Piezoelectric SAW (Surface Acoustic Wave) Device with Simulated Poling Condition

R. Xu, M. Guizzetti, K. Astafiev, E. Ringgaard and T. Zawada
Meggitt A/S, Kvistgaard, Denmark

13th October 2016, COMSOL conference 2016, Munich, Germany
Outline

1. Company introduction
2. Motivation
3. Uniform orientation polarization SAW
4. Interdigital polarization SAW
5. Conclusions
1 Company introduction
Meggitt - overview

» Provides high technology products and systems for the aerospace, defense and other specialist markets, including: medical, industrial, energy, test and automotive
» 60 years experience in extreme environment engineering
» Annual sales (2012), £1,605.8 million, 10% growth in comparison to 2011
» Listed on London Stock Exchange (MGGT)
» FTSE100 company

OE 52% / Aftermarket 48%
- Civil aerospace
- Military
- Energy and other
A global presence

Over 10,000 employees worldwide

North America
- Employees: 5,790
- Locations: 31
- USA, Canada and Mexico

UK
- Employees: 2,090
- Locations: 13

Mainland Europe
- Employees: 1,450
- Locations: 7
- Denmark, France, Germany, Spain and Switzerland

Asia and RoW
- Employees: 650
- Locations: 8
- Australia, Brazil, China, India, Singapore, UAE and Vietnam
Meggitt Sensing Systems Denmark

» Meggitt A/S is a manufacturer of piezoelectric materials, components, devices
» 2-3 million units produced annually
» Major markets
  - Medical ultrasound
  - Underwater acoustics
  - Acceleration sensors
  - Flow meters
  - Energy Harvesting
Motivation
The piezoelectric effect

*Piezoelectricity:* the formation of electricity due to mechanical stress – or the formation of mechanical stress caused by an electric voltage.

Discovered by Pierre & Jacques Curie in 1880.

(a) Equilibrium
(b-c) Mechanical excitation (open and shorted conditions)
(d) Electrical excitation
Surface acoustic wave (SAW) devices

- Composed of a piezoelectric substrate where two interdigital transducers (IDT) are deposited

Application fields
- Surface sensitive sensors
  - Physical sensors
  - Chemical/biological sensors

Common materials seen in literature
- Piezoelectric crystals (Natural polarization)

Meggitt as a piezoceramic manufacturer
- Replace crystals with piezoceramics
- Higher piezoelectric coefficients (d_{33})
- Cheap manufacturing
- More advanced polarization
Our challenges on SAW devices

» Produce the same product as SAW devices, i.e. a SAW device based on a uniform orientation polarization.
  - Electroding – normally a high temperature process (> $T_c$)
  - Poling steps need to be done after electroding
  - Remove the electrode for poling and redeposit SAW electrodes, without de-poling the original polarization

» We propose a different solution
  - Interdigital poling
  - Easier manufacturing
  - But will it work?
Uniform orientation polarization SAW
Single orientation polarization SAW
The COMSOL model

- Physics – Piezo device (solid mechanics and electrostatics)
- Frequency domain (1MHz – 3 MHz)
- 2D – IDT as boundary lines
- Material – Pz27 (soft PZT material)
- Z direction polarization
- PML
- Mechanical damping (0.2 %)
- Electrical boundary conditions
  - Ground
  - Terminal (1 V) on input electrodes
- Mesh - At least 8 mesh points per wavelength
Results

Frequency response module \(|H(j\omega)| = \left| \frac{V_{out}(j\omega)}{V_{in}(j\omega)} \right|\)
Results

» SAW wave at different frequencies

1.4 MHz

1.9 MHz

2.8 MHz
4 Interdigital polarization SAW
Interdigital polarization SAW
The COMSOL model

- Physics – Piezo device (solid mechanics and electrostatics)
- Frequency domain (2.5MHz – 4.5 MHz)
- 2D – IDT as boundary lines
- Material – Pz27 (soft PZT material)
- Interdigital polarization
- PML
- Mechanical damping (0.2 %)
- Electrical boundary conditions
  - Ground
  - Terminal (1 V) input electrode
Simulating the poling process to produce IDT polarization

- **IDT polarization**
  - Introduction of a stationary study to simulate the poling before the frequency domain study
  - High poling voltage on the terminals (red) and ground on the other (black)
  - Determine the electrical field caused by the applied poling voltage
  - The field magnitude determines piezoelectric coefficient with respect to the virgin curve of the material
Simulating the poling process to produce IDT polarization

Different poling voltages (standardized fields)

- $E_{poling} = 2.5 \text{ MV/m}$
- $E_{poling} = 7.5 \text{ MV/m}$
- $E_{poling} = 12.5 \text{ MV/m}$
- $E_{poling} = 15.0 \text{ MV/m}$
Simulating the poling process to produce IDT polarization

- At 15 MV/m
- Align z-direction of the material (the poling direction) with the field direction
Results

Frequency response module $|H(j\omega)| = \left| \frac{V_{out}(j\omega)}{V_{in}(j\omega)} \right|$
Results

» SAW wave at different frequencies with a poling field of 15 MV/m
5 Conclusions
Conclusions

» Better understanding of SAW devices through COMSOL
» A interdigital poled SAW device does not perform as well as a z-direction poled device
» A fully interdigital poled SAW will works, but the surface wave generation is not pronounced
» The interdigital poled SAW device has a higher center frequency
» Capability to do poling simulations for modeling complex structures

» Special thanks
  - Michele Guizzetti (Meggitt A/S)
  - Erling Ringgaard (Meggitt A/S)
  - Konstantin Astafiev (Meggitt A/S)
  - Tomasz Zawada (Meggitt A/S)
  - Morten Siwertsen (COMSOL Denmark)
  - COMSOL Support
Thank you
Industrial manufacture of piezoceramics

1. Raw materials
2. Mixing
3. Calcining
4. Milling
5. Binder addition
6. Pressing
7. Binder burn-out
8. Sintering
9. Grinding/polishing
10. Electroding
11. Poling
12. Final inspection