Flashlamp Annealing for Improved Ferroelectric Junctions

Master's Degree Project

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Contents

Abstract

Abstract here!

1 Introduction

Mål: Introducera området och ge en överblick.[1]

2 Semiconductors and Ferroelectrics

Mål: Klargöra varför III-V (utgå från Si) och FE är intressant. Varför gör vi detta? Vad är applikationern? Få med FTJ här!

2.1 III-V Semiconductors

Mål: Redogör för varför III-V är intressant. Direkt bandgap, lägre DOS –¿ FTJ

2.2 Ferroelectricity

Mål: Basics of FE; Kristallstrukturer (faser), Polarisation, Domäner och PE-kurvor.

2.2.1 $HfZrO_2$

Mål: Redogör för FE-HfO_2 och beskriv hur Zr kommer in i bilden.

2.3 Energyband Theory and Leakage Mechanics

Mål: Redogör för hur energibanden ser ut med Semiconductor-Insulator-Metal-cap och gå igenom de olika tunnelsätten.

3 Fabrication

Mål: Redogör för hela processen på LNL.

3.1 Processing Methods

Mål: Redogör för dem mest intressanta/relevanta metoderna. Kanske bara ALD och FLA?

3.1.1 ALD

3.1.2 Flashlamp Annealing

3.2 Sample Fabrication Process

Mål: Redogör för hela min process.

4 Electrical Charcterization

Mål: Redogör för metoderna på E-huset.

4.1 PUND and Endurance

4.2 UniCV

Frågor att besvara:

- Hur funkar metoden?
- Vilka defekter ser vi med denna metod?

5 Results and Analysis

5.1 Flashlamp Intensity and Film Temperature

Crystalization of the hafnia films using the flash lamp annealing (FLA) technique does not immediately reveal the temperature achieved in the films. Due to the short time frames and the geometry of the FLA setup, one must simulate the achieved temperature in the film from the compositional structure of the samples and the measured peak backside temperature during annealing. Furthermore, the experiment parameters of preheating temperature and flash duration are crucial for the simulations and are throughout this work set to 250 °C and 5 ms respectively. Figure 1 shows the resulting film temperature depending on flash intensity with the choosen set parameters.

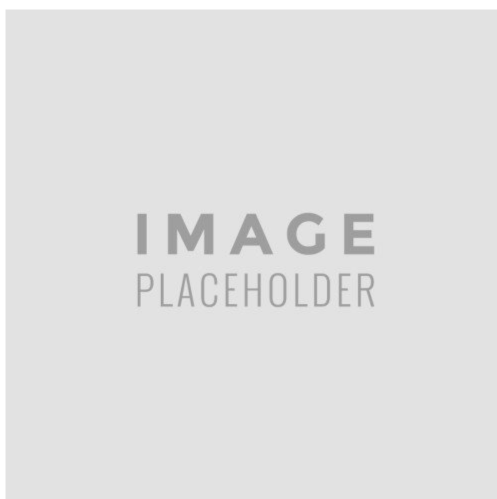


Figure 1: Figure showing how flashintensity relates to the peaktemperarure of the films through simulations. From this figure onwards we can then stick to Peak Temperature instead of Flash Intensity.

Explain in detail the figure above here and conclude the subsection. What type of figure (s) can I expect here??

5.2 Sample Specifications and Characterization

In addition to the samples of focus in this work, samples were processed using RTP as the annealing method in paralell with FLA samples. These samples proves as a point of comparison for the characterization of the FLA samples throughout the work. The RTP samples were annealed at a temperature of 600 °C for 30 seconds. Through the electrical characterization described in Section 4.1 the remnant polarization (P_r), coercive field (E_c) and endurance were measured and tabulated in table 1.

Table 1: Electrical characteristics for the RTP reference samples measured using a cycling voltage of 3 V.

PUND and Endurance			
Remnant Polarization	P_r	29.03 ± 0.21	μC/cm^2
Coercive Field	E_c	1.23 ± 0.18	MV/cm
Endurance		0.23 ± 0.11	10^5 cycles

The processing of the FLA samples are outlined in Section 3.2. For the first FLA series, hereby denoted sample series 1, the flash intensity was varied between 15-32.5 J/cm^2 to reach different peak temperatures in the film. The film deposition and annealing conditions for these samples are summarized in table 2.

Table 2: Selected processing conditions for sample series 1.

Sample Number		1	2	3	4	5
HZO						
Growth Temperature	[°C]	200	200	200	200	200
Film Thickness	[nm]	10	10	10	10	10
FLA						
Preheat Temperature	[°C]	250	250	250	250	250
Flash Intensity	[J/cm^2]	**15**	**20**	**25**	**30**	**32.5**
Number of Flashes		1	1	1	1	1

Resulting electrical characterization from sample series 1 are shown in figure 2. Samples annealed with an intensity less than 25 J/cm^2 did not show any ferroelectric behaviour and are hence omitted from some of the figures. As shown in figure 2a and b the PUND characteristics show ferroelectric behaviour with a strong dependance on peak film temperature. However, for higher peak temperatures these characteristics decline to both weaker polarization response and higher coercive fields which is undesireable. The peak PUND performance at 30 J/cm^2 does not reach the characteristics of the RTP references outlined in table 1 which shows that the energy deposited during the annealing process is not enough to crystalize the entire HZO film while not inducing other effects to reduce the ferroelectric response.

Although reduced PUND characteristics were found for these samples, figure 2c show an increased endurance for the flash annealed samples compared to the RTP reference.

6 Conclusion

Mål: Wrap it up. Lägg fram de främsta resultaten/ideerna och ge tips på hur man kan undersöka vidare.

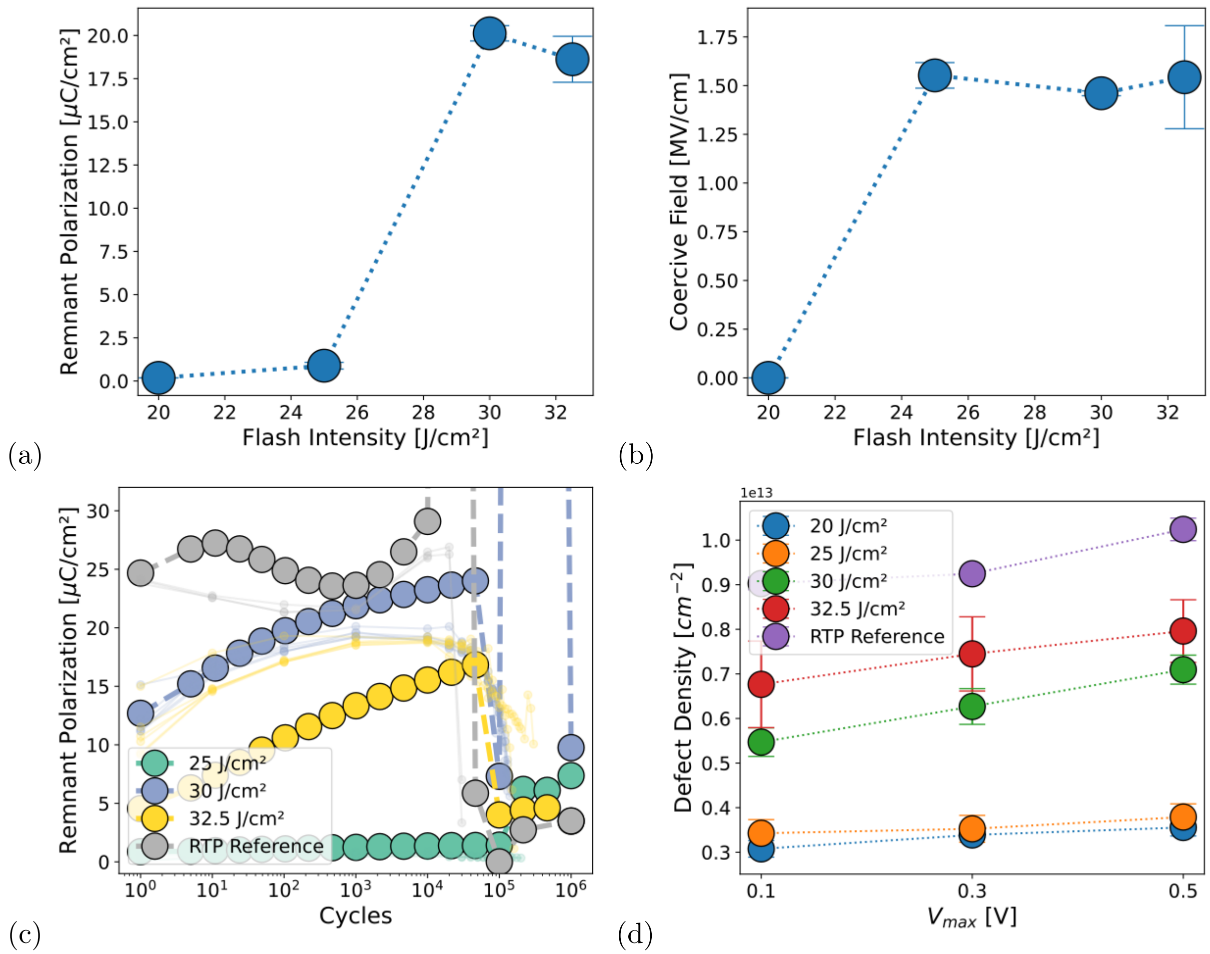
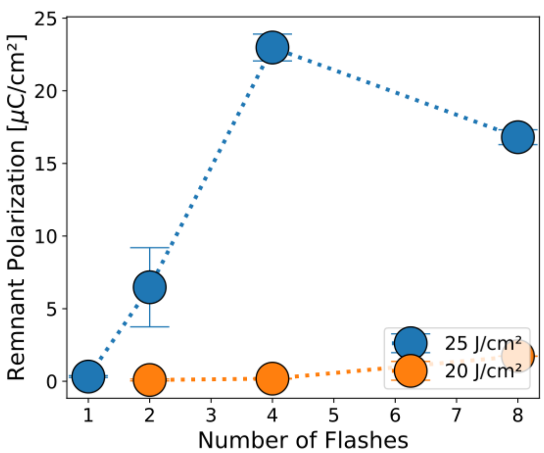


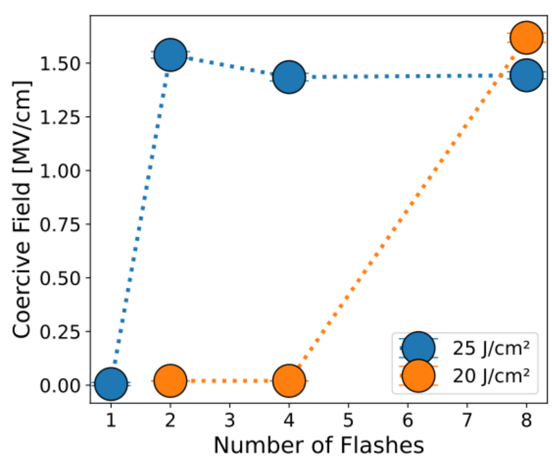
Figure 2: Figure showing all measured data from an intensity-varied batch. Low-doped subtrate, 200C ALD, HZO 1:1, 250C preheat, 5ms flash. RTP reference is included for Endurance and Defect Density.

7 References

[1] R. Atle, "Development of ferroelectric hafnium oxide for negative capacitance field effect transistors," *LUP Student Papers*, 2019.



(a)



(b)

Figure 3: Figure showing Pr and Ec trends from flashnumber-varied batches. Low-doped subtrate, 200C ALD, HZO 1:1, 250C preheat, 5ms flash at $25\,\mathrm{J/cm^2}$ and $20\,\mathrm{J/cm^2}$.

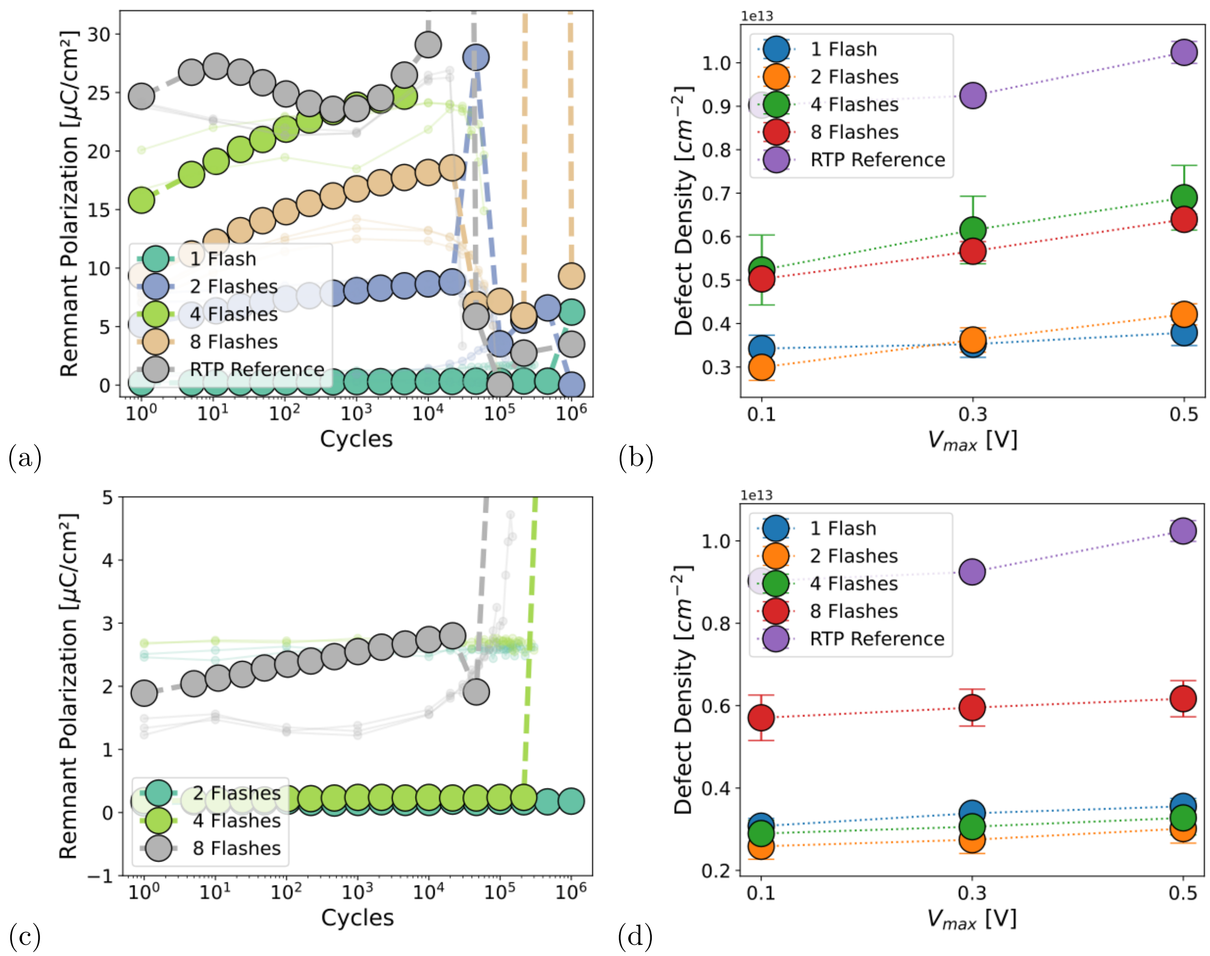


Figure 4: Figure showing Endurance and Defect Density from flashnumber-varied batches. Low-doped subtrate, 200C ALD, HZO 1:1, 250C preheat, 5ms flash at 20 J/cm^2. RTP reference is included.

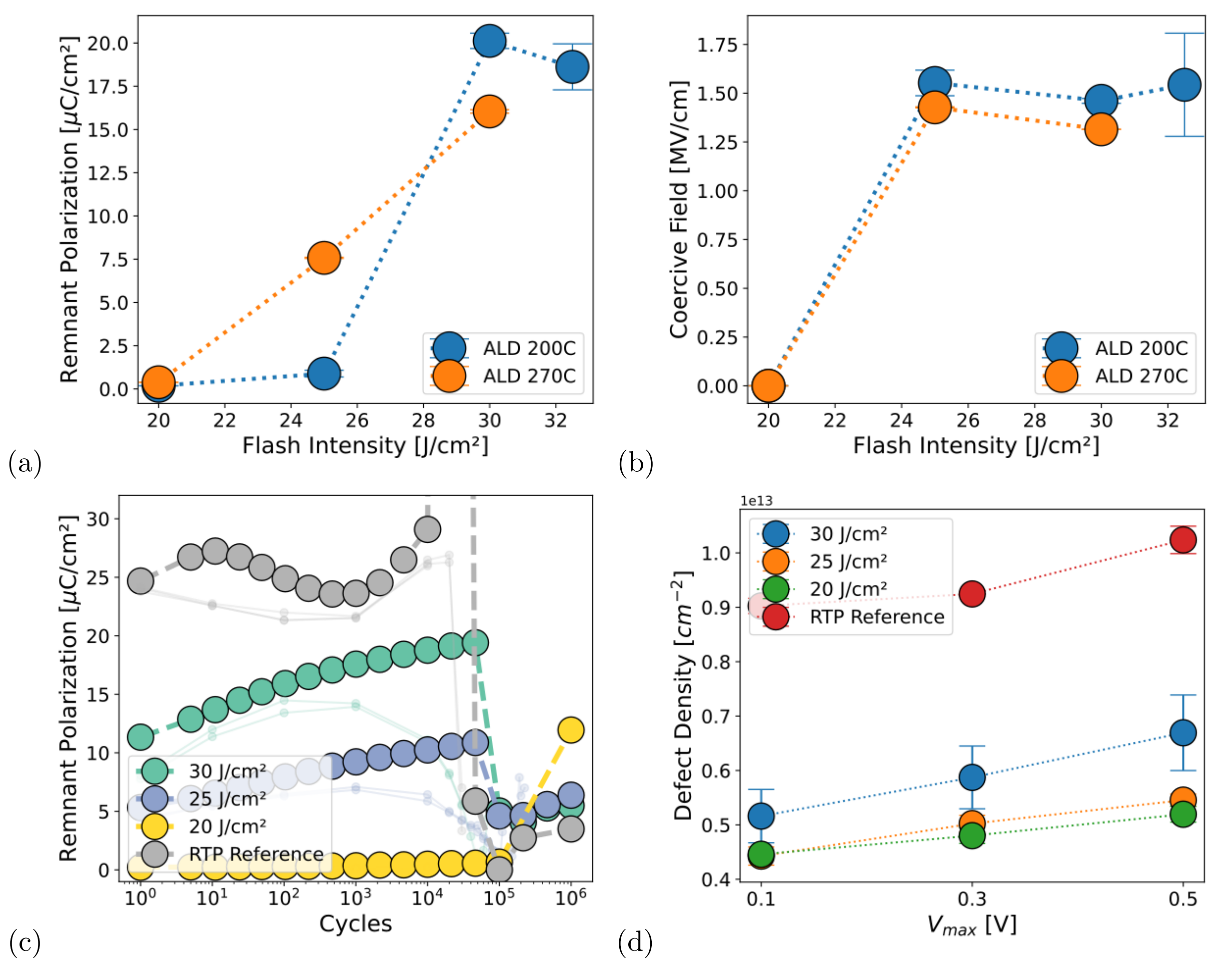
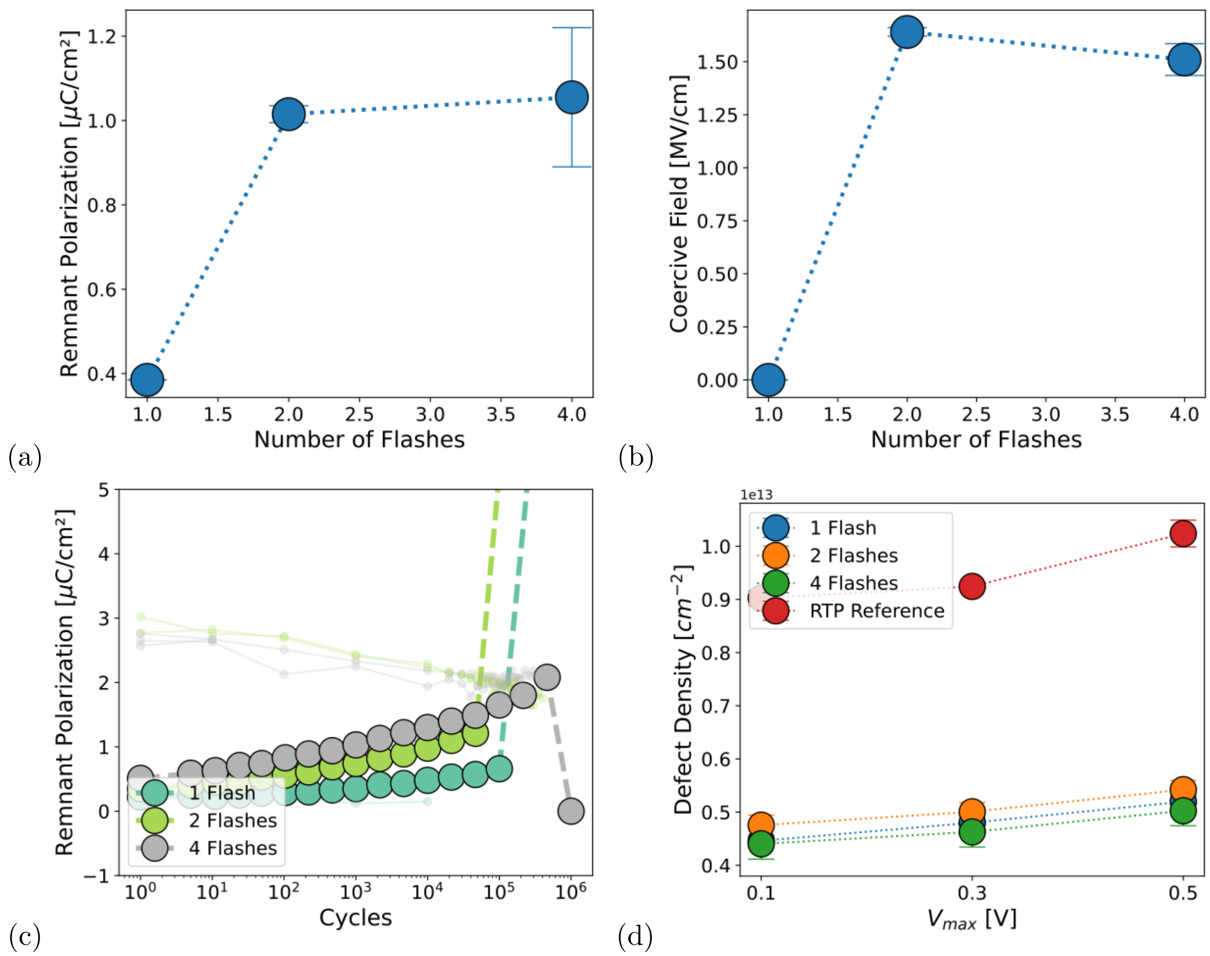


Figure 5: Figure showing all measured data from an intensity-varied batch. Low-doped subtrate, 270C ALD, HZO 1:1, 250C preheat, 5ms flash. RTP reference is included for Endurance and Defect Density.



(a) (b) (c) (d)

Figure 6: Figure showing all measured data from a flashnumber-varied batch. Low-doped subtrate, 270C ALD, HZO 1:1, 250C preheat, 5ms flash.