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D 5.1
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PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential , only for members of the consortium (including the Commission Services)	

Deliverable number:	D 5.1
Deliverable name:	Market analysis
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Author(s)		
Name	**Organisation**	**E-mail**
Rainer Herrmann	SOS	r.herrmann@solar-semi.com

Abstract

The data of the given market analysis are mainly based on a piezoMEMS market analysis by “Yole Développement” (market research company). The analysis presents an overview of the “ferroelectric thin film – market”. Parameters like market size, main applications and the key players are shown. Due to the expected forecasts, the market growth rates and the trends can be derived. In the final chapter the key facts, trends and general conclusions are summarized.

Public introduction[1]

[1] According to Deliverables list in Annex I, all restricted (RE) deliverables will contain an introduction that will be made public through the project WEBsite

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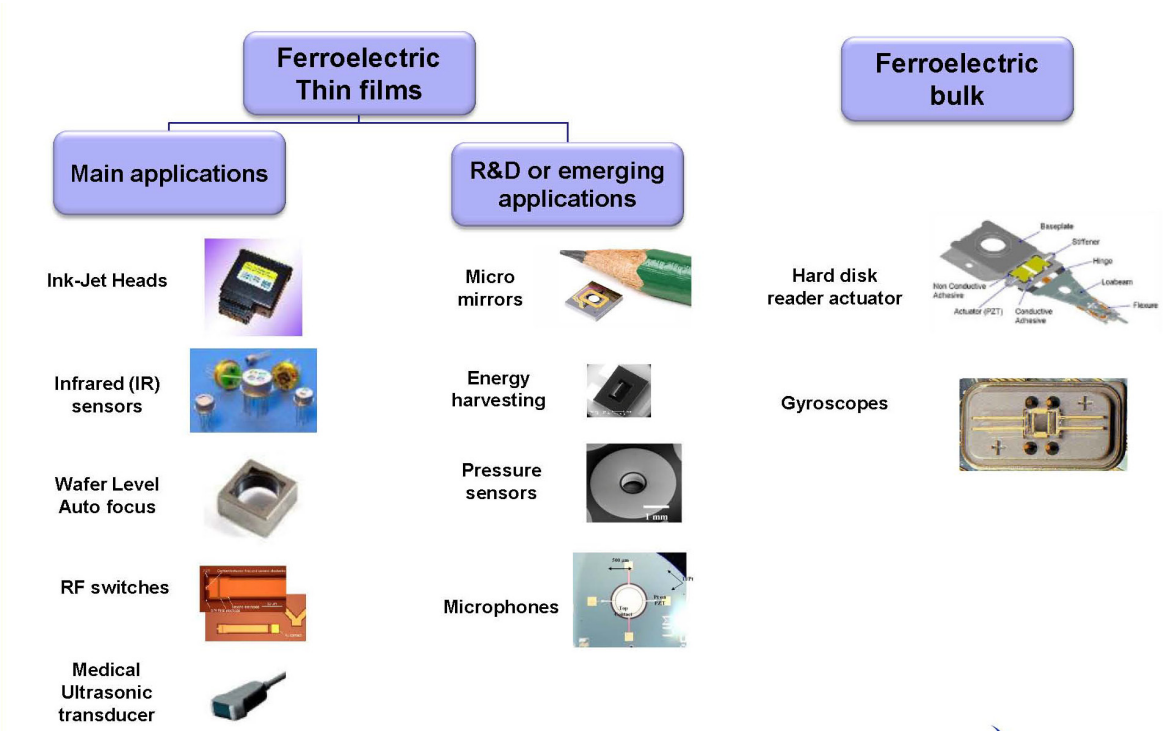
1 MARKET ANALYSIS

The data of the given market analysis are based on a piezoMEMS market analysis by "Yole Développement" (market research company): MEMS: Ferroelectric Thin Films Markets (http://www.i-micronews.com/reports/Ferroelectric-Thin-Films Markets/196/search?searchfield=piezoMEMS).

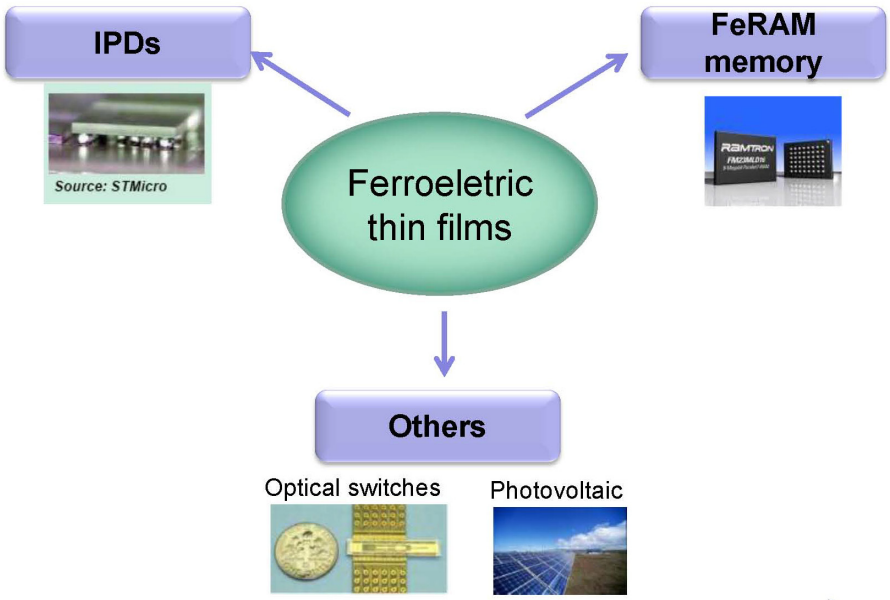
The report from Yole gives a very good overview over parameters like market size, main applications and the key players are shown. Due to the expected forecasts, the market growth rates and the trends can be derived. In the final chapter the key facts, trends and general conclusions are summarized.

1.1 Main ferroelectric thin film applications → MEMS

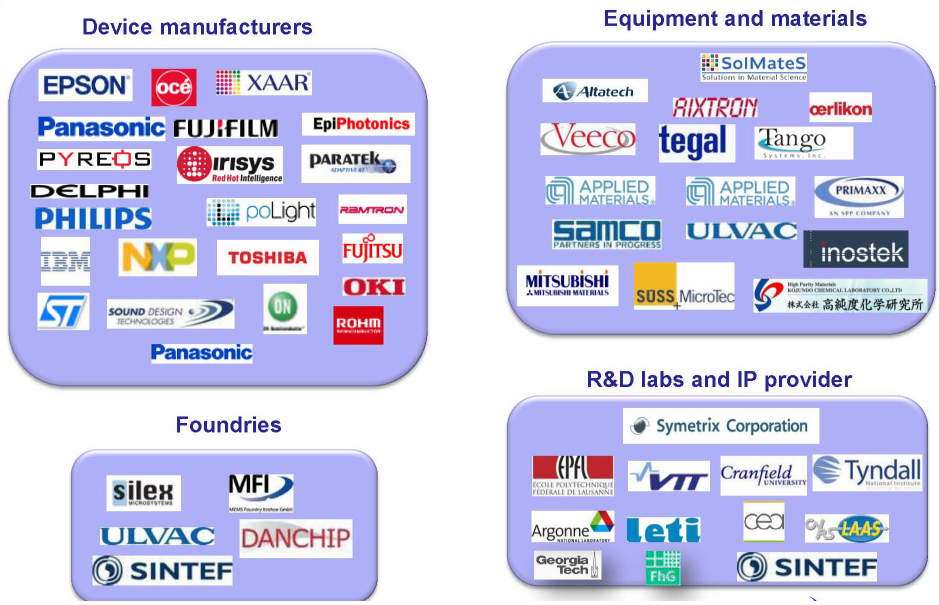


1.2 Main ferroelectric thin film applications → besides MEMS

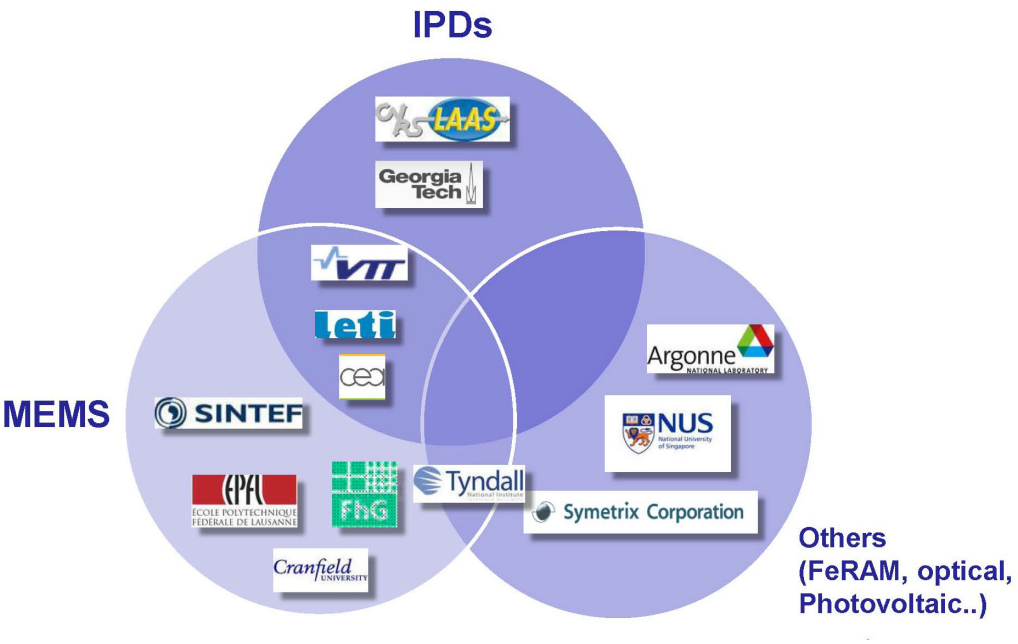
IPD = Integrated passive devices
FeRAM = Ferroelectric random access memory



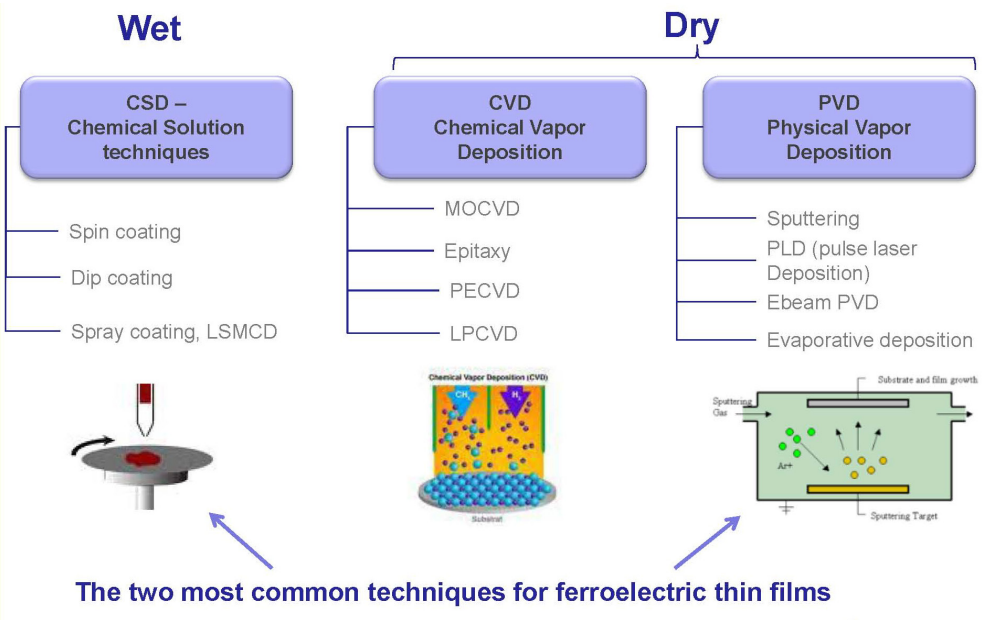
1.3 Key ferroelectric thin film market players



1.4 Main R&D labs active in ferroelectric thin films



1.5 Ferroelectric thin film deposition techniques → processes



1.6 Ferroelectric thin film functions and materials

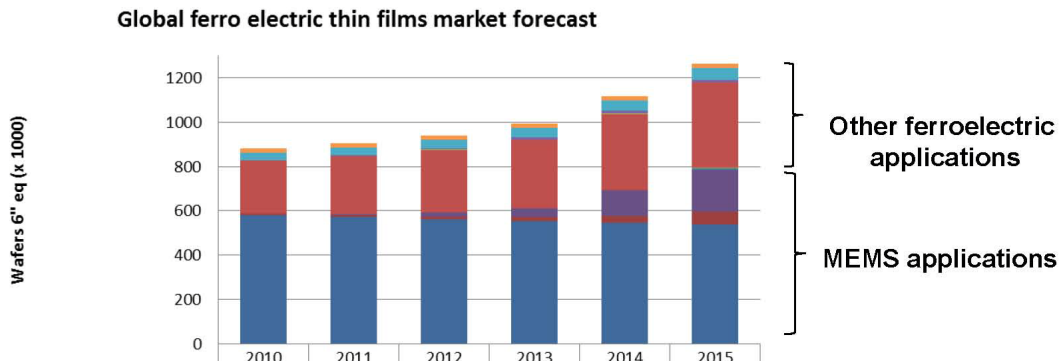
PZT = lead zirconate titanate
AIN = aluminium nitride
SBT = bismuth-strontium-tantalate
BST = barium strontium titanate

Domain	Applications	Thin film functions	Materials
MEMS	IJ heads, Wafer Level Auto focus, RF switches, Micro mirrors	Piezoelectric actuation	PZT, AIN
	Infrared (IR) Sensors	Pyroelectric effect (conversion from IR heat into volts)	SBT, PZT
	Ultrasonic sensors, energy harvesting, pressure sensors, microphones	Piezoelectric transduction	PZT
IPDs	IPD ESD/EMI audio (Fixed capacitor)	High dielectric constant	PZT and doped PZT
	IPDs Hearing Aids (Fixed capacitor)	High dielectric constant	BST
	IPDs RF tunable capacitor	Tunable dielectric constant	BST
Memories	FeRAM	Constant hysteresis cycle	PZT doped or SBT
Others	Telecom optical switch	Tunable optical index	PLZT doped

Remark:

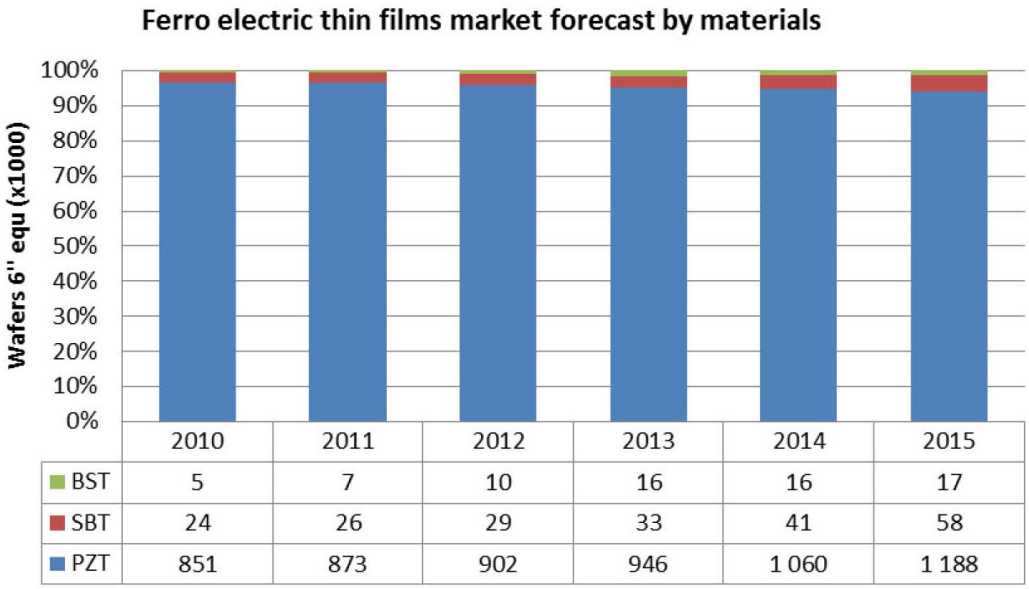
- **PZT is the dominant material for ferroelectric thin film applications**

1.7 Global ferroelectric thin film market forecast → in wafers



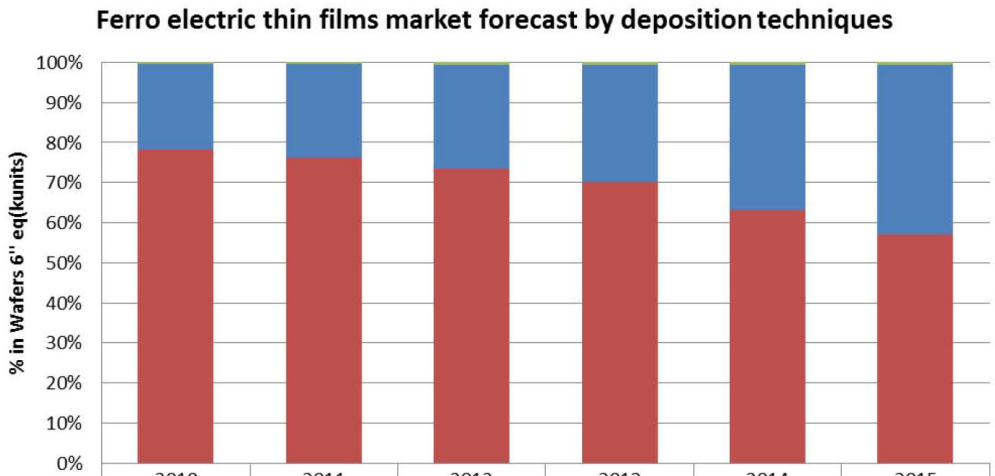
	2010	2011	2012	2013	2014	2015
TOTAL	881	905	941	995	1117	1263
R&D	20	20	20	20	20	20
Feram 6" eq.	32	35	38	42	46	51
IPD RF tunable capacitors 6" eq	1	3	6	11	12	13
IPD hearing aids 6" eq.	1	1	1	1	1	1
IPD Audio ESD 6" eq.	239	262	284	311	343	381
Ultra sonic 6" eq.	0	0	0	0	3	5
RF Switches 6" eq.	0	0	0	0	0	5
WL Auto Focus 6" eq.	0	3	17	36	115	189
IR sensors 6" eq.	8	10	12	20	30	60
IJHeads 6" eq.	580	571	563	554	546	538

1.8 Global ferroelectric thin film market forecast → by material



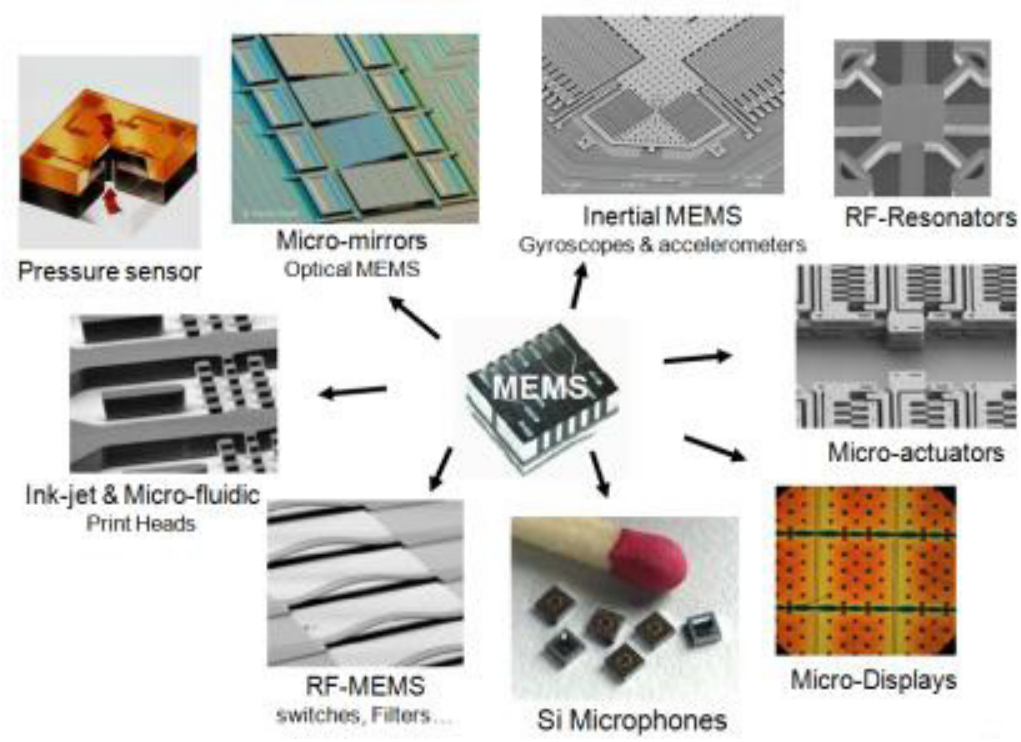
	2010	2011	2012	2013	2014	2015
BST	5	7	10	16	16	17
SBT	24	26	29	33	41	58
PZT	851	873	902	946	1 060	1 188

1.9 Global ferroelectric thin film market forecast → by deposition techniques

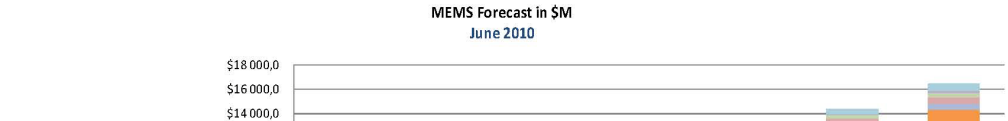


	2010	2011	2012	2013	2014	2015
CVD	4	5	5	6	6	7
CSD	187	211	245	290	404	535
PVD	688	690	691	700	706	721

1.10 MEMS ferroelectric thin films → an overview



1.11 MEMS 2009-2015 → Forecast in US $Million

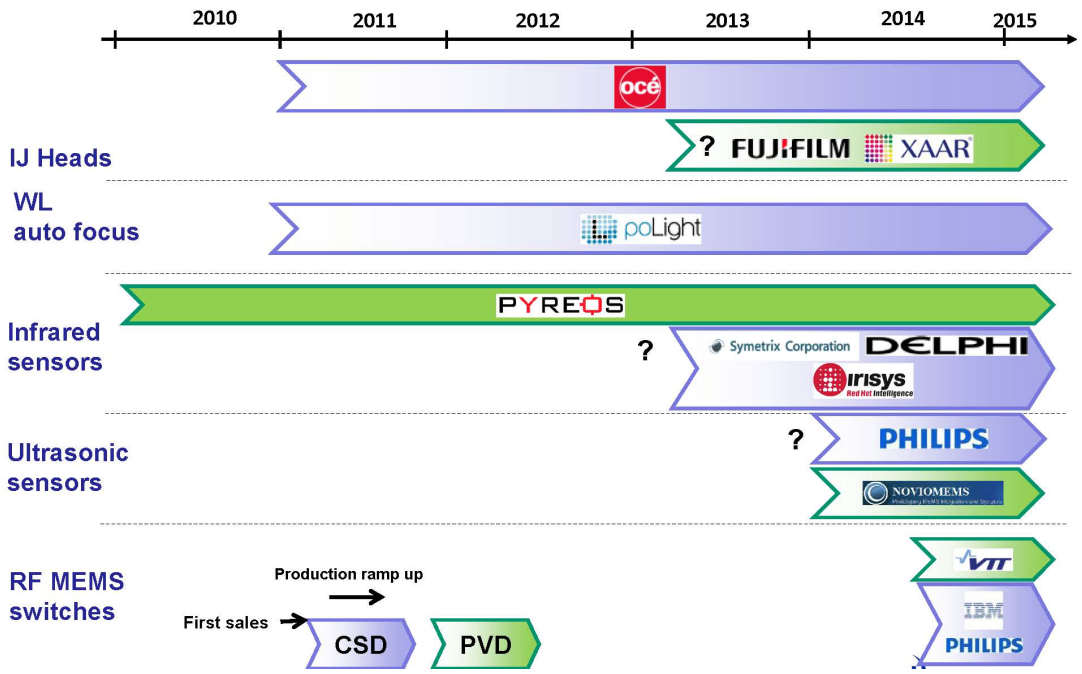


	2009	2010	2011	2012	2013	2014	2015
Others (microstructures, micro tips, flow meter ...)	$129,0	$150,4	$204,9	$270,0	$342,7	$462,4	$596,9
Micro speakers	$0,0	$0,0	$0,0	$10,0	$37,5	$90,0	$150,0
Oscillators	$7,9	$17,0	$33,6	$64,7	$119,9	$213,0	$347,6
RF MEMS	$228,9	$246,5	$286,5	$339,4	$402,1	$506,3	$602,5
Microdispensers (microfluidics)	$140,1	$174,3	$214,7	$261,3	$313,5	$376,1	$451,3
Microfluidics for IVD	$633,3	$757,5	$952,4	$1 196,8	$1 494,9	$1 875,5	$2 363,5
Microfluidics for Research	$199,3	$269,0	$363,1	$490,2	$637,3	$828,5	$1 077,1
Other optical MEMS	$77,4	$91,4	$107,8	$128,7	$154,9	$189,3	$225,9
Projection systems	$663,7	$707,4	$839,8	$1 068,6	$1 415,4	$1 814,2	$2 115,1
Micro displays	$0,5	$2,5	$9,6	$23,0	$45,0	$66,0	$86,0
Microbolometers	$204,5	$219,3	$233,5	$250,6	$277,6	$313,8	$375,0
Digital Compass	$111,5	$194,6	$248,5	$269,0	$281,7	$286,9	$285,0
Gyroscopes	$839,6	$1 012,1	$1 127,5	$1 235,7	$1 381,6	$1 442,4	$1 533,9
Accelerometers	$1 036,2	$1 117,0	$1 237,1	$1 341,2	$1 402,2	$1 429,1	$1 470,3
Microphones	$123,3	$170,5	$222,2	$292,4	$323,6	$370,5	$410,7
Pressure Sensors	$1 056,0	$1 200,6	$1 404,3	$1 694,9	$1 941,8	$2 154,7	$2 324,4
InkJet Heads	$1 547,7	$1 566,1	$1 625,7	$1 740,4	$1 831,5	$1 937,9	$2 043,7

1.12 General Overview of MEMS ferroelectric applications

	Main thin film applications					R&D emerging thin film applications			
	Ink-Jet Heads	IR Sensors	Wafer level Auto Focus	RF MEMS - Switches	Ultrasonic imagers	MEMS µphones	Pressure sensors	*µmirrors*	MEMS Energy Harvesting
2009 TOTAL Market ($)	$1547M	$204M	0	<$10M	<$1M	$123M	$1056M	$663M	0
2009 TOTAL Market (Units)	668M	0.2M	0	0.2M	<1M	318M	296M	1M	0
2015 TOTAL Market ($)	$2043M	$375M	About $200M	$387M	na	$410M	$2324M	$2115M	na
2015 TOTAL Market (Units)	719M	0.7M	237M	486M	na	1381M	689M	136M	na
Ferroelectric materials	PZT	SBT	PZT	PZT	PZT	PZT	PZT	PZT	PZT
Properties	Actuation	Pyroelectric effect	Actuation	Actuation (piezo)	Transduction (Piezo)	Transduction	Transduction	Actuation	Transduction (piezo)
Competing actuation principle	Thermal	Bolometer	VCM, EAP, SMA	Electro static	-	Capacitive	Capacitive	Electro static, magnetic	Electromagnetic, electrostatic, thermal effect
Deposition method	PVD/ CSD	PVD/CSD	CSD	CSD/PVD	CSD/PVD	CSD	CSD	?	PVD
MEMS thin film Players	Epson (JP) Océ (NL), Xaar (UK), Panasonic (JP),	Pyreos (UK) Irisys (UK) Symetrix/ delphi (US)	poLight (NO)	IBM (US), Philips Research (NL)	NovioMEMS (NL)	US Army Research Lab	US Army Research Lab	LG (Kr)	KIST (KR)

1.13 MEMS → Roadmap to production for new players



1.14 Piezoelectric MEMS → Key industrial market players

	PZT	SBT	AIN
IJ Heads	EPSON, XAAR, océ, FUJIFILM		
IR sensors	PYREOS, irisys Red Hot Intelligence	Symetrix Corporation, DELPHI	
WL auto focus	poLight		
RF switches	IBM, PHILIPS		TOSHIBA
Ultrasonic	NOVIOMEMS Prototyping MEMS Integration and Sensors, PHILIPS		

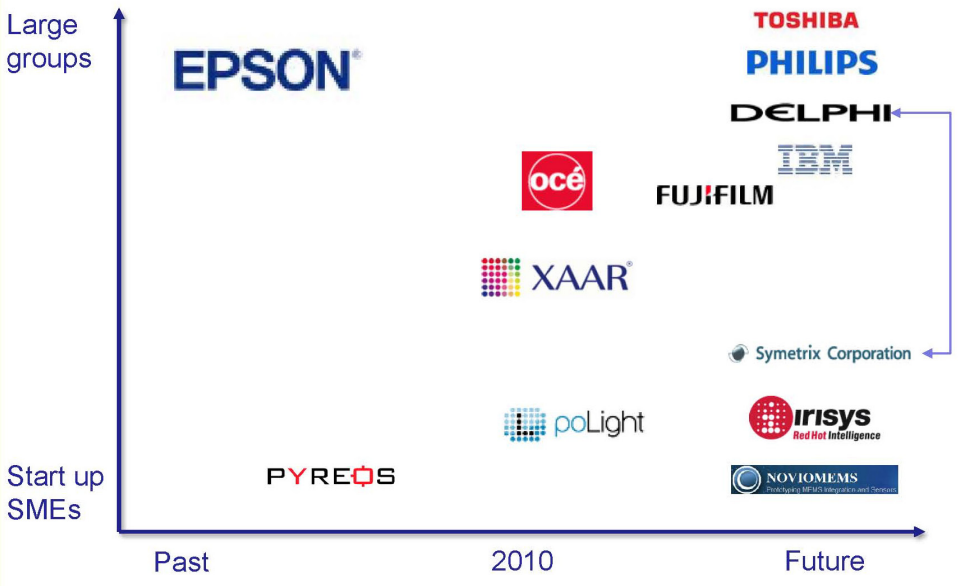
1.15 MEMS deposition techniques → Key industrial market players

	PVD	CSD
IJ Heads	EPSON, XAAR, FUJIFILM	océ
IR sensors	PYREOS	Symetrix Corporation, irisys Red Hot Intelligence, DELPHI
WL auto focus		poLight
RF switches		IBM, PHILIPS
Ultrasonic	NOVIOMEMS Prototyping MEMS Integration and Sensors	PHILIPS

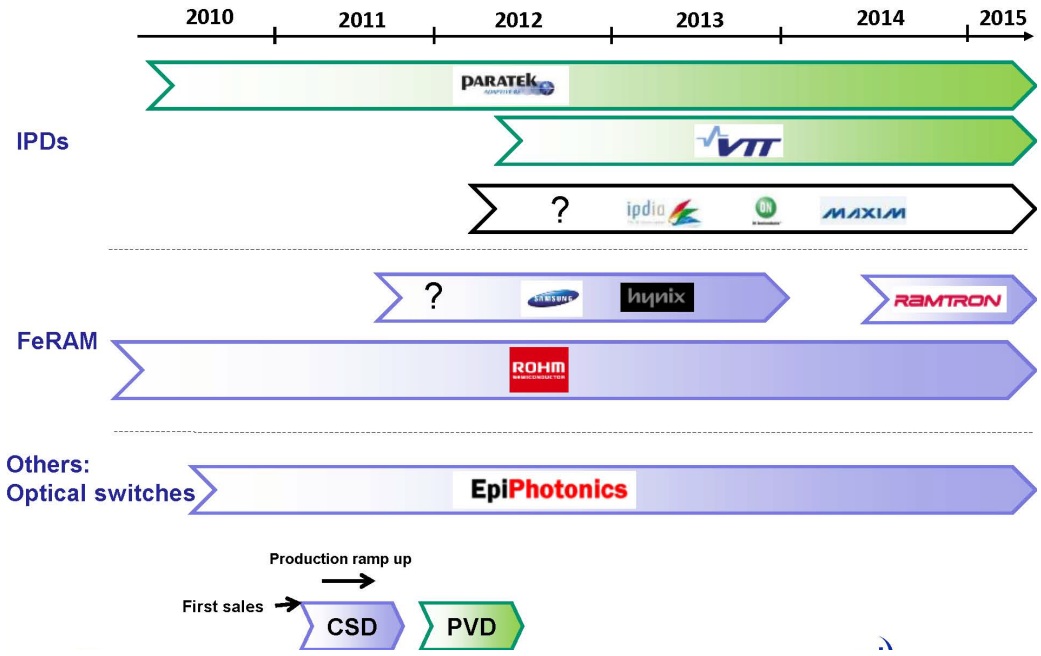
1.16 MEMS thin film thickness by application → Key market players

Application	Key players	Thin film thickness
IJ Heads	EPSON, XAAR, océ, FUJIFILM	1 - 4 µm
IR sensors	PYREOS, Symetrix Corporation, irisys, DELPHI	0.1 – 0.5 µm
WL auto focus	poLight	60 µm
RF switches	IBM, PHILIPS, TOSHIBA	2 - 50 µm
Ultrasonic	NOVIOMEMS, PHILIPS	0.5 - 50 µm

1.17 MEMS → key industrial market player positioning



1.18 Besides MEMS → Roadmap to production for new players



1.19 Besides MEMS → Materials and key device industrial players

	PZT and doped PZT	BST	SBT
IPD ESD audio 	NXP, ST		
IPD hearing aids 		SOUND DESIGN TECHNOLOGIES, ON	
IPD RF variable capacitors 		PARATEK, ST	
FeRAM 	50% RAMTRON, FUJITSU, ROHM		50% Panasonic, OKI
Others	EpiPhotonics		

1.20 Besides MEMS → Industrial player mapping by deposition technique and material

	Dry		Wet
	PVD	CVD	Chemical solution deposition (CSD)
PZT and doped PZT	RAMTRON, FUJITSU		ST, EpiPhotonics, ROHM, NXP
SBT			Panasonic, OKI, Symetrix Corporation
BST	PARATEK		SOUND DESIGN TECHNOLOGIES

Remark:

- The choice of the technique is mainly dependent on the processing culture and history of the company
- CSD is used for 66% of the total market (FeRAM / IPD)

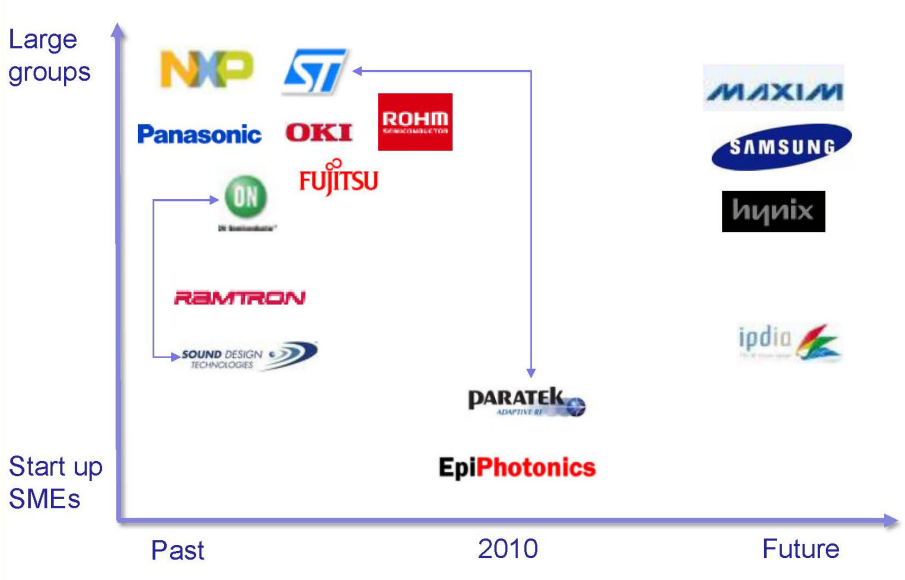
1.21 Besides MEMS → Ferroelectric thin film thickness by application

Application	Player examples	Thin film thickness
IPD ESD/EMI audio	NXP, ST	0.1- 0.2 µm
Hearing Aids IPDs	SOUND DESIGN TECHNOLOGIES, ON	5 µm
FeRAM	ROHM	0.2- 0.5 µm
Telecom optical switch	EpiPhotonics	6 µm
Piezoelectrical applications		2-60 µm

Remark:

- Ferroelectric thin films use at least 10 times less material than piezoelectric thin films used for MEMS

1.22 Besides MEMS → key industrial market player positioning



Remark:

- Large groups will probably continue to lead the IPD and FeRAM markets

1.23 Key facts, trends and general conclusions

Deposition techniques

- PVD is the technique used for the largest part of the ferroelectric thin film production, mainly thanks to EPSON inkjet head production with PVD.
- However, CSD is very popular in IPD applications (NXP and STM users) and will be increasingly used in MEMS applications thanks to the precise control of the material properties with CSD. Globally, the market shares of CSD will increase from 22 to 42% in 2015.
- CVD has been rarely used up to now. However, it may be use in the future in high density IPD capacitors which may appear before 2015.

Materials

- PZT is the dominant material for ferroelectric thin films thanks to its high ferroelectric performance: more than 95% of markets in 2010.
- Alternative materials, SBT and BST are used for FeRAM, IPDs and IR sensors.
- PZT will stay the dominant material unless the restriction on the use of lead (RoHS European directive) forces manufacturers to use materials that generally have a lower performance.

Applications

- Ferroelectric materials are historically not common for semiconductor manufacturing companies who are often reluctant to adopt these exotic materials in their fabs.
- This philosophy is changing in the 2000s with the adoption of ferroelectric thin films by well known companies in a variety of markets.
- In 2010, ferroelectric thin film production is 881k 6" wafers. It is done through two main applications: MEMS inkjet heads and IPD ESD/EMI planar capacitors that together represent 90% of the production. Large companies (Epson, STM, NXP) have adopted ferroelectric thin films at a large industrial scale for the past several years.
- Until 2015, the ferroelectric thin film business will continue to grow at rate of +7.5% / year with many current or new applications:
  - In the MEMS field: Wafer Level Autofocus, IR sensors, RF switches, medical ultrasonic transducers.
  - In other markets: IPD tunable capacitor, IPD hearing aids, FeRAM, optical switches.
- These applications will represent 26% of the total ferroelectric thin film production in 2015 which will be 1,263k 6" wafers.