

# FIRST LINE OF TITLE

## SECOND LINE OF TITLE

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présentée le 18 novembre 2020  
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laboratoire SuperScience  
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École polytechnique fédérale de Lausanne  
pour l'obtention du grade de Docteur ès Sciences  
par

Paolino Paperino

acceptée sur proposition du jury :

Prof Name Surname, président du jury  
Prof Name Surname, directeur de thèse  
Prof Name Surname, rapporteur  
Prof Name Surname, rapporteur  
Prof Name Surname, rapporteur

Lausanne, EPFL, 2020





Wings are a constraint that makes  
it possible to fly.  
— Robert Bringhurst

To my parents...



# Preface

A preface is not mandatory. It would typically be written by some other person (eg your thesis director).

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*Lausanne, 12 Mars 2011*

T. D.



# Abstract

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# Zusammenfassung

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## Résumé

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# 1 Introduction

## 1.1 AlScN as the material of the future

Since the beginning of the decade Aluminum-Scandium Nitride became more and more a common buzzword in scientific publications. The main reasons behind the increased interest on this novel materials are two: IC fabrication compatibility and most importantly increased piezoelectric coupling.

## 1.2 Material properties

The first occurrence of an alloying of aluminum and scandium was in 1971 (1) and its first application was to improve the strain resistance of Al in aeronautics application. With the advent of miniaturisation in FR front-ends the bulky Quartz crystal started to be replaced by MEMS-based resonator such as SAW, BAW, or CMR. The reason being that MEMS devices have a higher throughput and a lower footprint than quartz crystals, allowing for batch fabrication and integrability, still keeping the higher Q that mechanical systems show compared to LC tanks. In parallel to the architecture evolution of RF MEMS a range of new materials to replace quartz have been investigated, PZT, ZnO, AlN. The latter is the most important one to understand how the evolution of AlScN.

### 1.2.1 AlN

Aluminum Nitride is a binary nitride ceramic whose wurtzite phase exhibits piezoelectric properties. AlN can be deposited on a proper seed layer so that the growth is oriented in the c-axis (the perpendicular to surface axis) in a wurtzite phase. The crystal phase depends on the seed layer over which AlN is deposited. Literature (2) shows that the preferential growth substrate material for AlN is Pt, due to the lattice matching between the Hexagonal structure of AlN and the cubic phase of Pt.

### 1.3 Deposition of AlScN

Piezoelectricity in AlN is a consequence of the dipolar nature of the crystalline cell of wurtzite-type crystal. From the first studies using DFT (1) (3) show that the doping of aluminum with scandium increases the piezoelectric coupling coefficient of AlN. The reason lies in the lattice distortion induced by Sc in AlN, causing a structural phase transition. According to (3) a second effect on the piezoelectricity improvement lies in the hybridisation of ionic into covalent bond, due to the lower electronegativity of Sc compared to Al (1.36 vs 1.61). An increase of the concentration of Sc results in an enhancement of response up to 43% Sc followed by a drastic performance drop. The actual state-of-art includes depositions carried with Sputtering (4) (5) (6), co-sputtering (3), Molecular Beam Epitaxy (7) (8) (?), Metal-Organic CVD (9)

#### 1.3.1 Sputtering of AlScN

The first and most simple to describe method for AlScN deposition is sputtering from an alloyed target using reactive sputtering.

#### 1.3.2 Co-Sputtering of AlScN

#### 1.3.3 MBE of AlScN

#### 1.3.4 MOCVD of AlScN

### 1.4 Types of MEMS Resonator



## Body 1 Part I



## 2 State of research

In this chapter we will see some examples of tables and figures.

### 2.1 Fabrication of AlScN based Contour Mode resonators

#### 2.1.1 Sputtering deposition optimisation

Carried over from the doctoral studies of Kaitlin M. Howell (10) the first objective of research in AlScN technologies is to optimize the deposition of AlScN in the Spider600 cluster tool at CMi. The Spider600 is a sputtering cluster which allows deposition from different targets in the same fabrication round, without breaking the vacuum

#### AlScN on AlN

#### 2.1.2 Inductively coupled plasma etching

#### 2.1.3 CMR based oscillator

Let's see how to make a well designed table.

The table 2.1 is a floating table and was obtained with the following code:

```
1 \begin{table}[tb]
```

Table 2.1: A floating table.

name	weight	food
mouse	10 g	cheese
cat	1 kg	mice
dog	10 kg	cats
t-rex	10 Mg	dogs

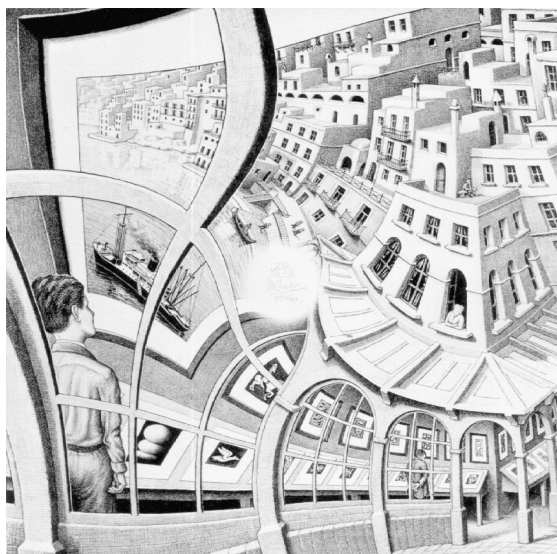


Figure 2.1: A floating figure (the lithograph *Galleria di stampe*, of M. Escher, got from <http://www.mcescher.com/>).

```
2 \caption[A floating table]{A floating table.}
3 \label{tab:example}
4 \centering
5 \begin{tabular}{ccc}
6 \toprule
7     name      & weight & food   \\\
8 \midrule
9     mouse     & 10 g   & cheese \\\
10    cat       & 1 kg   & mice   \\\
11    dog       & 10 kg  & cats   \\\
12    t-rex     & 10 Mg  & dogs   \\\
13 \bottomrule
14 \end{tabular}
15 \end{table}
```

## 2.2 Figures

Let's see now how to put one or several images in your text.

The figure 2.1 is a floating figure and was obtained with the following code:

```
1 \begin{figure}[tb]
2 \centering
3 \includegraphics[width=0.5\columnwidth]{galleria_stampe}
4 \caption[A floating figure]{A floating figure ... }
5 \label{fig:galleria}
6 \end{figure}
```

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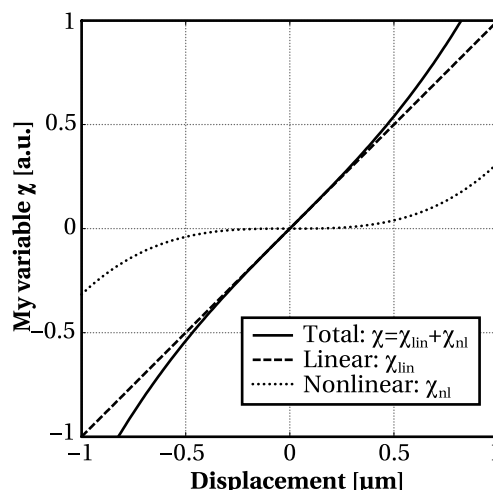


Figure 2.2: A floating figure with text typeset in "Utopia LaTeX", a font provided in the template folder for typesetting figures with greek characters. The text has been "outlined" for best compatibility with the repro during the printing.

consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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The figure 2.3 is a floating figure and was obtained with the following code:

```

1 \begin{figure}[tb]
2 \centering
3 \subfloat[Asia personas duo.]
4 {\includegraphics[width=.45\columnwidth]{lorem}} \quad
5 \subfloat[Pan ma signo.]
6 {\label{fig:ipsum}}%
7 \includegraphics[width=.45\columnwidth]{ipsum}} \\\
8 \subfloat[Methodicamente o uno.]
9 {\includegraphics[width=.45\columnwidth]{dolor}} \quad
10 \subfloat[Titulo debitas.]
11 {\includegraphics[width=.45\columnwidth]{sit}}
12 \caption[Tu duo titulo debitas latente]{Tu duo titulo debitas latente.}

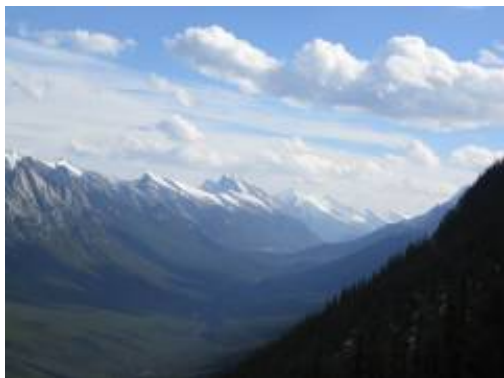
```



(a) Asia personas duo.



(b) Pan ma signo.



(c) Methodicamente o uno.



(d) Titulo debitas.

Figure 2.3: Tu duo titulo debitas latente.

```
13 \label{fig:esempio}  
14 \end{figure}
```

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## Body 2 Part II



## 3 Future research

In this chapter we will see some examples of mathematics.

### 3.1 N77 N78 and N79 band

#### 3.1.1 Stepper-based fabrication of electrodes

### 3.2 AlScN on SiC power

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$$\frac{d}{dt} \begin{bmatrix} P_0 \\ P_I \\ P_T \end{bmatrix} = \begin{bmatrix} \frac{P_I}{\tau_{I0}} + \frac{P_T}{\tau_T} - \frac{P_0}{\tau_{ex}} \\ -\frac{P_I}{\tau_{I0}} - \frac{P_I}{\tau_{isc}} + \frac{P_0}{\tau_{ex}} \\ \frac{P_I}{\tau_{isc}} - \frac{P_T}{\tau_T} \end{bmatrix} \quad (3.1)$$

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$$\bar{I}_f(\vec{r}) = \gamma(\vec{r}) \left( 1 - \frac{\tau_T P_T^{eq} \left( 1 - \exp\left(-\frac{(T_p - t_p)}{\tau_T}\right) \right)}{1 - \exp\left(-\frac{(T_p - t_p)}{\tau_T} + k_2 t_p\right)} \times \frac{(\exp(k_2 t_p) - 1)}{t_p} \right) \quad (3.2)$$

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## 4 Another chapter

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### 4.1 One section

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#### 4.1.1 One subsection

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus.

#### **Chapter 4. Another chapter**

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## A An appendix

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# Bibliography

- [1] M. A. Caro, S. Zhang, T. Riekkinen, M. Ylilammi, M. A. Moram, O. Lopez-Acevedo, J. Molarius, and T. Laurila, "Piezoelectric coefficients and spontaneous polarization of ScAlN," *Journal of Physics: Condensed Matter*, vol. 27, p. 245901, June 2015.
- [2] J. Xiong, H.-s. Gu, K. Hu, and M.-z. Hu, "Influence of substrate metals on the crystal growth of AlN films," *International Journal of Minerals, Metallurgy, and Materials*, vol. 17, pp. 98–103, Feb. 2010.
- [3] M. Akiyama, T. Kamohara, K. Kano, A. Teshigahara, Y. Takeuchi, and N. Kawahara, "Enhancement of Piezoelectric Response in Scandium Aluminum Nitride Alloy Thin Films Prepared by Dual Reactive Cosputtering," *Advanced Materials*, vol. 21, no. 5, pp. 593–596, 2009.
- [4] B. Heinz, S. Mertin, O. Rattunde, M. A. Dubois, S. Nicolay, G. Christmann, M. Tschirky, and P. Mural, "Sputter deposition technology for Al(1-x)ScxN films with high Sc concentration," in *2017 China Semiconductor Technology International Conference (CSTIC)*, pp. 1–3, Mar. 2017. ISSN: null.
- [5] L. Colombo, A. Kochhar, C. Xu, G. Piazza, S. Mishin, and Y. Oshmyansky, "Investigation of 20% scandium-doped aluminum nitride films for MEMS laterally vibrating resonators," in *2017 IEEE International Ultrasonics Symposium (IUS)*, pp. 1–4, Sept. 2017.
- [6] V. Felmetger, M. Mikhov, M. Ramezani, and R. Tabrizian, "Sputter Process Optimization for Al<sub>0.7</sub>Sc<sub>0.3</sub>N Piezoelectric Films," in *2019 IEEE International Ultrasonics Symposium (IUS)*, pp. 2600–2603, Oct. 2019. ISSN: 1948-5727.
- [7] M. Park and A. Ansari, "Epitaxial Al<sub>0.77</sub>Sc<sub>0.23</sub>N SAW and Lamb Wave Resonators," p. 3.
- [8] J. Casamento, "Physical Properties of Epitaxial ScAlN," p. 3.
- [9] S. Leone, J. Ligl, C. Manz, L. Kirste, T. Fuchs, H. Menner, M. Prescher, J. Wiegert, A. Žukauskaitė, R. Quay, and O. Ambacher, "Metal-Organic Chemical Vapor Deposition of Aluminum Scandium Nitride," *physica status solidi*

## Bibliography

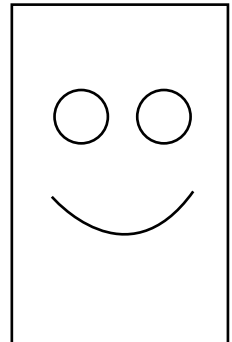
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(RRL) – *Rapid Research Letters*, vol. 14, no. 1, p. 1900535, 2020. \_eprint:  
<https://onlinelibrary.wiley.com/doi/pdf/10.1002/pssr.201900535>.

- [10] K. M. Howell, *Dielectric Actuation Techniques at the Nanoscale: Piezoelectricity and Flexoelectricity*. PhD thesis, 2019. Number: THESIS Publisher: EPFL.

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70  
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Date of Birth : 2nd of October 1981  
Nationality : Swiss  
Legally work : legally work in EU  
Marital status : with partner  
Children : none  
  
Languages : Chinese/Mandarin, English, French, German  
Education level : Bachelors degree  
Hospitality work experience : 3-5 years  
Special experience : Europe work experience  
  
Date of availability : September 2009  
Current location : Africa  
Travelling Status : will be travelling single status  
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Position(s) sought : Permanent position for graduates  
Department(s) sought : Food & Beverage Bar/Sommelier



## Personal profile:

As a Bachelor of Business Administration and after obtaining first relevant international work experience within the hospitality industry, I am now ready to take on new responsibilities to further my professional career. My key strengths include strong analytical and logical skills, an eye for detail, communication and interpersonal skills.  
I enjoy working in a team and help others progress. At the same time I work well independently.  
As a highly motivated and driven individual I strive on taking up challenges.

## Interests:

Travelling  
Foreign Cultures  
Photography  
Sports

## Educational qualifications:

Oct 99 - Feb 02                      Higher Diploma (Hotel Management)  
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## Employment history:

Mar 04 - Ongoing	<p>Assistant Manager (Rooms Division/Food &amp; Beverage)</p> <p>Hotel Atlantic Kempinski Hamburg <a href="http://www.kempinski.com">www.kempinski.com</a> 5 star business hotel, part of Leading Hotels of the World 412 guest rooms, large function facilities, 3 food &amp; beverage outlets</p> <p>Optimization of bar procedures, reinforcing SOPs</p> <p>Developing &amp; implementing promotions</p> <p>Responsible for day-to-day operations</p> <p>Optimization and streamlining of housekeeping and laundry procedures</p> <p>Implementation of new SOPs</p> <p>Analyzing monthly reports for rooms division performance and sub departments</p>
Mar 03 - Mar 04	<p>Management Trainee</p> <p>Hospitality Graduate Recruitment <a href="http://www.h-g-r.com">www.h-g-r.com</a> Leading company for placements within the Hospitality industry.</p> <p>Traineeship covering all aspects of an online recruitment agency.</p>
Mar 02 - Mar 03	<p>Management Trainee (Rooms Division)</p> <p>Hyatt Regency Xian, China <a href="http://www.hyatt.com">www.hyatt.com</a> 5 star business hotel 404 guest rooms, 4 food &amp; beverage outlets</p> <p>Traineeship covering all rooms division departments on operational as well as supervisory level.</p>

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