

On the Critical Threshold for the Expansion of a Single Shockley-Type Stacking Fault in n-Type 4H-SiC

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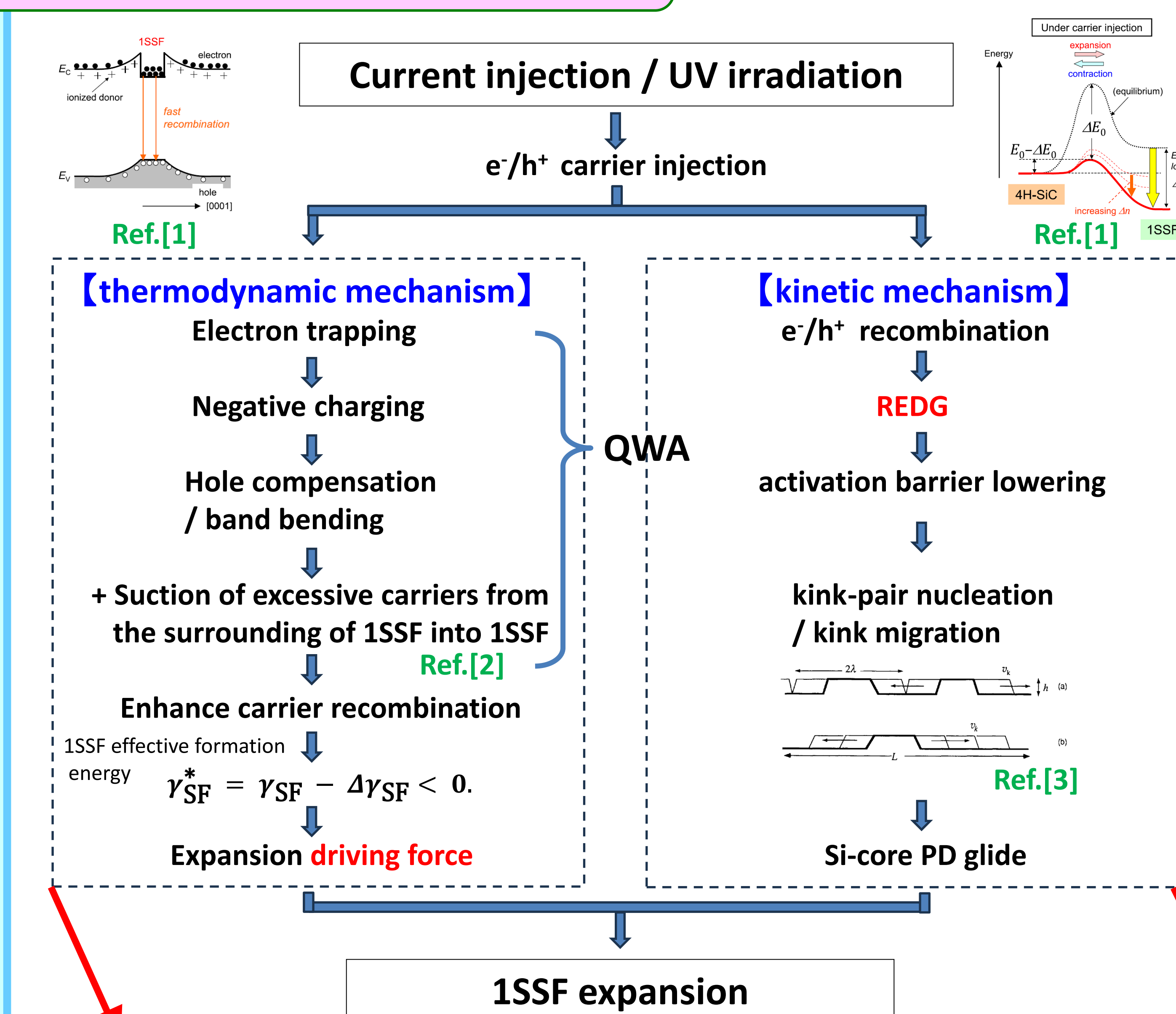
The objective of this study

To quantitatively establish the relationship between forward-bias **current stress** and **UV irradiation** for 1SSF expansion.

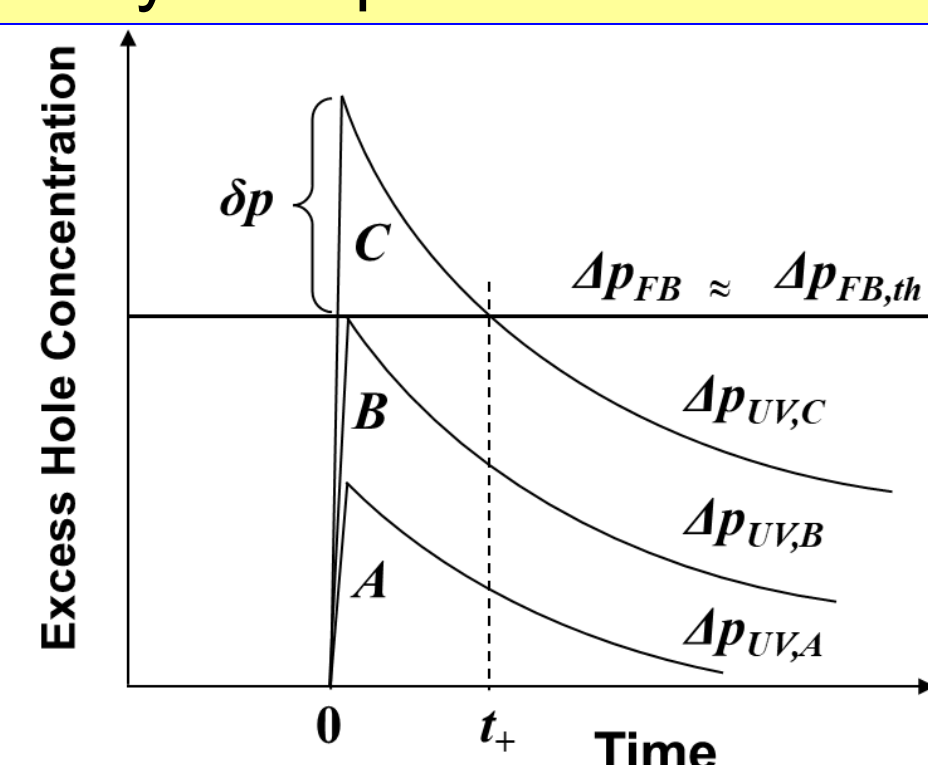
Summary

- Forward-bias **current stress** and **UV irradiation** were sequentially applied to **the same 1SSFs**, with low-temperature annealing between tests.
- Re-expansion thresholds were substantially lower than the initial expansion thresholds.
- **Two distinct types of equivalence**—**expansion threshold** and **expansion extent**—must be considered when quantitatively relating forward-bias current stress to UV irradiation.
- UV irradiation conditions must balance **detection sensitivity** against **screening overkill**.

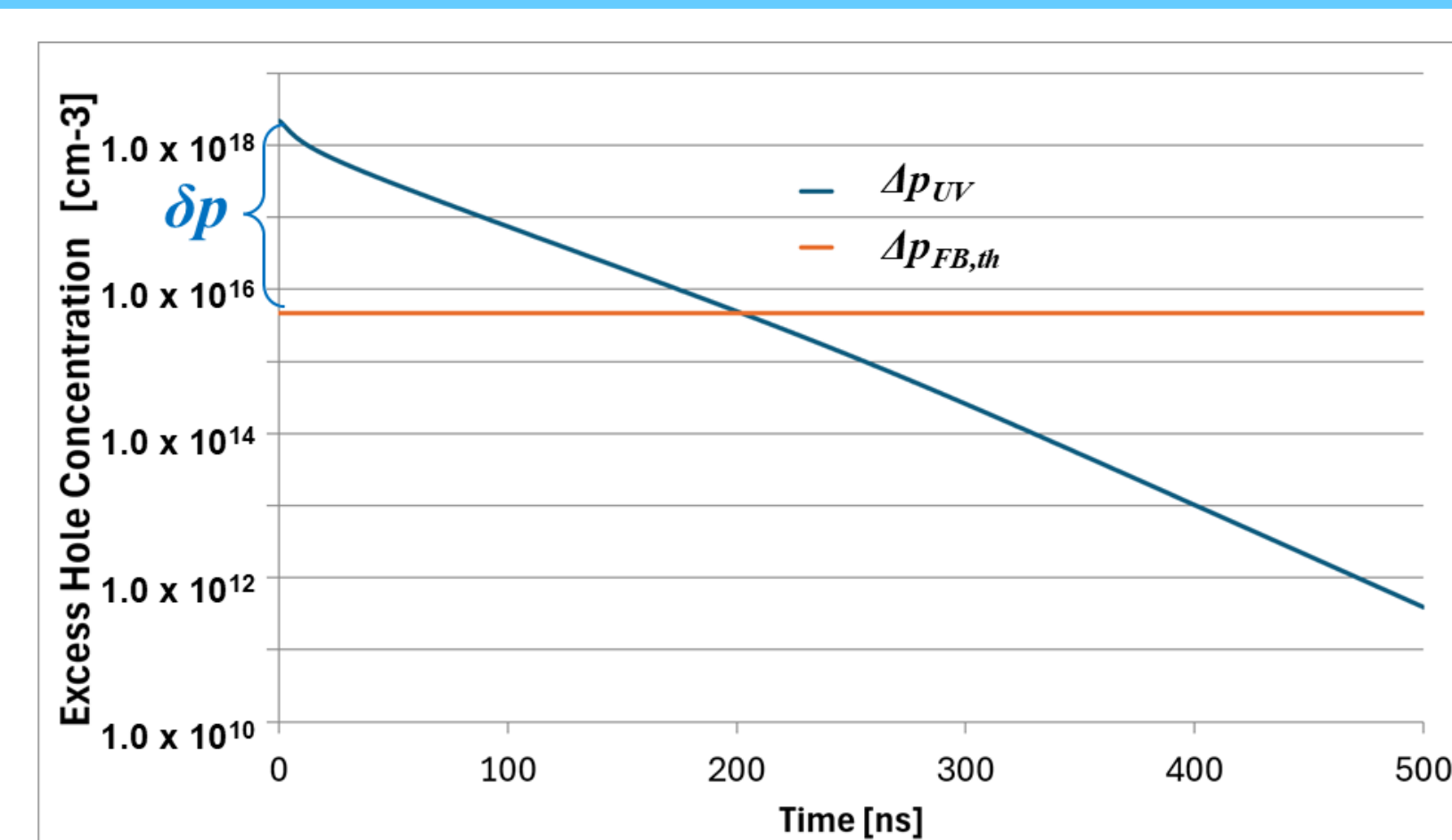
1SSF Expansion Mechanism



Equivalency of expansion threshold



- Case A :**
Sustained expansion does not occur.
- Case B :**
No finite interval above the threshold exists, and sustained expansion is not expected.
- Case C :**
The concentration exceeds the threshold for a finite interval, during which a driving force for expansion exists



Calculated temporal variation of the excess hole concentration for **1SSF C** under forward-bias current stress at 150 A/cm² and pulsed UV irradiation at 28.2 W/cm², with $\tau_{HL} = 100$ ns

UV irradiance optimization:
 $\delta p \uparrow$: improves detection sensitivity; $\delta p \downarrow$: suppresses overkill.

References:

- [1] T. Kimoto, and H. Watanabe, Appl. Phys. Express 13, 120101 (2020).
[2] K. Maeda, S. Asada, K. Murata, and H. Tsuchida, J. Appl. Phys. 139, 145703 (2026).
[3] K. Maeda and S. Takeuchi, Dislocations in Solids, 10, ed. (North-Holland, Amsterdam, 1996) pp.443-504.

Experiments and Results

Sample structures and chip IDs

Wafer	Chip ID		p ⁺ anode	n ⁻ drift	n ⁺ buffer	n ⁺ substrate
#1	a, b	Thickness [μm]	0.5	19	3.0	350
		Doping [cm ⁻³]	5×10 ¹⁹	1×10 ¹⁶	1×10 ¹⁸	6×10 ¹⁸
#2	c, d	Thickness [μm]	0.5	9.1	1.0	350
		Doping [cm ⁻³]	5×10 ¹⁹	4×10 ¹⁵	1×10 ¹⁸	6×10 ¹⁸

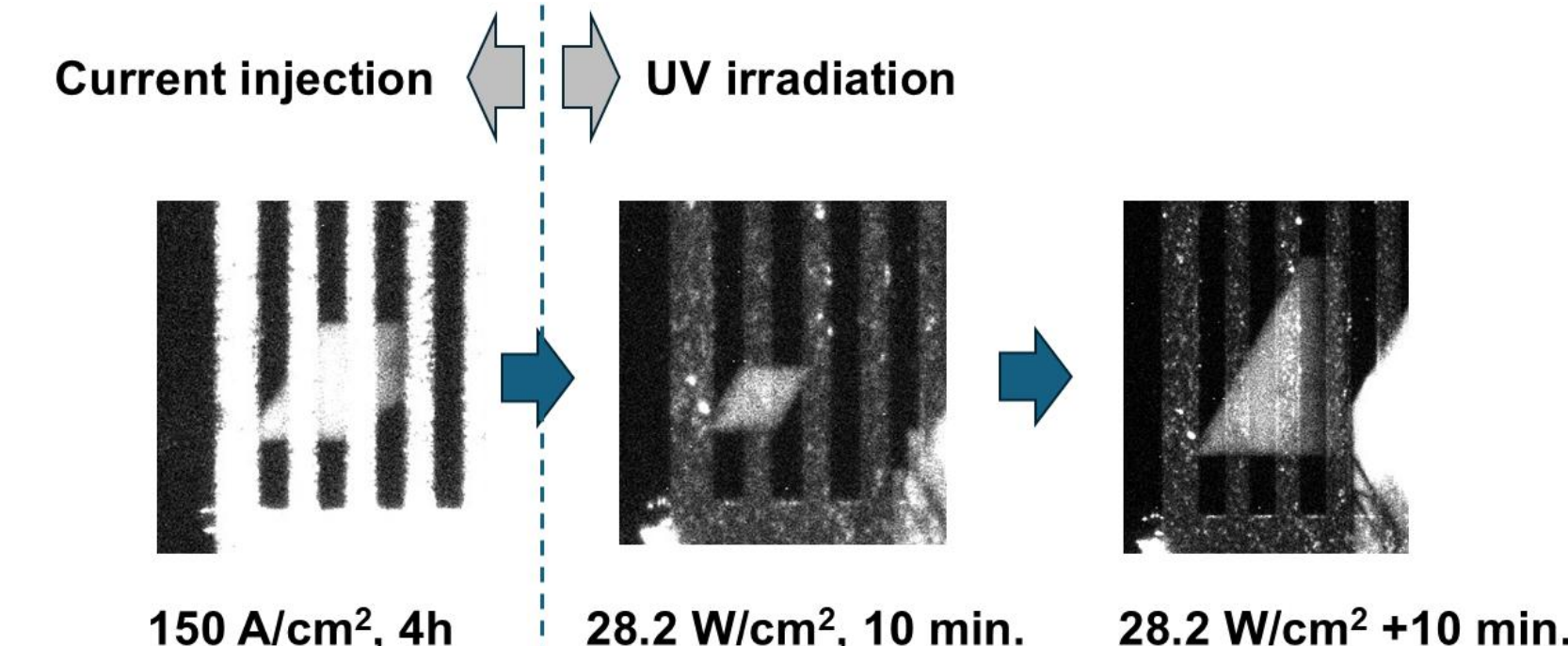
Summary of forward-bias current-stress results

Chip ID	SF ID	Current Stress Sequence
a	A	450 A/cm ² 500 A/cm ² C 72 hrs 350 A/cm ² C 24 hrs 200 A/cm ² C 24 hrs 150 A/cm ²
b	B	450 A/cm ² 500 A/cm ² C 12 hrs 450 A/cm ² C 12 hrs 350 A/cm ² C 24 hrs 250 A/cm ² C 24 hrs 200 A/cm ² C 24 hrs 150 A/cm ²
c	C	500 A/cm ² C 24 hrs 450 A/cm ² C 24 hrs 250 A/cm ² C 16 hrs 200 A/cm ² C 12 hrs 150 A/cm ² C 24 hrs 100 A/cm ²
d	D	300 A/cm ² C 48 hrs 325 A/cm ² 350 A/cm ² C 48 hrs 100 A/cm ²

Expansion thresholds for the initial expansion and re-expansion after contraction

SF ID	Wafer #1		Wafer #2	
	Initial Expansion	Re-Expansion after Contraction	Initial Expansion	Re-Expansion after Contraction
A	500 A/cm ²	≧ 150 A/cm ²	> 500 A/cm ²	150 A/cm ²
B	> 500 A/cm ²	≧ 150 A/cm ²	350 A/cm ²	≧ 100 A/cm ²

Equivalency of expansion extent



PL images of **1SSF C** after current stress and subsequent UV irradiation.

The cumulative recombination density:

$$R_{tot,FB} D T_{FB} = f_{rep} T_{UV} \int_0^{t_+} R_{tot,UV}(t) dt$$

where $R_{tot} = R_{SRH} + R_{BB} + R_{Auger}$

D = duty cycle, T_{FB} = current stress time,

f_{rep} = repetition frequency, T_{UV} = irradiation time

(0 to t_+) = the interval in which δp_{UV} exceeds $\delta p_{FB,th}$