MEMS Micro-actuators enabling new and unforeseen applications

STMicroelectronics

AME Microsystems Product Marketing

2017
• MEMS Sensors and Actuators at ST: introduction and history

• Technologies for MEMS Micro-actuators: four pillars

• Changing the MEMS Landscape: innovative applications

• In-depth: Micro-Mirrors and Laser Beam Scanning Engines
MEMS Sensors & Actuators at ST

Physical change

Sense

Electro

MEMS

Mechanical

Actuate

Fluidic Micro-actuators
Piezo actuators
Micro Mirrors

Motion
Environmental
Audio

Signal

Electric
MEMS micro-actuators & MEMS sensors use the same principles and same basic processes

MEMS sensors have ultra-low power analog signal processing parts

MEMS micro-actuators have high voltage/current analog and power management parts (since higher voltages required for some applications)

Leveraging our BCD technologies
20 Years of MEMS Sensors & Actuators

ST Innovations

- Accelerometer
- Gyroscope
- Inertial module
- Pressure sensor
- Microphones
- UV sensor
- Humidity sensor
- GAS & VOC
- Fluidic Micro-actuators
- Micro Mirrors
- Piezo actuators
20 Years of MEMS Sensors & Actuators

Iconic Products

[Timeline with images of iconic products from 2000 to 2017]
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Micro-Actuation Technologies
Enabling Multiple Applications

- Camera autofocus
- Speakers
- PMUT
- Commercial Inkjet print head
- Vaporizer/Atomizer

- Consumer Inkjet print head
- Vaporizer/Atomizer

- Piezo-Electric
- Electrostatic

- Thermal
- Electro-Magnetic

- Micro-mirrors
- 3D scanning
- Mobile projection
Electrostatic Working principle

- Electrostatic force is used as actuation mechanism by means of a comb drive structure, i.e. interdigitated silicon fingers, which apply a torque moment on the MEMS.

Electrostatic torque on mirror structure
→ Voltage control

Energy stored in a Capacitor

\[ E = \frac{1}{2} CV^2 \]

Differentiating to get Comb Drive Forcing Moment:

\[ M_{\text{forcing}} = \frac{1}{2} \frac{dC_{\text{comb}}}{d\theta} V^2 \]
Electrostatic Sample Images

Torsional spring for **linear** actuation

Staggered comb finger for **linear** Micro-Mirror

Torsional spring for **resonant** actuation

In-plane comb finger for **resonant** Micro-Mirror
Electro-Magnetic Actuation Principle

Electromagnetic actuation on mirror structure

Current flows into Drive coils part of the moving structure

Device houses magnets which induce fixed magnetic field on the structure

Actuation Based on Lorentz Force:

$$F = q(E + \mathbf{v} \times \mathbf{B})$$
**Electro-Magnetic**

**Sample Images**

**Coil Wire** for magnetic actuation. Thick ECD growth (>20um)

View of **Coils** and **Torsional Spring**

Top View with **Coils** and **Springs**

MicroVision, Inc. 720p Bi-axial mirror
Thin-Film Piezo
Actuation Principle

The piezo element generates a voltage when deformed

Direct piezoelectric effect:
Strain $\rightarrow$ Charge

Sensors

If a voltage is applied across the piezo element, it will deform

Reverse piezoelectric effect:
Voltage $\rightarrow$ Stress/Strain

Actuators
## Thin-Film Piezo

### Bulk Piezo vs Thin-Film Piezo

<table>
<thead>
<tr>
<th>Bulk Piezo</th>
<th>Thin Film Piezo</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large Form Factor</td>
<td>• Micron thick layers produce 2D form factor</td>
</tr>
<tr>
<td>• High Power Consumption</td>
<td>• Lower drive voltages for similar mechanical displacements</td>
</tr>
<tr>
<td>• Mechanical assembly requires high capital or low volume manufacturing</td>
<td>• Integrated into fab processing for very high volume manufacturing</td>
</tr>
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</table>
ST-Agrate has developed an industrial “Thin Film PZT” process which is able to address a wide range of applications.

20V, 1Hz → 30µm displacement
Thin-Film Piezo
Sample Images

Very dense film structure
No defects/voids
Film is flat with very small grains

PZT and the metallic electrodes patterned by dry-etch
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Changing the MEMS Landscape
Strategic Partnerships

Piezo Autofocus

MEMS Loudspeaker

Micro-mirror Projection
STMicroelectronics and USound Agree to Make World's First Spectacular-Sounding MEMS Speakers

Feb. 21st 2017

“Compared to standard speakers, our piezo-MEMS devices offer unprecedented mechanical precision, improving audio reproduction fidelity and device reliability in very thin form factors. As the first-of-its-kind device, our MEMS “Moon” speaker targets earphone applications, bringing superior performance to the audio world at a competitive price”

TLens® uses a piezoelectric to change the shape of a transparent polymer film, imitating the functioning of the human eye.

Source: www.poLight.com
Agenda

- MEMS Sensors and Actuators at ST: introduction and history
- Technologies for MEMS Micro-actuators: four pillars
- Changing the MEMS Landscape: innovative applications
- In-depth: Micro-Mirrors and Laser Beam Scanning Engines
What is a MEMS μMirror Scanner?

- Tiny **reflective mechanical device** that swings at a given frequency
- Applications spanning from **Visible to Invisible** (IR typically)
Technology Comparison

**ELECTROSTATIC**

**PROS:**
- Simpler Technology (resonant)
- MEMS Power Consumption

**CONS:**
- High Voltage Required
- Quasi-Static Operation
- Requires More Complex Technologies

**PERFORMANCE:**
- Total Force: Low
- Force Density: Low

**ELECTROMAGNETIC**

**PROS:**
- Low Voltage
- Very Good for Linear Operation

**CONS:**
- MEMS Power Consumption
- External Magnets

**PERFORMANCE:**
- Total Force: High
- Force Density: Medium/Low

**PIEZOELECTRIC**

**PROS:**
- Mid Voltage
- High Fidelity Feedback
- MEMS Power Consumption

**CONS:**
- PZT Small Displacements
- Just Resonant Operation

**PERFORMANCE:**
- Total Force: Medium/High
- Force Density: High
Laser Beam Scanning (LBS)
Technology Principles and Applications

**Principles:**
- Light from one/multiple **lasers** is combined into a single beam
- Beam is relayed onto **MEMS scanning mirror(s)**
- Mirror(s) scan the beam in a raster pattern
- A **projected image** is created by modulating the lasers synchronously with the position of the scanned beam

**Applications:**
- **Pico-projection** and **heads-up display** (HUD)
- **Virtual** and **Augmented Reality** (VR, AR)
- **3D Sensing** and **Advanced Driver Assistance Systems** (ADAS)
Laser Beam Scanning (LBS)

Display Systems: Block Diagram

Complete System: Scanning Engine

- Electronics Subsystem
  - Mirror(s) Drivers
  - Laser Drivers
  - Video Projection ASIC
  - Power Management

- Optical Engine
  - Lasers
  - Optics
  - Photodetectors
  - MEMS Mirror(s)
Laser Beam Scanning (LBS)

Key Benefits for Pico-Projection Applications

Focus Free Operation
Enhances the user experience, eliminates mechanical focus wheels

Ultra Compact Engine Size
Very small and thin all-in-one package; does not require additional focus lenses; smaller than any DLP solution achieving same resolution

Low Power Consumption
Extremely power efficient even at maximum brightness

1.2 Short Throw Ratio
for variable screen sizes from a short distance – from 12” to 120” and beyond

Wide Color Gamut Range
Laser diode light sources provide the widest color gamut for vivid images

Industry leading Intense Contrast Ratio
of over 80,000:1 and pure black for striking images; pixel level modulation (no backlight) eliminates background glow effect
ST & MicroVision Co-Marketing Agreement

On Nov 10, 2016, ST and MicroVision entered a co-marketing agreement:


ST is a worldwide leader in MEMS
- More than 12 billion MEMS shipped
- Mass production of Electrostatic and Electromagnetic MEMS μ-mirrors
- Biz Model is to supply μ-mirrors and ASICs

Microvision is a leader in LBS Technology
- More than 20 years of experience
- More than 500 patents in LBS components and applications
- Biz model is to supply Engines/Components

Create a strong market position and better serve our customers:
- Cooperate in marketing MEMS scanner based solutions
- Continue to work closely on new markets and products
- Cooperate in joint Technology development and roadmap
MicroVision LBS Engines

Small Form Factor Display Engine: PSE-0403

H1 2017

- Products: Pico Projection for Small devices

Display Engine With 3D Sensing for Interactivity

H2 2017

- Products: Interactive display applications: mobile and IoT
Small Form Factor Display Engine
PSE-0403-101/102 - Key Features

- **MicroVision’s PSE-0403 display engines** offer an industry leading combination of made-for-mobile features in a small form factor
- High definition, focus free images even in motion
- Vivid, saturated colors
- Laser brightness and power efficiency
- Thinner than a pencil
- Intense contrast ratio
- Industry leading throw ratio
- Short focal length option
Short Throw Interactive Display Engine

PSE-0403sti-101 – Key Features

MicroVision is combining Projected Display + 3D Sensing into a single, integrated scanning engine for **Interactivity with projected content**

Enables new and exciting products by mimicking a Windows 10 or Android touch screen display or providing access to intermediate point cloud data

- Short Throw projection
- **Multi-touch** interactivity
- High definition *always-in-focus* images
- Vivid saturated colors
- Intense contrast ratio with true black
- Multi-mode operation:
  - Display: table top and wall mode
  - Interact: touch and point cloud modes
## Small and Ultra Small Engines

**Side by Side Comparison**

<table>
<thead>
<tr>
<th>Ultra Small Form Factor Reference Design</th>
<th>Small For Factor Display Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on ST Mono-axial Electrostatic Mirrors</td>
<td>Based on MVIS Bi-axial Electromagnetic Mirror</td>
</tr>
<tr>
<td>Volume = 3.45 cm³ Thickness = 0.5cm</td>
<td>Volume = 11.63 cm³ Thickness = 0.6cm</td>
</tr>
<tr>
<td>→ fits very slim and very small <strong>Mobile Devices</strong></td>
<td>→ fits slim, small <strong>Mobile Devices</strong></td>
</tr>
<tr>
<td><strong>Ultra Low Power</strong> consumption</td>
<td><strong>Low Power</strong> consumption</td>
</tr>
<tr>
<td>25 Lumens</td>
<td>35 Lumens</td>
</tr>
<tr>
<td><strong>Good Image Quality:</strong> 600p</td>
<td><strong>Superb Image Quality:</strong> 720p HD</td>
</tr>
</tbody>
</table>
Changing the MEMS Landscape

Building a completely new Micro-actuators portfolio:
- > 15M Mirrors shipped
- Thin Film Piezo technology in Mass Production
- Product diversification through strategic partnerships
Thank you