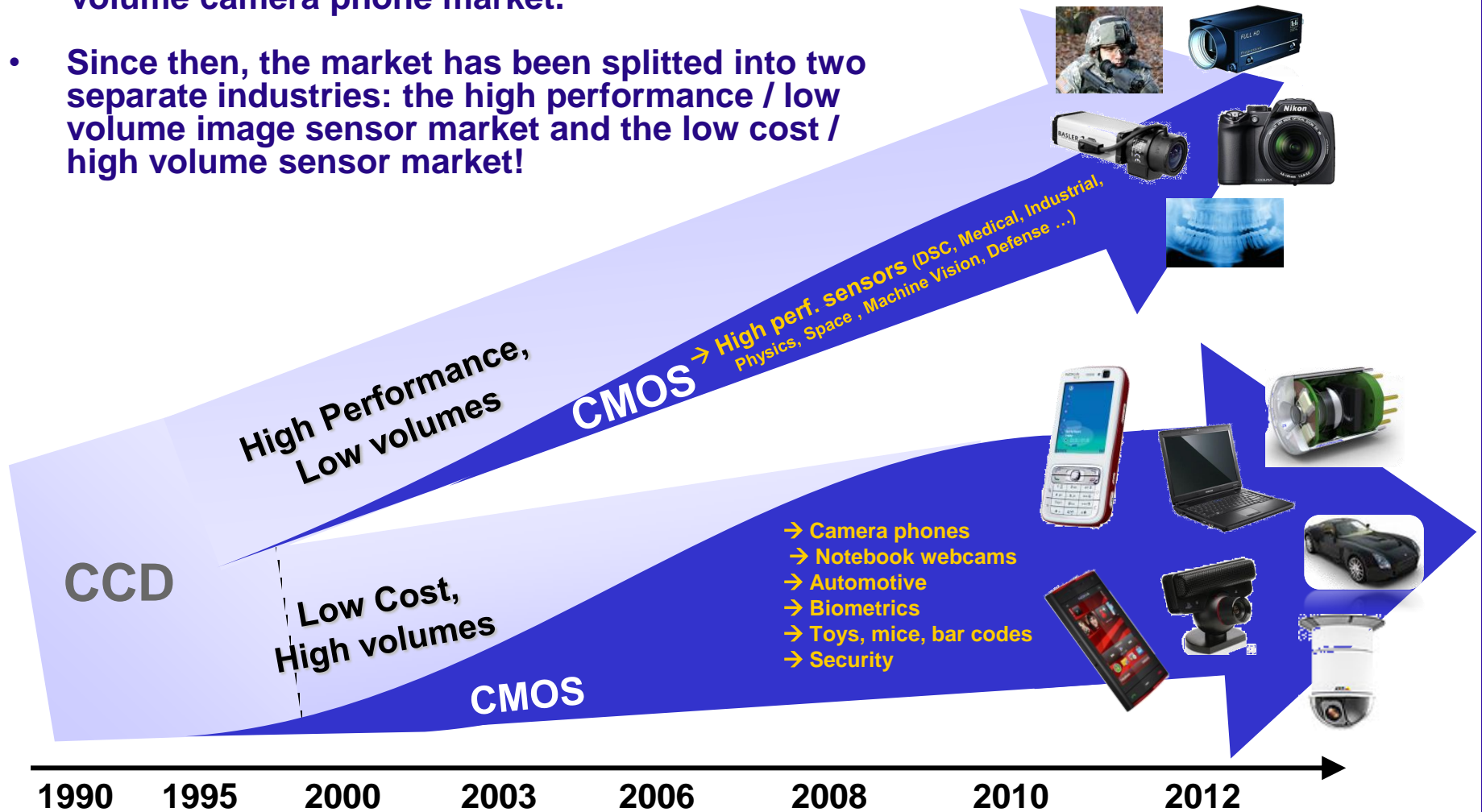
- **CMOS image sensor manufacturers:**
 - Evaluate market potential of future technologies and products for new applicative markets
 - Screen potential new suppliers for introducing new disruptive technologies such as BSI, new pixel architectures, Wafer level camera, Auto-focus & image stabilization for camera modules
 - Monitor and benchmark your competitor's advancements
- **CMOS & Packaging Foundries:**
 - Spot new opportunities and define diversification strategies
 - Position your company in the moving CMOS imaging value
- **Assembly & Test Service companies:**
 - Get the list of the Top CMOS image sensor players
 - Understand the impact of new optical assembly technologies such as wafer level cameras for your business
- **Equipment & Material manufacturers:**
 - Understand the evolution of image sensor and camera module value chain
 - Understand the differentiated value of your products and technologies in this market
 - Identify new business opportunities and prospects
- **Electronic module makers & Original Equipment Makers:**
 - Evaluate the benefits of using these new technologies in your end system
 - Screen and select new image sensor suppliers
- **Financial & strategic investors:**
 - Understand the potential of new imaging technologies such as BSI, WLOptics and Auto-focus
 - Get the list of main key players and emerging start-ups of this industry

Companies cited in this Report

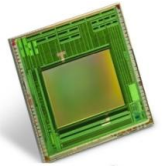
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Image sensors Technology Migration

- Image sensors have done a long way since the first introduction of CCD sensor technology in the 1990's. They have done a big jump since the 2000's with the introduction of CMOS sensor technology which gave birth to the low-cost, high volume camera phone market.
- Since then, the market has been splitted into two separate industries: the high performance / low volume image sensor market and the low cost / high volume sensor market!



CMOS image sensors Applications Window



Macro-economic views on imaging industry evolution (1/3)

- Image sensor are today part of our everyday's life: from cell-phone cameras, to notebook webcams, digital cameras, video camcorders to security & surveillance systems. In the future, new markets are also emerging such as sensors for medical applications, automotive security features but also gaming and home TV webcams ...
- The reason why we decided to release our first report on CMOS image sensor industry is that we feel that we are at an historical key turning point of this young but yet maturing industry:
 1. We expect that overall imaging revenues (CMOS + CCD array sensors) are set to moderately grow at a CAGR of 5% within the next 5 coming years. However, if CCD image sensor sales are set to decrease with time, this is not the case of CMOS image sensors as we forecast CIS sales to grow at a **CAGR of 11% from 2010 to 2015**. Actually, CMOS image sensors already surpassed CCD sensor revenues in 2007 and this trend will be even accelerated with the emergence of a wider 300mm CIS infrastructure in Asia and the introduction of future CMOS BSI (Backside illumination) technology.
 2. On the “high-end side” of the image sensor market, we are currently assisting to a **real convergence** of different consumer imaging products: Digital cameras are on the way to get real HD video camcorders features. With auto-focus capability, camera cell-phones are on the way to get real digital still camera features along with basic video recording functionality... This digital imaging convergence is actually bringing into the same battlefield image sensor players from very different backgrounds: On one hand the Omnivision, Aptina imaging, STMicro and Toshiba's coming from the low-end camera phone sensor industry and on the other hand the high-end image sensor suppliers such as Sony, Canon, Panasonic and Samsung who are coming from the traditional CCD imaging business but who are now heavily investing in CMOS technology... It is hard to bet on whom will best succeed in the long run as

Macro-economic views on imaging industry evolution (2/3)

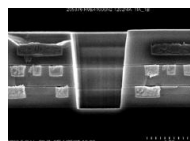
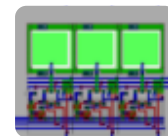
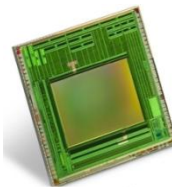
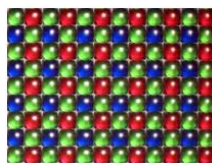
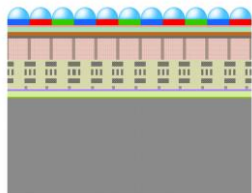
both of these players bring very different imaging expertise: the first ones are coming with strong advantage in low manufacturing cost while the others are the true historical experts in digital sensor and optical imaging performance.

3. Meanwhile, on the “low-end” side of the image sensor market, companies find it **harder and harder to get a profitable business** out of low resolution CMOS image sensors (from VGA to 3MPixels resolutions). To tackle this cost challenge, most low-end CIS sensor suppliers are today in the quest of developing the **Wafer Level Camera (WLC)** approach, in order to be able to sustain their margins in such ultra cost competitive space! Indeed, demand for low-end but ‘still with reasonable imaging performance’ cameras is really strong: in India for example, the camera sensor is now one of the most wanted feature in a cell-phone as a big proportion of the population can now afford to acquire a camera phone at a reasonable cost although not ready to pay for an extra digital still camera product for just shooting pictures and recording videos. Therefore, we believe that the wafer level camera approach complemented with digital zoom and auto-focus capabilities like **eDoF (Extended Depth of Focus)** or **Wafer Level Auto-focus technologies** will enable a true digital imaging and video experience in the low-cost but yet high volume low-end market segment. We are expecting a really aggressive competition on cost in this low-end image sensor space, and we believe that main protagonists are likely to be CMOS image sensor leaders Omnivision, STMicro, Toshiba and Samsung but also emerging CIS companies such as Korea’s SETi, Hynix, SiliconFile and Taiwanese’s Pixart, Himax Imaging or even Chinese’s Rui-Xin & GalaxyCore ...
4. Last but not least, one should not forget that while much things are happening in the low cost, high volume image sensor market, numerous opportunities are still to be caught in the lower volume but higher end market space: indeed, we do forecast strong adoptions of CMOS image sensors in **medical applications** especially (mainly driven by disposable endoscopy, medical pills, intra-oral and X-Ray imaging products). Another key area of developpement in the **automotive and transportation** area are CMOS image sensors with High dynamic range (HDR) and near infra-red (NIR) capabilities for vision assistance and safety features.

Macro-economic views on imaging industry evolution (3/3)

- Image sensor have done a long way since the first introduction of CCD sensor technology in the 1990's.
- They have done a big jump since the 2000's with the introduction of CMOS sensor technology which gave birth to the low-cost, high volume camera phone market.
- Since then, the market has been splitted into two separate industries: the high performance / low volume image sensor market on one hand and the low cost / high volume sensor market on the other hand.
- From 2010 to 2020, time has come that these markets now start converging! And as these markets will progressively converge, key enabling technologies are paving the way to the future growth of digital imaging industry, namely:
 - **CMOS sensor** technology will continue to expand and finally take the advantage on the remaining CCD application space as soon as 300mm infrastructure will build-up in Asia and BSI CMOS technology will be available.
 - In the high-end camera phone market segment, disruptive new camera module concepts including thinner **Auto-focus**, **Zoom** and **Image stabilization** features will be developed and introduced to the market.
 - In the ultra-competitive low-end market, the race toward **Wafer Level Cameras**, low cost **autofocus** and **digital zoom** features will enable the few remaining players to preserve their margins in this aggressive and cost driven market.
 - Future CIS markets such as medical and automotive sensor applications will re-use extensively all these newly developed concepts (BSI, WLCamera, digital zoom) plus will need new vision features to be developed such as **High Dynamic Range** & **NIR** capability.

CMOS Image Sensors Technology Drivers: New Challenges to Face !



- **BSI** (*Backside illumination*)
- **New color filters, AR coatings**
- **Pixel isolation, substrate techno**

- **HDR** (*High Dynamic Range*)
- **eDoF** (*Extended Depth of Focus*)
- **NIR** (*Near IR Capability*)



Front-end

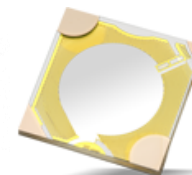
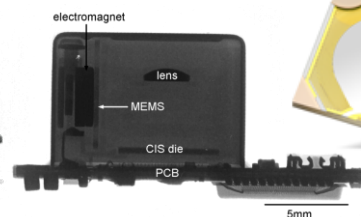
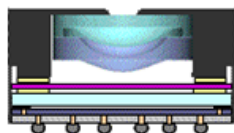
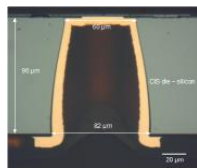
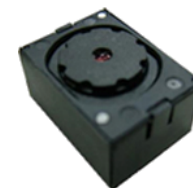
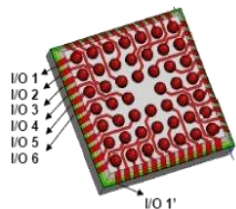
Software / Design

Packaging / Assembly

Optical module

- **WLP** (*Wafer Level packaging*)
- **3D TSV interconnects**
- **Wafer Level Camera & Molding**

- **WLO** (*Wafer Level Optics*)
- **Image stabilization** (*MEMS inertial...*)
- **Auto-focus** (*VCM, Liquid crystal, MEMS...*)



BSI product commercialization as of Q1-2010

→ In the “**Low-end**” camera cell-phone market, BSI will hit the mainstream from 1.1µm pixel generations

→ In the “**High-end**” market, BSI is accelerating CMOS image sensors penetration into traditionally served CCD markets!

Cell-phones cameras

Expected in 2010 !

D-SLR cameras



DSC cameras

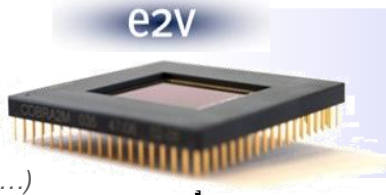


Video camcorder



High-end Professional Imaging

(Machine vision, Science, CMOS X-Ray ...)



2008

2009

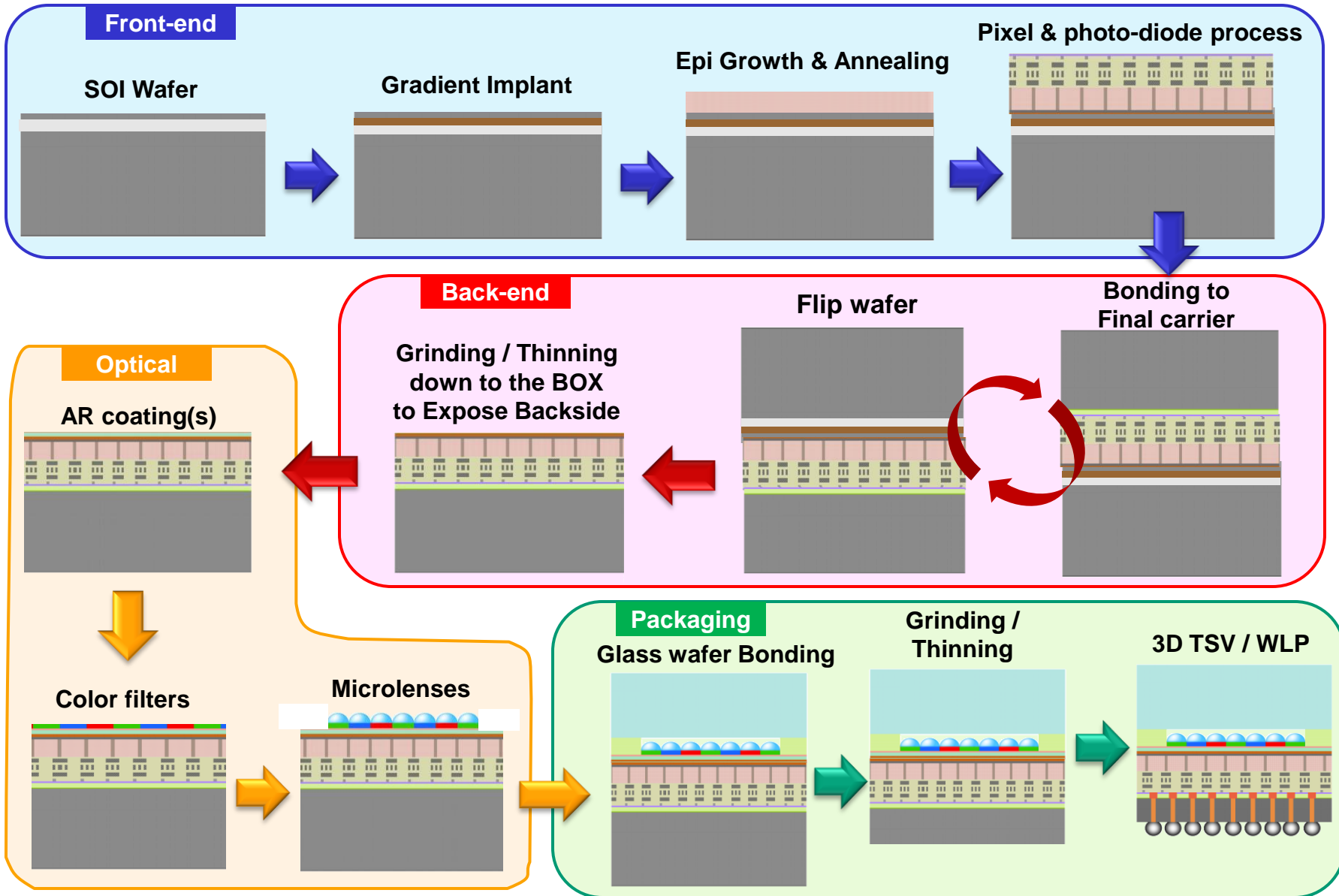
2010

2011

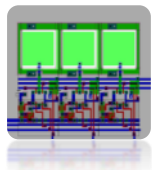
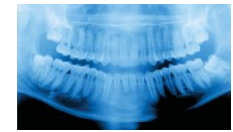
2010: Year of the CMOS BSI sensor wave?

- Recent announcements in the digital imaging area clearly show that CMOS image sensors are on the verge of making another giant step in technology this year. And Japanese imaging companies seem to be leading the way in this area!
- Indeed, Sony made the first step last year by introducing its CMOS BSI sensor technology. The Japanese electronics giant is now mass producing the CMOS BSI sensor in its newest video camcorders and digital still cameras. But Sony is not an isolated case as in early January, many other announcements have followed and not only Casio but also Nikon, Ricoh, Samsung, JVC and Fujifilm all separately announced their first digital camera products using a CMOS sensor... based on BSI “Backside illumination” technology!
- So, a lot of interesting announcement in the high-end imaging market have happened early this year. But the low-end image sensor market will not stand by and watch as we believe that CMOS BSI technology will also appear into different smart-phone camera products later this year. Omnivision is ready and currently sampling its second generation BSI image sensor. Aptina Imaging, Toshiba, Samsung and STMicro are also in the starting-blocks!

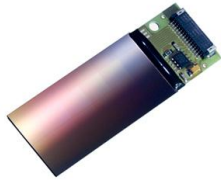
Example of CMOS BSI "SOI" Process flow scenario



CIS Supply Chain in Medical Applications



Design



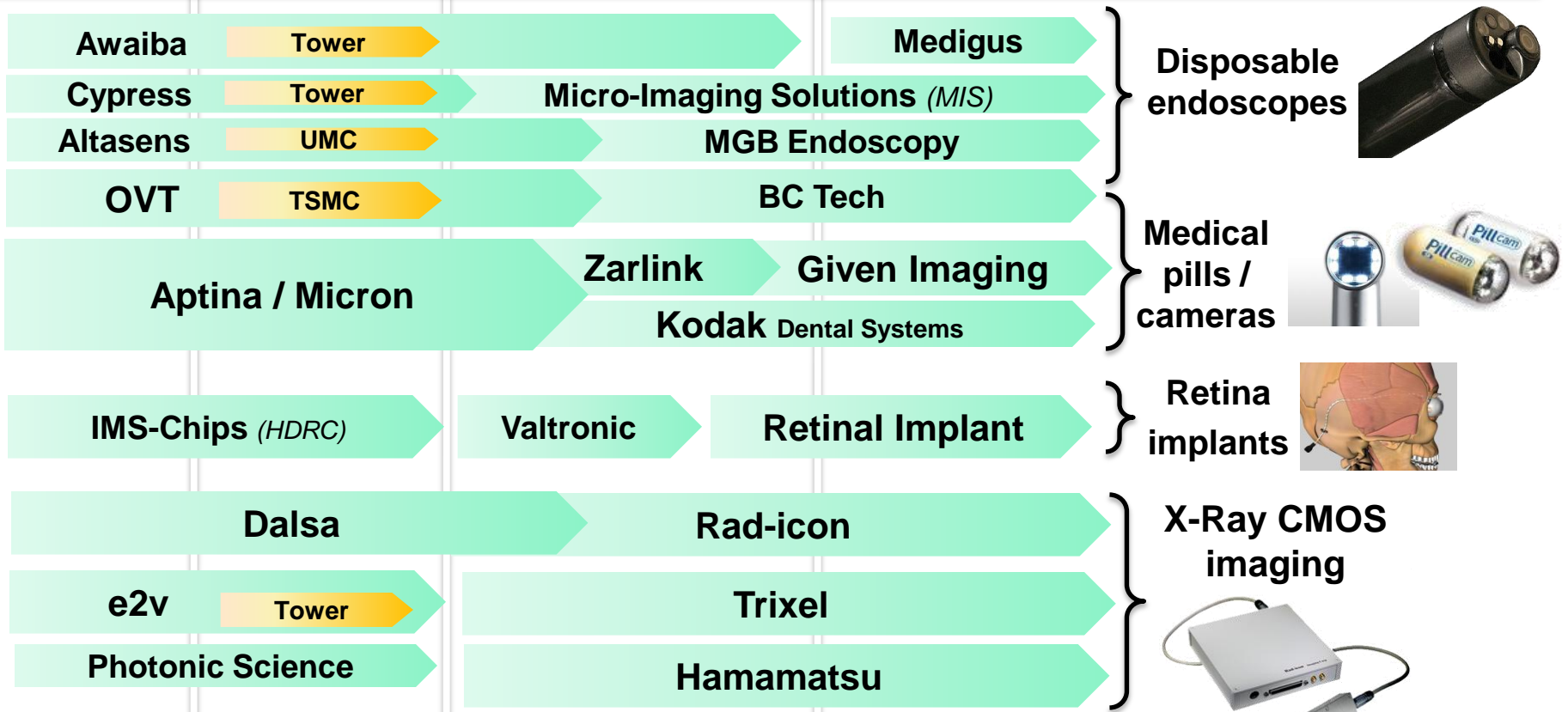
CMOS Sensor



Sensor Module & Assembly



Medical Systems & Subsystems



Legend: Outsourced

Penetration of secondary front cameras in handset for video-call feature

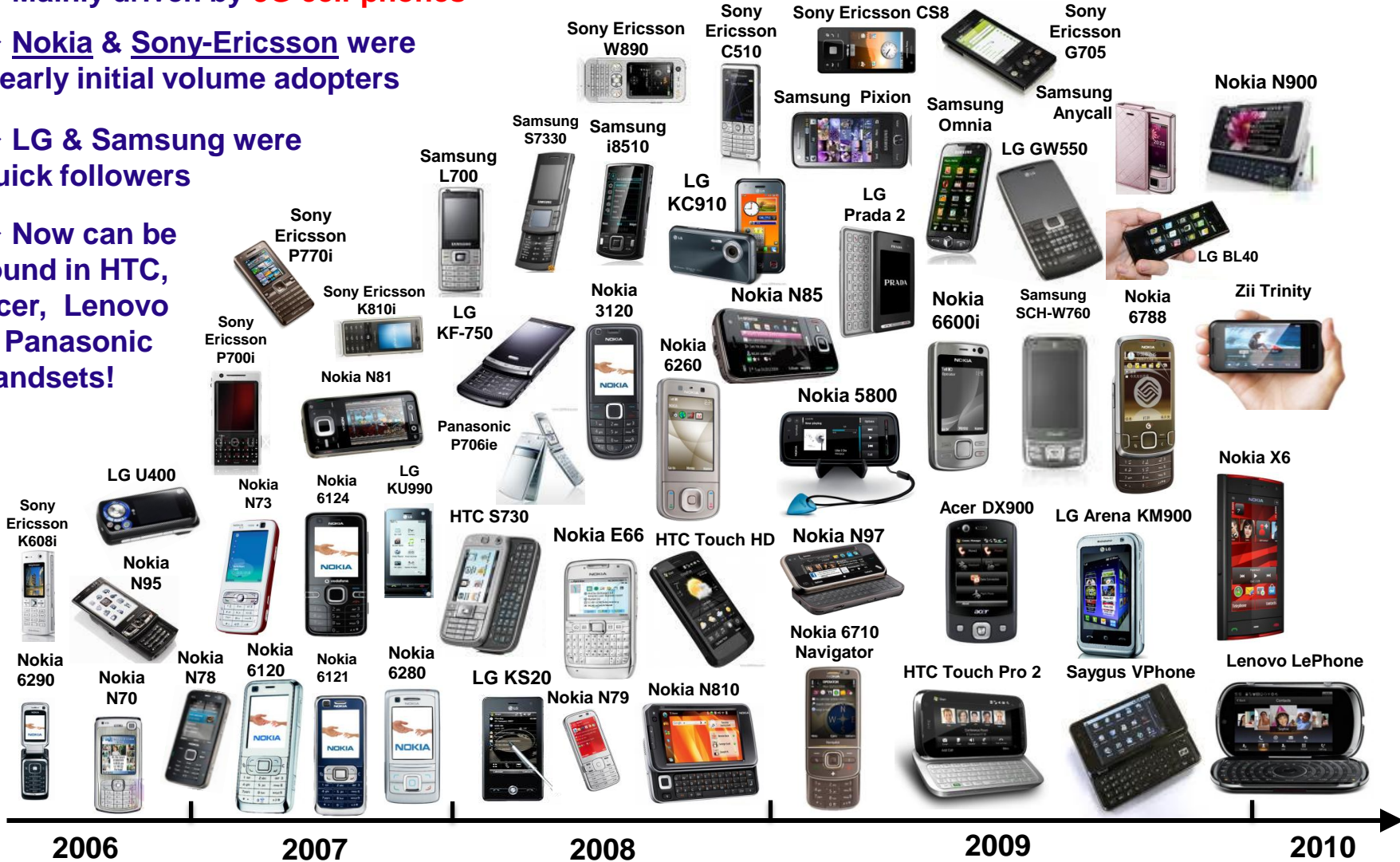


→ Mainly driven by **3G cell-phones**

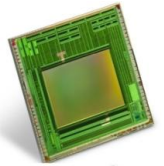
→ Nokia & Sony-Ericsson were clearly initial volume adopters

→ LG & Samsung were quick followers

→ Now can be found in HTC, Acer, Lenovo & Panasonic handsets!



CMOS image sensors Revenues - 2009 Market Shares

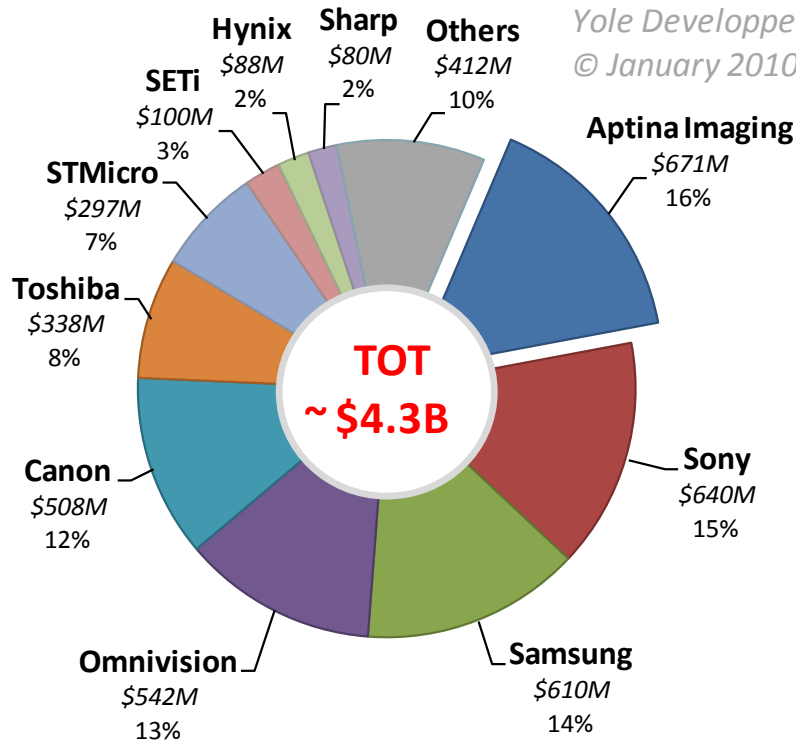


CMOS image sensors Revenues

- 2009 Market Shares -

(Based on estimated business value of 'first-level-packaged' CIS sensors)

Yole Développement
© January 2010



* **Others include** Cypress, Kodak, Pixart, SiliconFile, PixelPlus, GalaxyCore, Melexis, Himax Imaging, Panasonic, NIT, CMOSIS, Forza Silicon, e2v, Awaiba, SuperPix, Canesta, ViTi, Foveon, KunShan RuiXin Micro, Crysview, AnaFocus, Altasens, Novatek, Pixim and Dalsa

CMOS Image Sensors Revenues:
2009 Market Shares (\$M)

Company	2009	share
1 Aptina Imaging	\$671	16%
2 Sony	\$640	15%
3 Samsung	\$610	14%
4 Omnivision	\$542	13%
5 Canon	\$508	12%
6 Toshiba	\$338	8%
7 STMicro	\$297	7%
8 SETi	\$100	2%
9 Hynix	\$88	2%
10 Sharp	\$80	2%
Others	\$412	10%
TOT	\$4 287	

- **Sony** has grown fast, mainly thanks to the success of the introduction of its **BSI CMOS** sensor in the camcorders and DSC / SLR camera's space along with its high-end mobile camera module activity
- **Samsung** is also growing, both in the low-end and high-end CMOS image sensor space
- **Canon** pioneered in the introduction of CMOS sensor technology in its high-end DSC / SLR and video camcorder cameras product line

Some more slides extracted from the Report ...

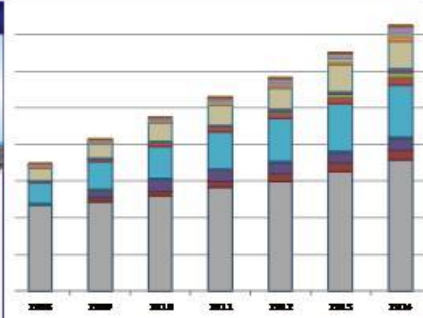
CMOS image sensors manufacturing 2009 wafer fab production estimate (8" wspy eq.)



CIS wafer production Forecast by Application (in 8" wspy eq.)

CIS wafer production Forecast by Application (in 8" wspy eq.)

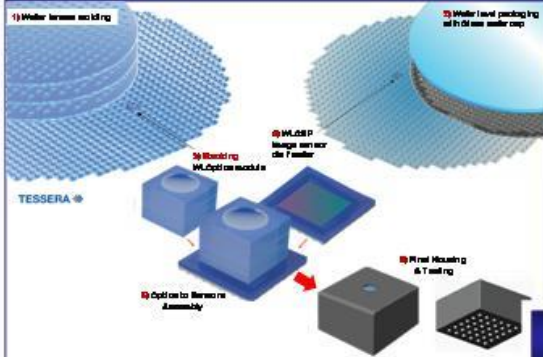
From: Technology Research & Advisory, 2009



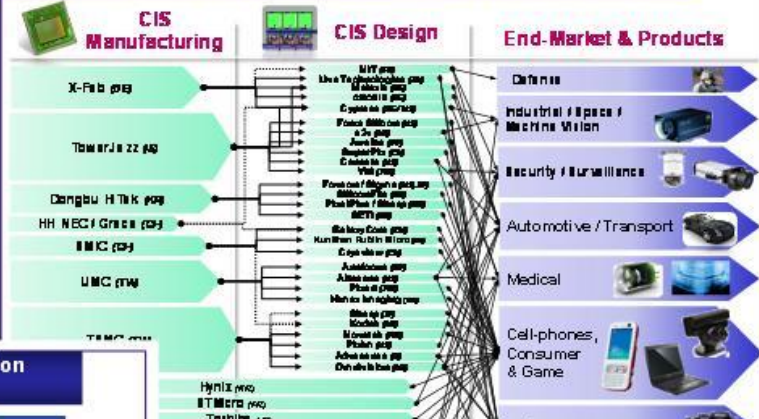
CMOS image sensor Players Roadmap for BSI



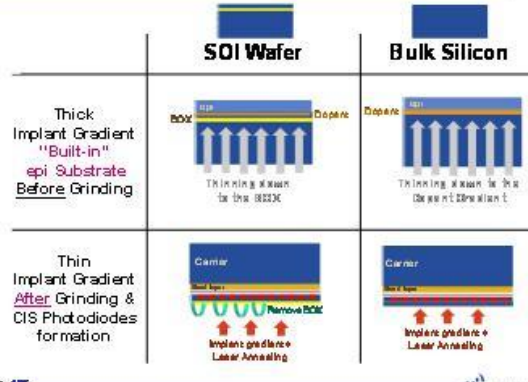
WL Camera module assembly steps



Global CMOS image sensor Value Chain (2010, Non Exhaustive)



BSI: Dopant Gradient process integration Scenarios



Leading WLOptics technologies Provider

	anteryon	HEPIALON	TESSERA
Local facilities	Heterland	HQ: Milan / Friend Manufacturing Singapore	North America (Chesham)
Available products	Ball mount WLOptical Modules	Ball mount WLOptics	WLOptics, Lenses IP + Base plating (in low volumes before production ramp)
Current available glass thickness	~ 0.284 Wafer scale lenses, up to 0.356	~ 0.284 Wafer scale lenses, up to 0.356	~ 0.18 Wafer scale lenses, up to 0.356
Current available glass thickness	Round 91mm in 2008	Round 93mm in 2008	N/A
Major customers / Partners	Toyota, Eltron, Matsushita...	BMW, Aptina Imaging?	See Sony, Toshiba?
Technology	Molded Polymer on Glass + epi + final over mold	Molded Polymer on Glass + epi + epi	Molded Polymer on Glass + epi + epi
Photo	Technology based on optical inspection of infrastructure readiness	Technology based on optical inspection of infrastructure readiness	Total WLOptics solution (MVT, WLOptics + MCP)
Cost	After dramatic technology, available	After dramatic technology, available	Lenses less cost, Wafer substrate expensive, Wafer infrastructure

Overview of cameraphone Auto-Focus technologies

- VCM solution is challenged by emerging technologies for new generations of camera modules
- Emerging applications such as liquid lenses, electro polymer, SMA, MEMS technologies show attractive specifications
 - But while some developments have reached market introduction stage, other still have to demonstrate their reliability and manufacturability

	VCM	Piezo AF	MEMS AF	Liquid Lenses	EDOF	WL Auto-Focus
Size / Thickness	-	+++	+	-	+++	+++
Shock resistance / Lifetime	+	+++	++	-	+++	++
Cost	+	++	+	-	+++	++
Image quality / Resolution	+++	+++	+++	+++	-	++
Power consumption	-	+	+	+++	++	++
Speed	+	+ / +++	++	+++	- / +++	++
Potential for integration	-	+ / +++	+++	+	+++	+++

About the Authors of this Report

- **Laurent Robin:**

- Laurent is in charge of the MEMS & Sensors market research at Yole Développement. He previously worked at image sensor company e2v Technologies (*Grenoble, France*). He holds a Physics Engineering degree from the National Institute of Applied Sciences in Toulouse, plus a Master Degree in Technology & Innovation Management from EM Lyon Business School, France

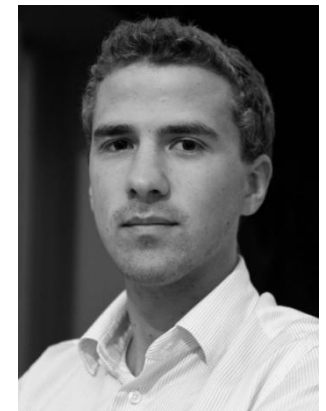
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- **Jerome Baron:**

- Jerome is leading the MEMS & Advanced Packaging market research at Yole Développement. He has been involved in the analysis of the CMOS image sensor industry at the sensor, packaging, assembly & test levels. He is also involved in the research linked to new equipment and materials for image sensor manufacturing. He was granted a Master of Science degree in Nanotechnologies from the National Institute of Applied Sciences in Lyon, France

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