Trend on Camera Module Technology for Mobile Phone

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Trend in Camera Module Technology for Mobile Phone

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Samsung Electronics, Telecommunication R&D Center

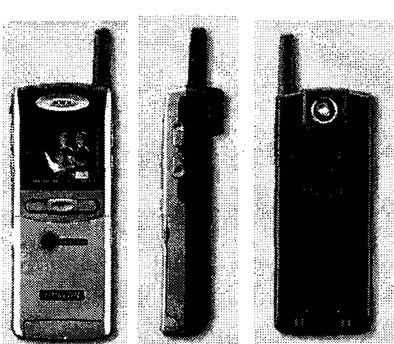
Yoon, Young-Kwon

Contents

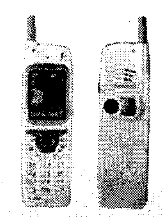
- Introduction to Camera Module for Mobile Application
- Market Trend on Camera Module
- Technical Trend on Camera Module

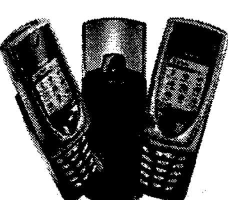
First Camera Phone

Model	Samsung, SCH-V200
When	2000, July
Pixels	350k total/ 30k effective (640 X 480)
Memory	~ 800KB



J-phone
SH04(Sharp)
2000.11
110k pixel





Nokia 7650
2002.04,
300k pixel

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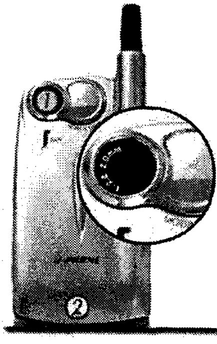
2/35

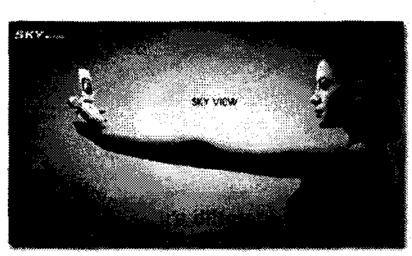
Popularization of Camera Phone

➢ In Japan



J-phone
SH07(Sharp)
2000.11
300k/month

➢ In Korea



SK Teletech, SKY VIEW (IM-3100)
2001.8

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3/35

Camera Phone Penetration

- **Camera Phone Penetration Rate Increase Rapidly**
  - 48% in 2005 => 75% in 2010 : world wide
  - 95% in 2005 : Japan

WORLDWIDE MOBILE PHONE MARKET
Camera Phone Penetration

Units (M)
Percent Penetration

Penetration in Japan

March '03	March '04	October '05
59%	89%	95%

Total Mobile Phones
Camera Phone Penetration
Camera Phones
Digital Still Camera

1,200 1,000 800 600 400 200 0
80% 70% 60% 50% 40% 30% 20% 10% 0%
2002 2003 2004 2005 2006 2007 2008 2009 2010

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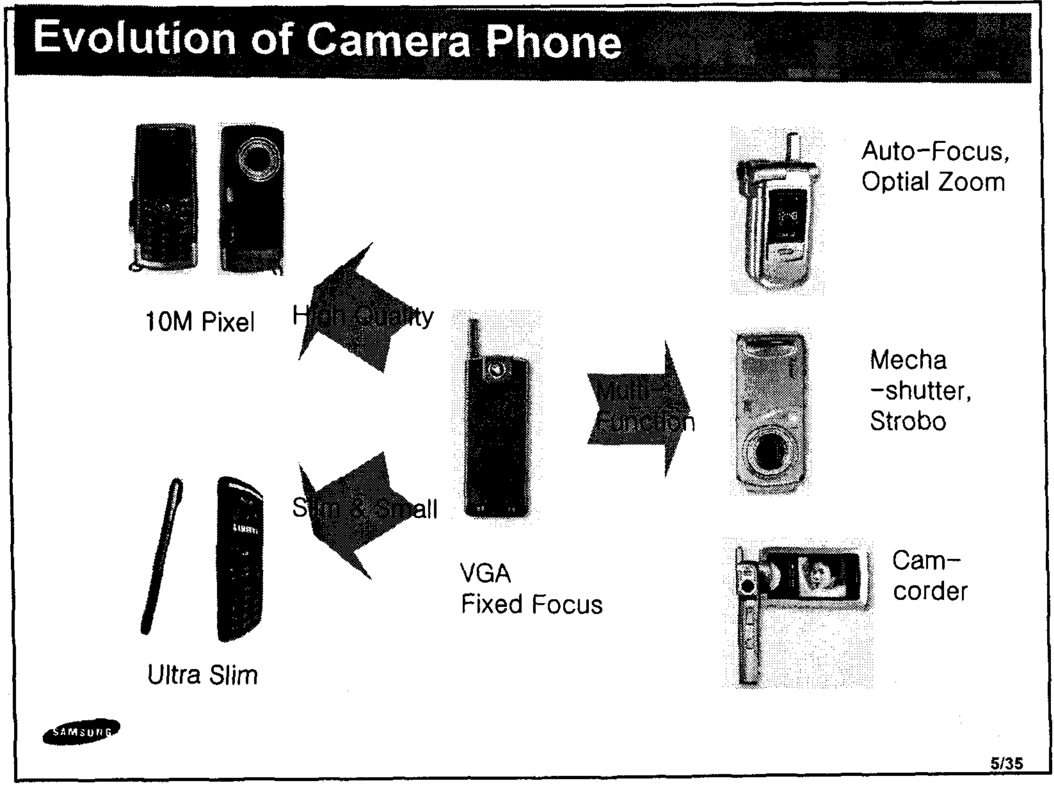
4/35

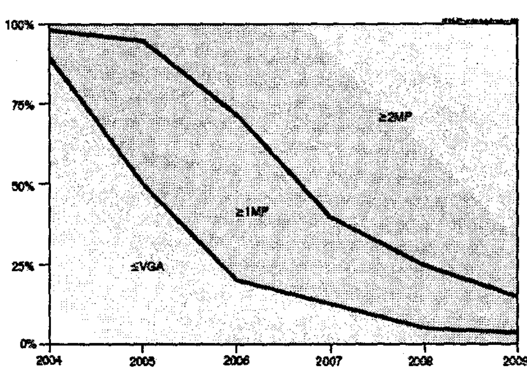


Market Trend 1/3: Number of Pixel

❑ Mega Pixel Camera Phone Becomes Popular

- 50% VGA and 5% ≥ 2M in 2005
  => 5% VGA and 80% ≥ 2M in 2009

CAMERA PHONE IMAGE ARRAY SIZE



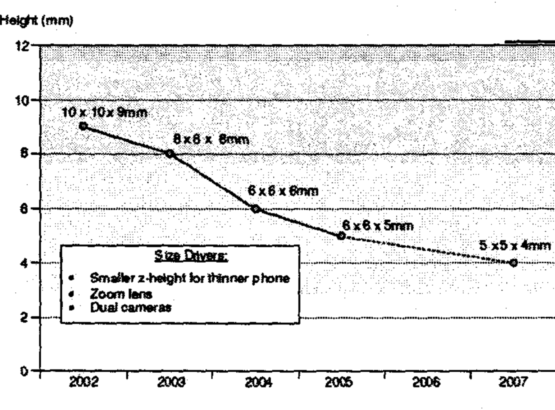
6/35

Market Trend 2/3: Size

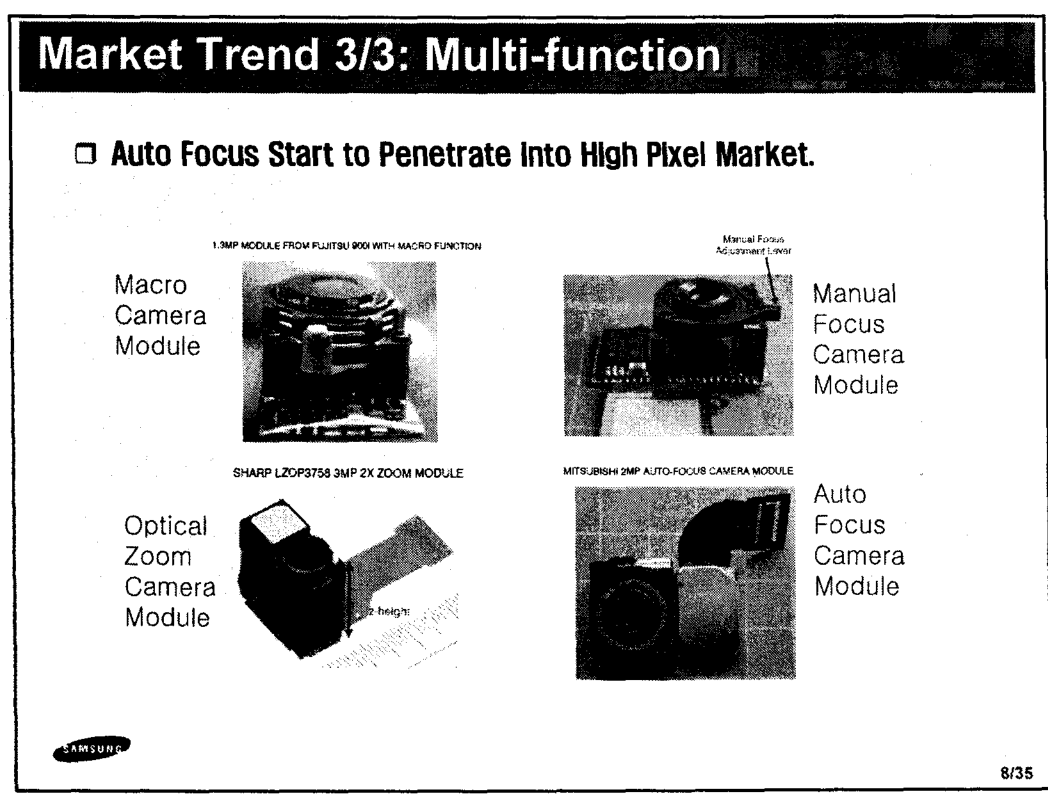
❑ Camera Module Becomes Slim and Small

- Size of VGA moudule: 10x10x9mm in 2002
  => 5x5x4mm in 2007

VGA CAMERA MODULE SIZE (X, Y, Z)



7/35


Market Trend 3/3: Multi-function
Auto Focus Start to Penetrate Into High Pixel Market.
1.3MP MODULE FROM FUJITSU 900I WITH MACRO FUNCTION
Macro
Camera
Module
Manual Focus
Adjustment Lever
Manual
Focus
Camera
Module
SHARP LZOP3758 3MP 2X ZOOM MODULE
Optical
Zoom
Camera
Module
MITSUBISHI 2MP AUTO-FOCUS CAMERA MODULE
Auto
Focus
Camera
Module
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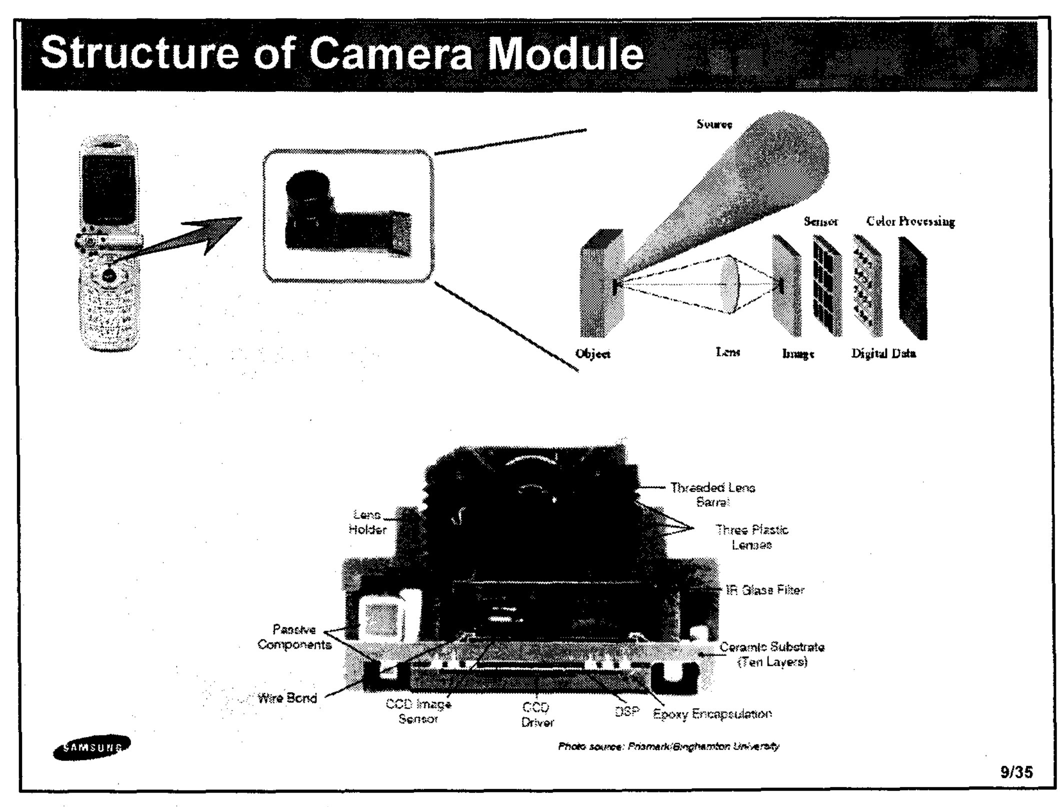
8/35


Structure of Camera Module
Source
Sensor
Color Processing
Object
Lens
Image
Digital Data
Threaded Lens
Barrel
Lens
Holder
Three Plastic
Lenses
IR Glass Filter
Passive
Components
Ceramic Substrate
(Ten Layers)
Wire Bond
CCD Image
Sensor
CCD
Driver
DSP
Epoxy Encapsulation
Photo source: Prismark/Binghamton University
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9/35

Technologies in Camera Module

- Image Sensor: CIS, CCD
- Imaging Optics System: Lens, AF Actuator, Mecha-Shutter ...
- Imaging Process: ISP, DSP
- Assembly and Packaging: COB, COF, CSP

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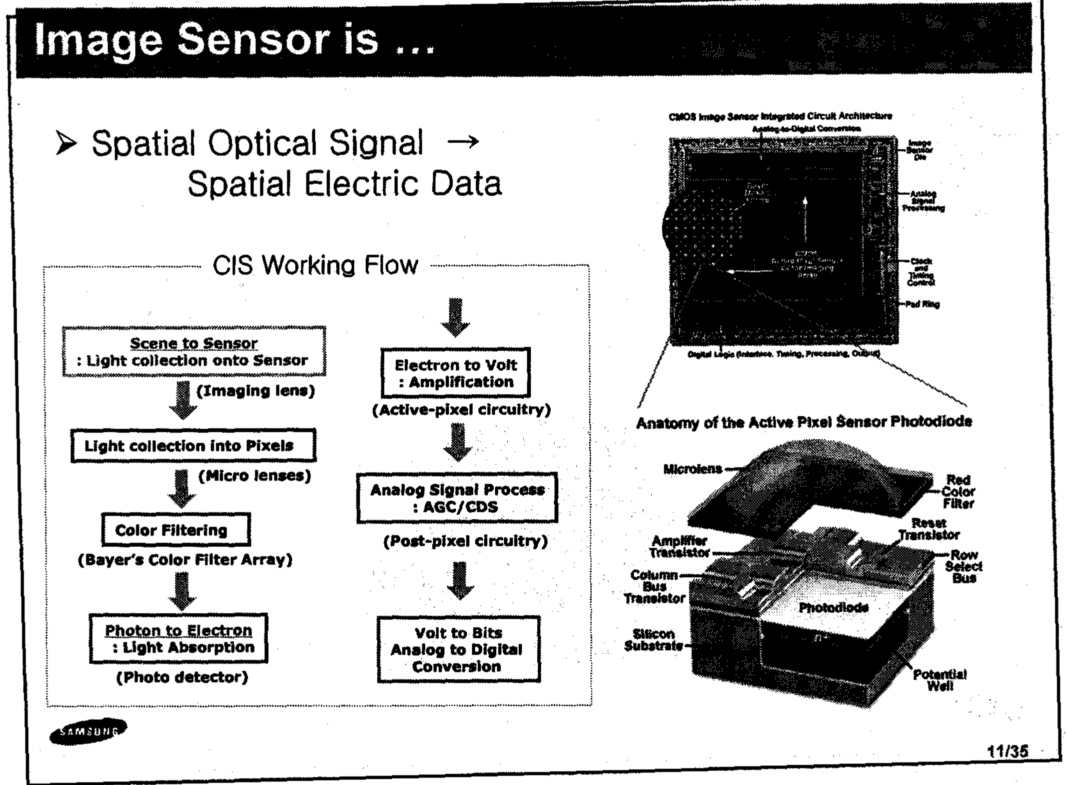


Trend in Image Sensor 1/2: CIS vs CCD

- **Mobile Phone is the Largest Market for Image Sensor**
- **CIS Replaces CCD**
  - Low cost, High integration, and Low power consumption

IMAGE SENSOR MARKET (M UNITS)

Market Segment	2005	2006	2007	2010	CAAGR 2005 - 2010
Optical Mouse	140	156	175	247	12%
Mobile Phone	380	480	570	850	18.4%
Digital Camera	70	79	88	114	10.2%
PC Camera	30	32	34	40	6.1%
Camcorder	19	20	21	24	4.6%
Scanner	19	22	25	37	14%
Toys	20	22	24	33	10.8%
Security	13	14	15	20	8.4%
Industrial	11	12	14	21	13.4%
Other	45	49	53	67	8.3%
Total	747	846	1,019	1,453	14.2%

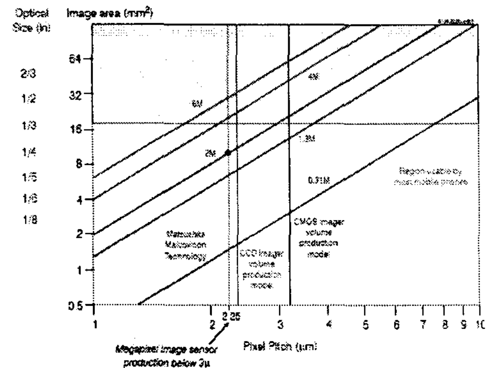
IMAGE SENSOR MARKET BY TYPE

Market Segment	2005 (M Units)			2010 (M Units)		
	CMOS	CCD	% CMOS	CMOS	CCD	%CMOS
Optical Mouse	140	0	100%	247	0	100%
Mobile Phone	285	95	75%	799	51	94%
Digital Camera	7	63	10%	46	68	40%
PC Camera	30	0	100%	40	0	100%
Camcorder	1	18	5%	6	18	25%
Scanner	14	5	75%	34	3	92%
Toys	20	0	100%	33	0	100%
Security	8	5	60%	15	5	75%
Industrial	1	10	5%	3	18	15%
Other	23	22	50%	47	20	70%
Total	529	218	71%	1,270	183	87%

Trend in Image Sensor 2/2: Pixel Size

- **Reduction of Pixel Size of Image Sensor**
  - Pixel Size: 2.8um → 2.2um → 1.8um
  - Fabrication Process: 0.25um → 0.18um → 0.15um

IMAGE SENSORS – RESOLUTION AND PIXEL SIZE

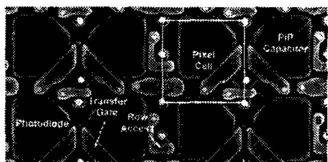


- 2.2um Pixel
  - 2M, 1/4"
  - 3M, 1/3.2"

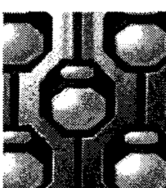
New Tech. of Image Sensors

➢ **Driving force: Cost Down, Better Sensitivity, Higher Resolution**

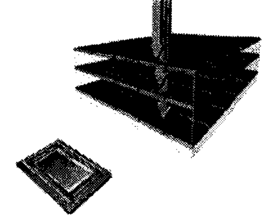
TR sharing

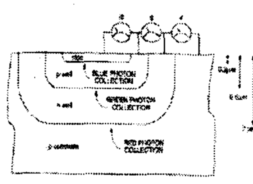


Honeycomb Pixel, Fujifilm

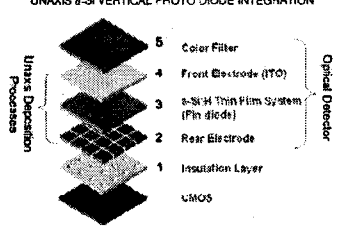


Pixel Stacking, Fovion, X3





Pixel Layer Separation, Uniaxis Corp.



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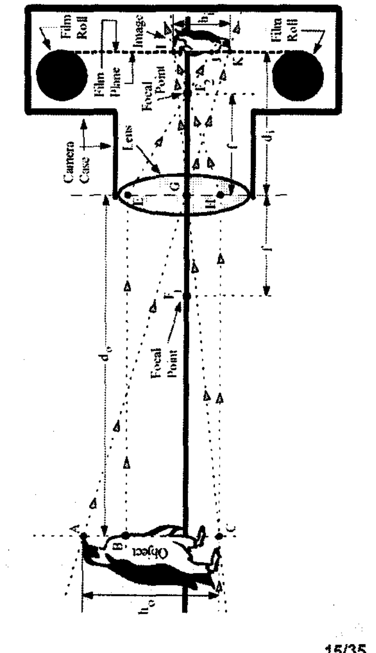
14/35

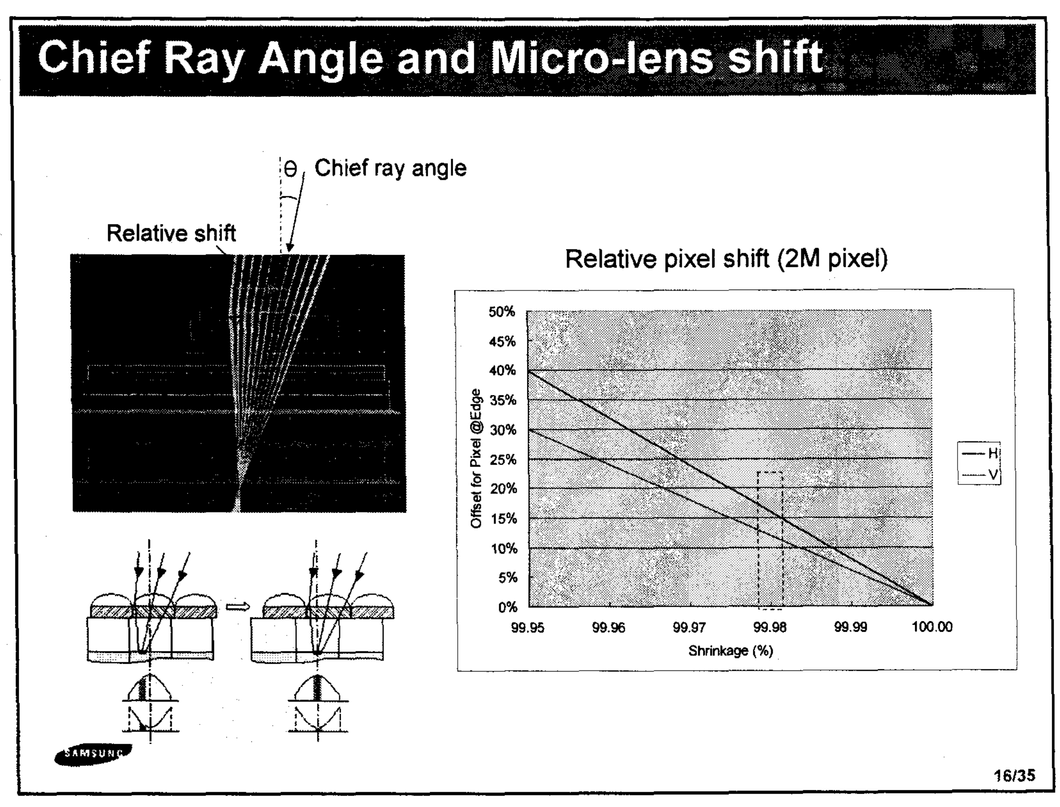
Imaging Optical System is ...

➢ Generate a Copy of Object Plane on Image Plane with Certain Magnification.

➢ Key Characteristics
- Optical Format: 1/8", 1/4", 1/3.2",...
- Lens Construction: 2P, 3P, 1G2P,...
- MTF or Resolution: 800 lines/PH,...
- Chief Ray Angle
- Depth of Focus
- Optical Track Length
- Distortion
- View Angle
- Relative illuminance



15/35


Chief Ray Angle and Micro-lens shift
θ
Chief ray angle
Relative shift
Relative pixel shift (2M pixel)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Offset for Pixel @Edge
99.95
99.96
99.97
99.98
99.99
100.00
Shrinkage (%)
H
V
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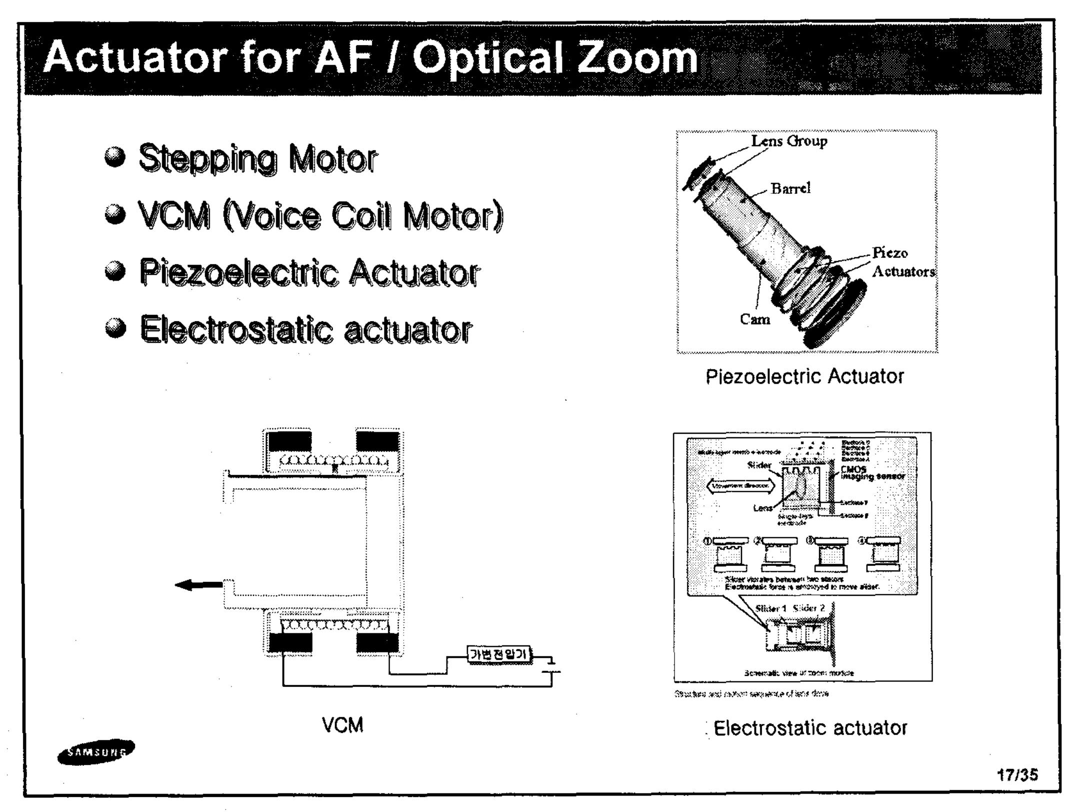
16/35


Actuator for AF / Optical Zoom
Stepping Motor
VCM (Voice Coil Motor)
Piezoelectric Actuator
Electrostatic actuator
Lens Group
Barrel
Piezo
Actuators
Cam
Piezoelectric Actuator
가변전압기
VCM
CMOS
imaging sensor
Slider 1
Slider 2
Electrostatic actuator
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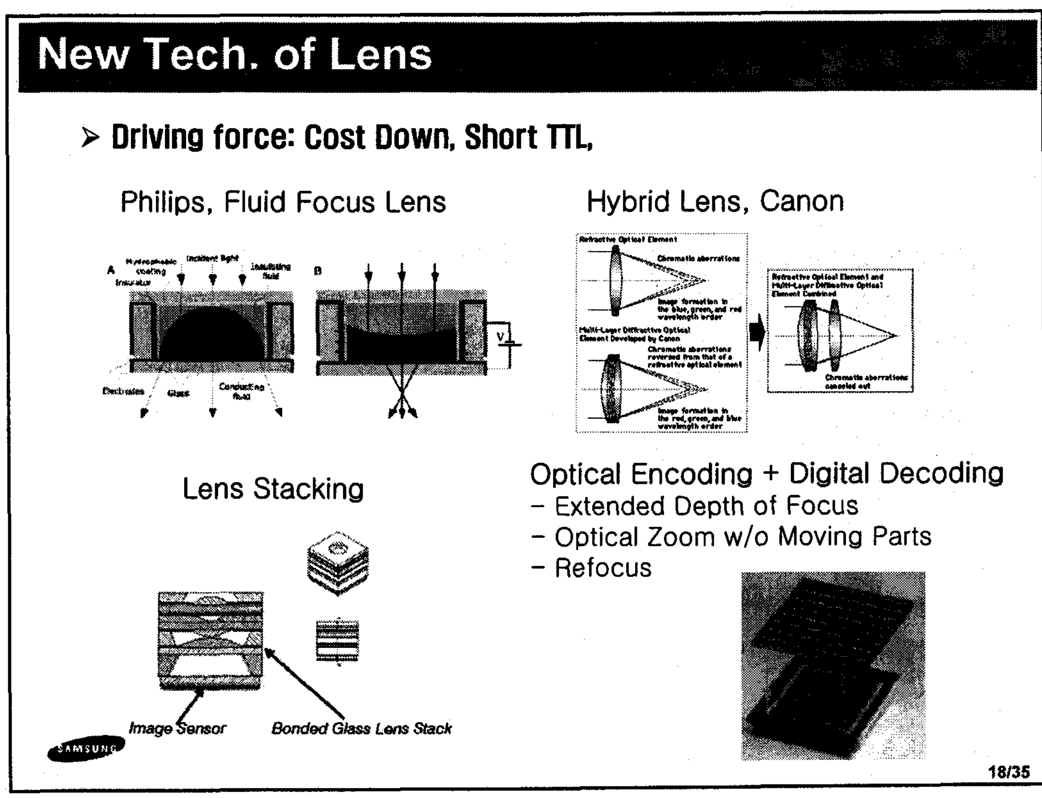
17/35



Assembly Structure of Camera Module

COB (Chip On Board)	CSP (Chip Size Package)	COF (Chip On Film)
Sensor, PCB	Sensor, PCB	Sensor, FPCB
Die bonding and Wire bonding of image sensor on a board (PCB)	SMT solder boning of CSP packaged image sensor on a board (PCB)	ACF(or ultra sonic) bonding of image sensor on a film (FPCB)
- Matured technology - Low cost - Large foot print and height	- Simple assemble process (SMT process) - Patent license required Shellcase Isarael - Low image quality	- Small foot print and height - Low yield - Electronic noise(?)

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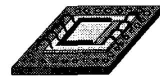
19/35

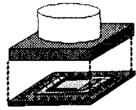
Assembly Process Overview

> COB (Chip on Board) Process

1. Sensor Chip Making



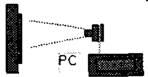
2. Chip Die & W/B on PCB



3. Lens Ass'y Bonding

4. Lens Align & Fixing

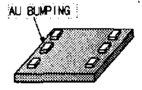
5. FPC Fixing on PCB

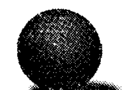


6. Final Test

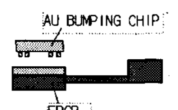
COF Process

> COF with ACF bonding Process





Sensor Chip Making



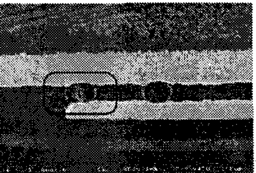
Chip Bonding on FPCB

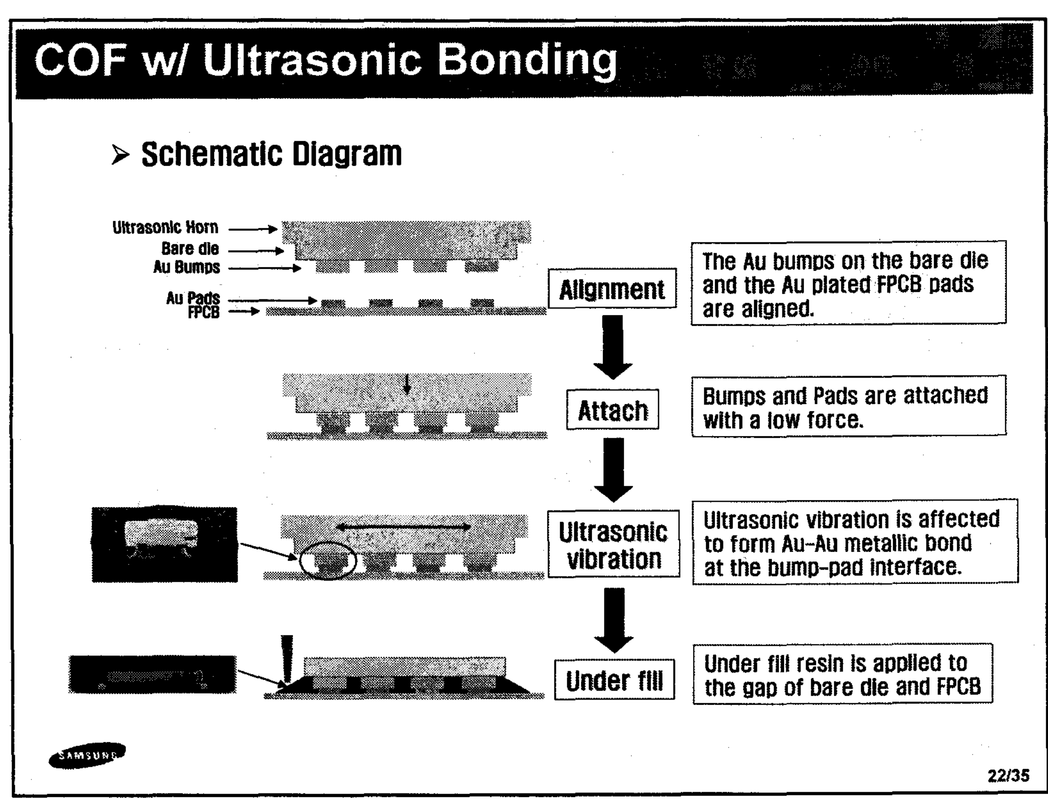
Bumped IC
BUMP
ITO
Substrate
Passivation
Anisotropic Conductive Film
Electrode
Adhesive

ACF bonding

ACF (Anisotropic Conductive Film)

• Conductive particle size: ~10um





Flip Chip Bonding Methods

Flip chip method	Ultrasonic	ACF	Solder bump
Structure			
Mechanism	Metallic bond	Physical contact	Solder wetting
Contact resistance	Low	High	Low
Available pitch	< 40㎛	> 50㎛	> 100㎛
Bonding force	Low	High	No need
Bonding temperature	R.T.~100℃	200~300℃	200~250℃
Bonding time	< 1 sec	20~30 sec	5~10sec
Feature	• High productivity • Low temperature process • Fine pitch application	• Low productivity • High material cost	• High productivity • High reliability

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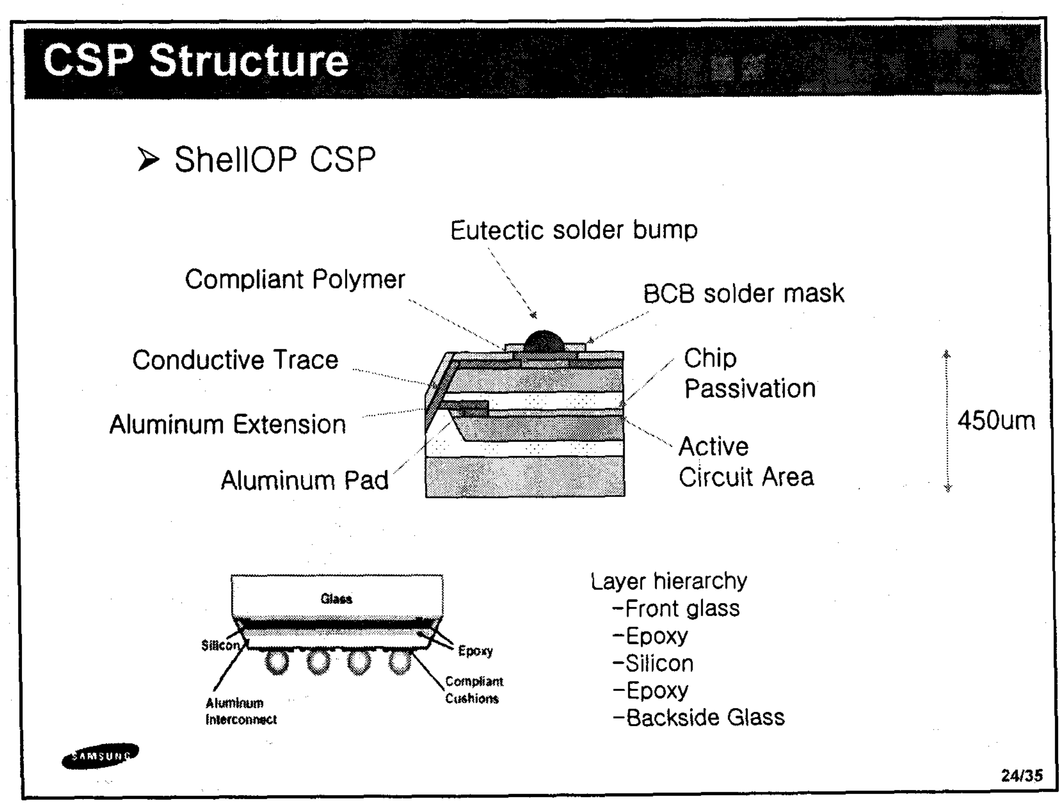
23/35


CSP Structure
➤ ShellOP CSP
Eutectic solder bump
Compliant Polymer
BCB solder mask
Conductive Trace
Chip
Passivation
Aluminum Extension
450um
Active
Circuit Area
Aluminum Pad
Glass
Silicon
Epoxy
Compliant
Cushions
Aluminum
Interconnect
Layer hierarchy
-Front glass
-Epoxy
-Silicon
-Epoxy
-Backside Glass
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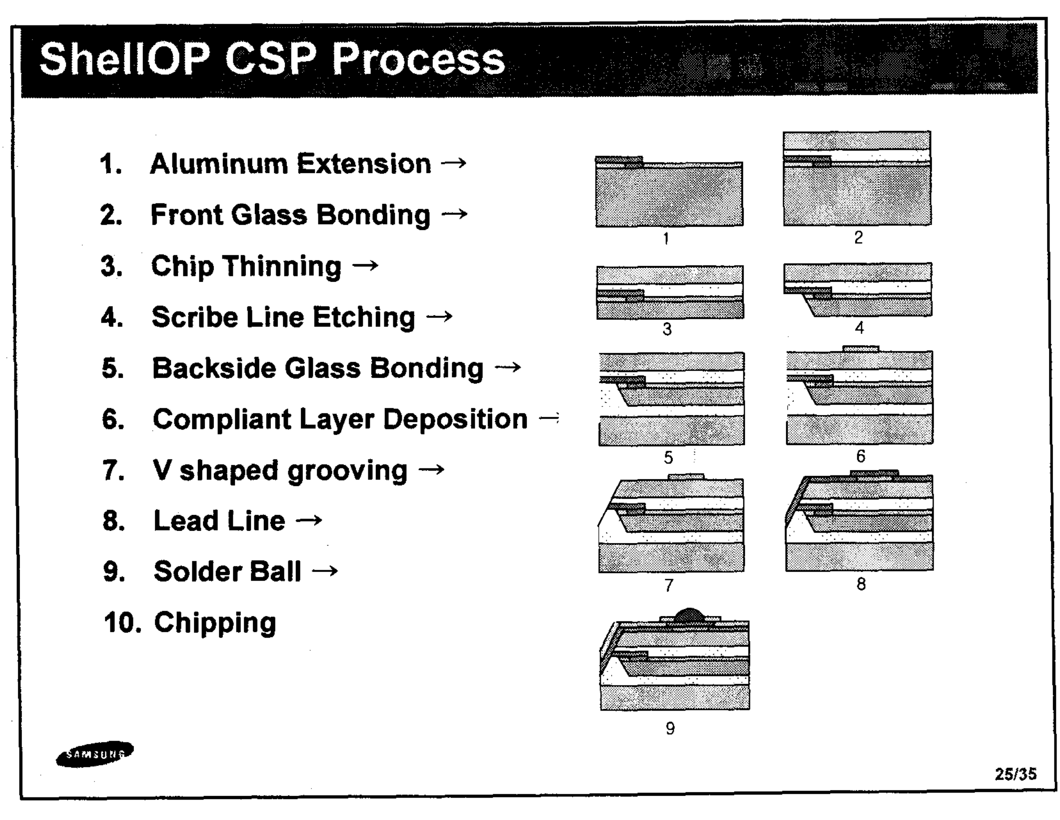
24/35


ShellOP CSP Process
1. Aluminum Extension →
2. Front Glass Bonding →
3. Chip Thinning →
4. Scribe Line Etching →
5. Backside Glass Bonding →
6. Compliant Layer Deposition →
7. V shaped grooving →
8. Lead Line →
9. Solder Ball →
10. Chipping
1
2
3
4
5
6
7
8
9
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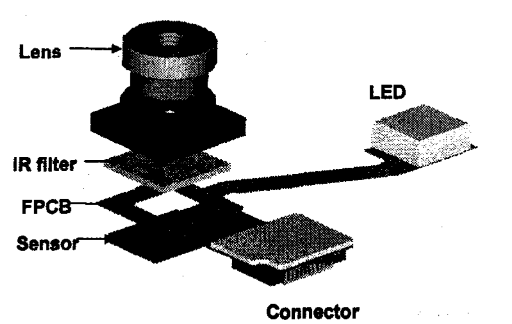
25/35

Particle Management

➢ **Driving force**
- Largest failure source
- Pixel size reduction

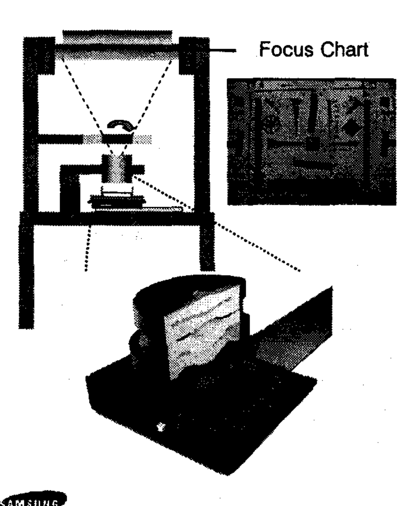
- **High class clean room**
- **Parts management (Plastic parts, Epoxy bonded parts)**
- **Parts and jig cleaning**
- **Process automation**
- **Auto-focus**
- **CSP structure**



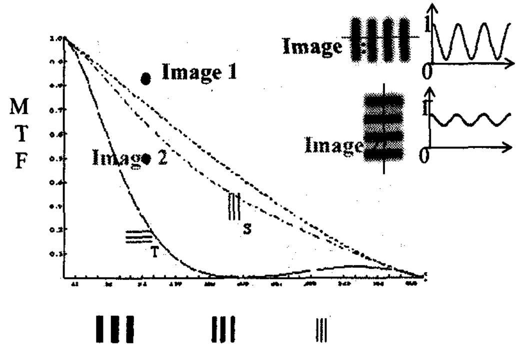
26/35

Focusing Process Automation

- The distance between lens and image sensor need to be aligned
- The MTF characteristics of lens is used for the auto-process



Use a certain spatial frequency checker chart
+ MTF characteristics of lens
⇒ Find a correlation b/w MTF and resolving power

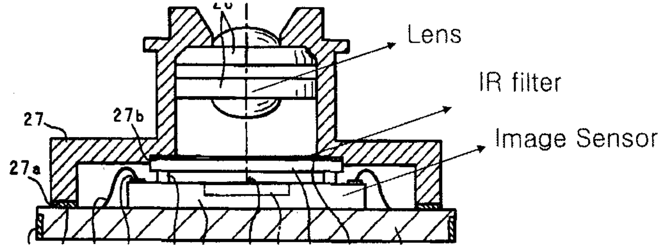


Spatial Frequency (cycles/mm)

27/35

No-Focus Camera Module

➢ **Sharp, 2006 Patent**
- No screwed barrel and no focusing process.
- Lens is integrated in the housing.
- IR filter is integrated on the sensor.
- DOF of the lens and tilting between optical axis and sensor normal is critical.
  . Housing press the IR filter on the sensor.
  . Dimension accuracy of the housing is critical.



28/35

Reliability Requirement

Reliability Items	Condition	Number of samples
Temperature Cycling	-40℃ -> 85℃ (each 30 min, 30 cycles)	10 EA (max 20 EA)
Damp Heat	85℃, RH : 85 %	10 EA (max 20 EA)
ESD	Human body model : 2000V(100pF/1500 ohm)	3 EA
Vibration	10~500Hz, 500~1800Hz	10 EA
FPCB & PCB adhesiveness	Peeling Test : 0.5 kg	5 EA
Holder adhesiveness	3kgf	5 EA
Drop	1.52m, X19	10 EA (max 20 EA)
Lens Torque	0.4 kgf	5 EA
Functional Test low & high temp	Camera ready state at -10℃ & 65℃, Camera operate after 2 hr	10 EA

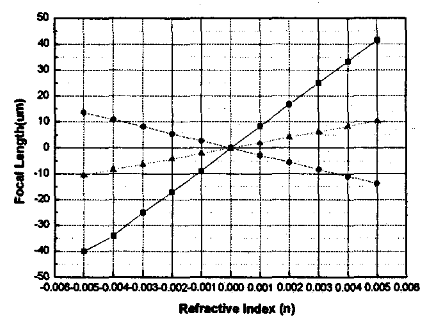
Temperature Cycling and Damp Heat Test are critical for Megapixel Camera module

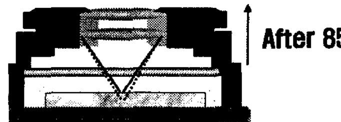
29/35

Damp Heat Issues

> **Factors on Damp Heat**

- Depth of focus of lens
- Index change of lens material
- Focal Length change of lens with index change
- Hydrolic reaction of materials (Exposy, Engineering Plastic, PCB, …)





30/35

Material Selection

> **Materials in Camera Moudule**

- Engineering Plastic: Housing and Lens Barrel
- Adhesive material : Die Attach , Housing Attach and Lens Fixing
- Optimal Curing Condition : release package stress

	flowability	Stability	Water Absorption	CTE ($X10^{-6}$/℃, FR4 ~ 12)
LCP	Excellent	Good	Good	~ 6
PPS	Bad	Good	Good	~ 18
PPA	Middle	Middle	Middle	~ 20
PA46	Middle	Bad	Bad	~ 32
PCT	Bad	Middle	Good	~ 20

LCP : Liquid Crystalline Polymers
PPS : Polyphenylene Sulfide
PPA : High Temp Nylon (PA6T, PA9T)
PCT : Polycyclohexane dimethylene terephthalate

31/35

Epoxy for Camera Module Packaging 1/2

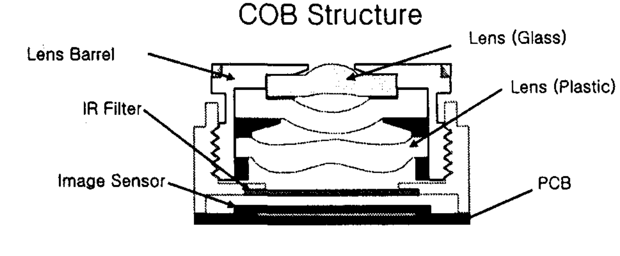
◆ Product trend

1. Down sizing of camera module (adhesion area is being smaller)
2. Increase number of pixels (adhesion area is being tough, out-gasing, particles)
3. Integrated functions (auto focus, shutter and iris; contain complex cure)

◆ Requirement for epoxy

1. Fine pattern dispensing (viscosity, dispensing condition)
2. Adhesion strength to various substrates
3. Meet reliability test
4. Low temperature cure and rapid cure

COB Structure



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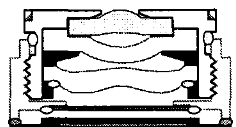
Selection of Epoxy

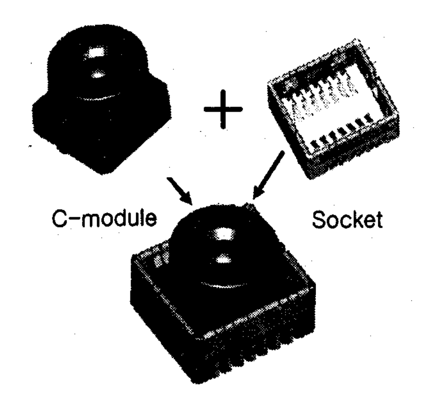
➢ Selection Factors

- Curing condition: Thermal, UV, temperature, time,···
- Materials
- Strength
- Color
- Reliability: Hydrolic reaction



	Ablestik 2035SC	Loctite 3103	Loctite 3129	Loctite 190024
Type	Non-conductive, heat cure	Epoxy	Acrylated Urethane, UV cure	Acrylated urethane
Color	Pink	Black	Pale, yellow	Bone-white (beige, after cured)
Viscosity @25℃	10,500cP	24,900cP, Shear rate $2s^{-1}$	10,000cP	18,000cP
Curing condition	90sec. @110℃	30min.@60℃	60sec. @30mW/cm²	3sec.@30mW/cm² Room temperature
Shear strength @25℃	4270 psi (Si die / PBGA-FR4)	13.5N/mm²	869 psi (PC / Glass)	

- **Driving force**
  - Cost
  - R&D Efficiency
- **SMIA(Standard Mobile Imaging Arhicheture)**
  - Nokia and STM
  - 2004



Name	Length	Width	Height Option 1	Height Option 2
SMIA65	6.5 mm	6.5 mm	4.6 mm	5.8 mm
SMIA85	8.5 mm	8.5 mm	6.1 mm	7.1 mm
SMIA95	9.5 mm	9.5 mm	7.6 mm	8.6 mm

34/35