

Influence of Ion Implantation and Epitaxial Overgrowth on the Charge Carrier Lifetime in 4H-SiC Epilayer Stacks

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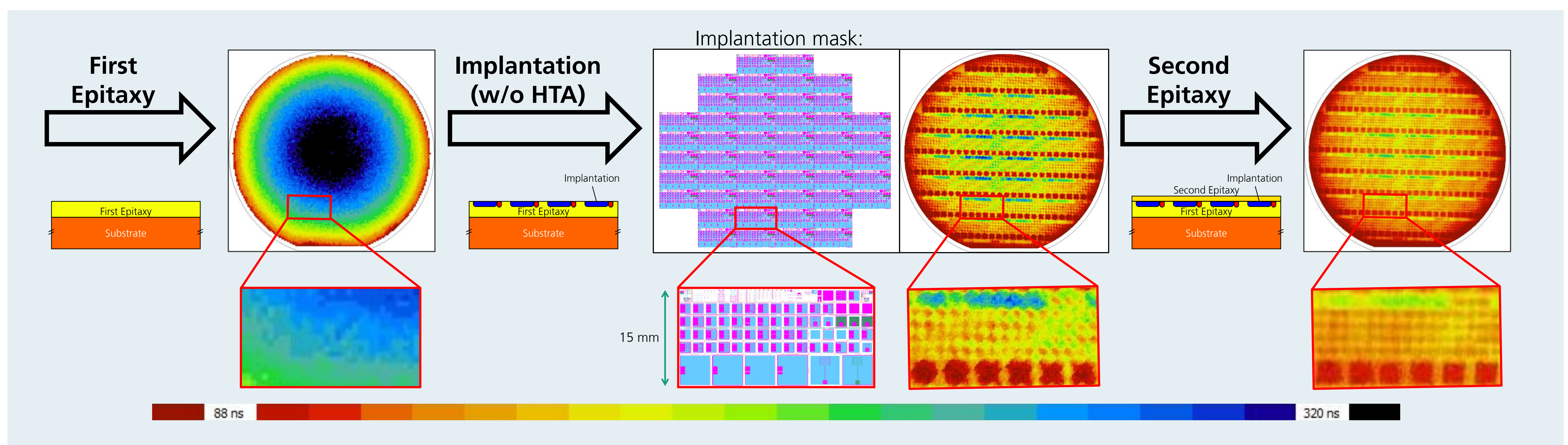
Motivation:

- Within our institute a monolithically integrated two-pole SiC solidstate circuit breaker (SSCB) has been designed [1]
- At various steps along the process chain of the device the effective charge carrier lifetime as been measured
- The lifetime of minority charge carriers plays an important role in the application of high-voltage bipolar devices [2]
- Processing steps such as ion implantation can significantly influence the effective carrier lifetime in the epitaxial layer [3]

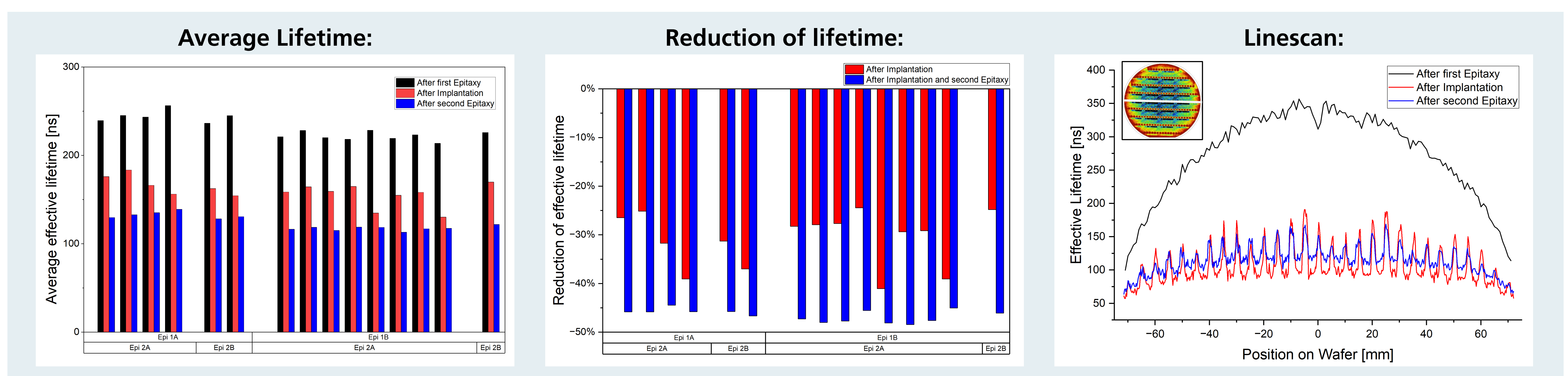
Experimental setup:

- Growth of two epitaxial layers using AIXTRON planetary reactors G10-SiC:
 - First epitaxy: **Spec 1A:** 13 μm layer @ $1 \times 10^{16} \text{ cm}^{-3}$
Spec 1B: 12 μm layer @ $7 \times 10^{15} \text{ cm}^{-3}$
 - Second epitaxy: **Spec 2A:** 1.0 μm layer @ $7 \times 10^{16} \text{ cm}^{-3}$
Spec 2B: 0.7 μm layer @ $2 \times 10^{17} \text{ cm}^{-3}$
- Implantation of aluminum and nitrogen using an Axcelis OptimaMDx ion implanter – without high-temperature annealing (HTA)
- Measurement of lifetime by microwave detected photoconductivity decay (μ -PCD) using a Semilab WT-2000

Lifetime Maps:



Development of Lifetime:



- Wafers with same first epitaxial layer exhibit similar average lifetime
- Implantation induces reduction of lifetime (implantation mask visible in map)
 - Implantation can generate carbon vacancies, resulting in lower lifetime [3]
 - However, the effect varies in intensity, even within the same groups
- Second epitaxial layer with higher doping further influences the lifetime
 - Lifetime in implanted and non-implanted areas converge (see linescan)
 - Epitaxial process acts as high-temperature annealing, causing interstitial carbon atoms to fill the carbon vacancies in the implanted regions

Conclusion and outlook

- Implantation has strong effect on effective lifetime in epitaxial layers by affecting the concentration of carbon vacancies [3]
- Overgrowth of second epitaxial layer masks this effect and can acts as thermal annealing, further influencing the carbon vacancies
- Further experiments can be conducted, how the process chain can be optimized to preserve the charge carrier lifetime

1 N. Boettcher and T. Erlbacher, IEEE Electron Device Letters, vol. 42, no. 10, pp. 1516-1519, Oct. 2021, doi: 10.1109/LED.2021.3102935.

2 M. E. Levinstein et al., IEEE Transactions on Electron Devices, vol. 48, no. 8, pp. 1703-1710, Aug. 2001, doi: 10.1109/16.936692.

3 J. Erlekampf, B. Kallinger, J. Weiße, M. Rommel, P. Berwian, J. Friedrich, T. Erlbacher; J. Appl. Phys. 28 July 2019; 126 (4): 045701. <https://doi.org/10.1063/1.5092429>.



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