

Alternative silicon and carbon precursors for 4H-SiC epitaxy



M. Titl¹⁾, C. Wißgott¹⁾, M. Pfeffer²⁾, J. Koehler²⁾, K. Albrecht²⁾, B. Kallinger¹⁾

maximilian.titl@iisb.fraunhofer.de

¹⁾ Fraunhofer Institute for Integrated Systems and Device Technology, IISB, Schottkystraße 10, 91058 Erlangen, Germany

²⁾ AIXTRON SE, Schottkystraße 10, 91058 Erlangen, Germany



1.) MOTIVATION:

- Alternative precursors are well studied in single wafer reactors^{1,2,3} but not in industrial scale warm-wall CVD reactors such as **AIXTRON G10-SiC**
- Non-standard precursors are needed for **isotopically pure ²⁸Si¹²C layers**
- Higher epitaxial growth rates reduce manufacturing time, energy consumption, and cost
- Current precursor combinations are limited in their growth rate

Goal:

Identify new robust precursor combinations for 4H-SiC homoepitaxy that maintain excellent layer quality and are suitable for quantum applications and high-rate epitaxy

2.) EXPERIMENTAL PLAN:

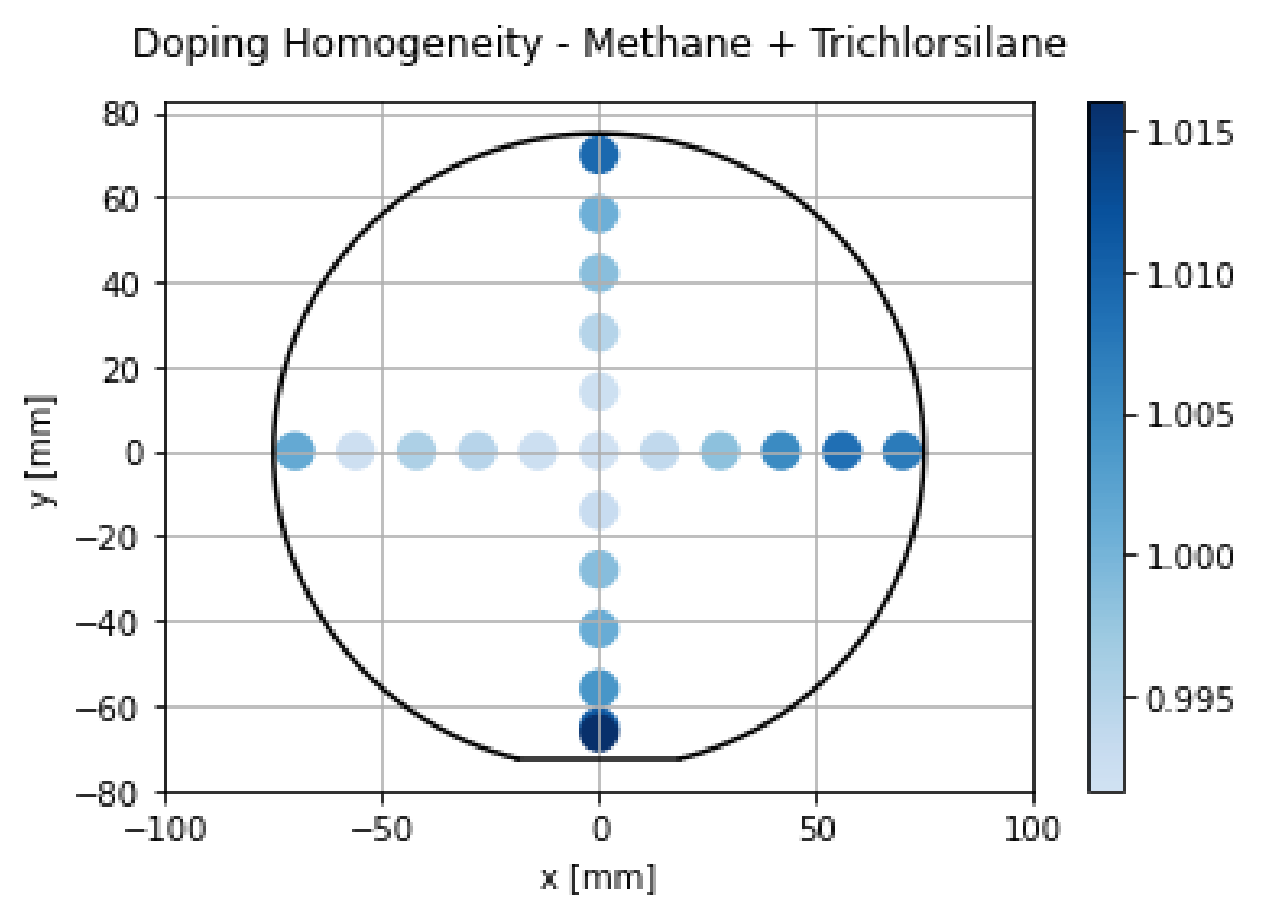
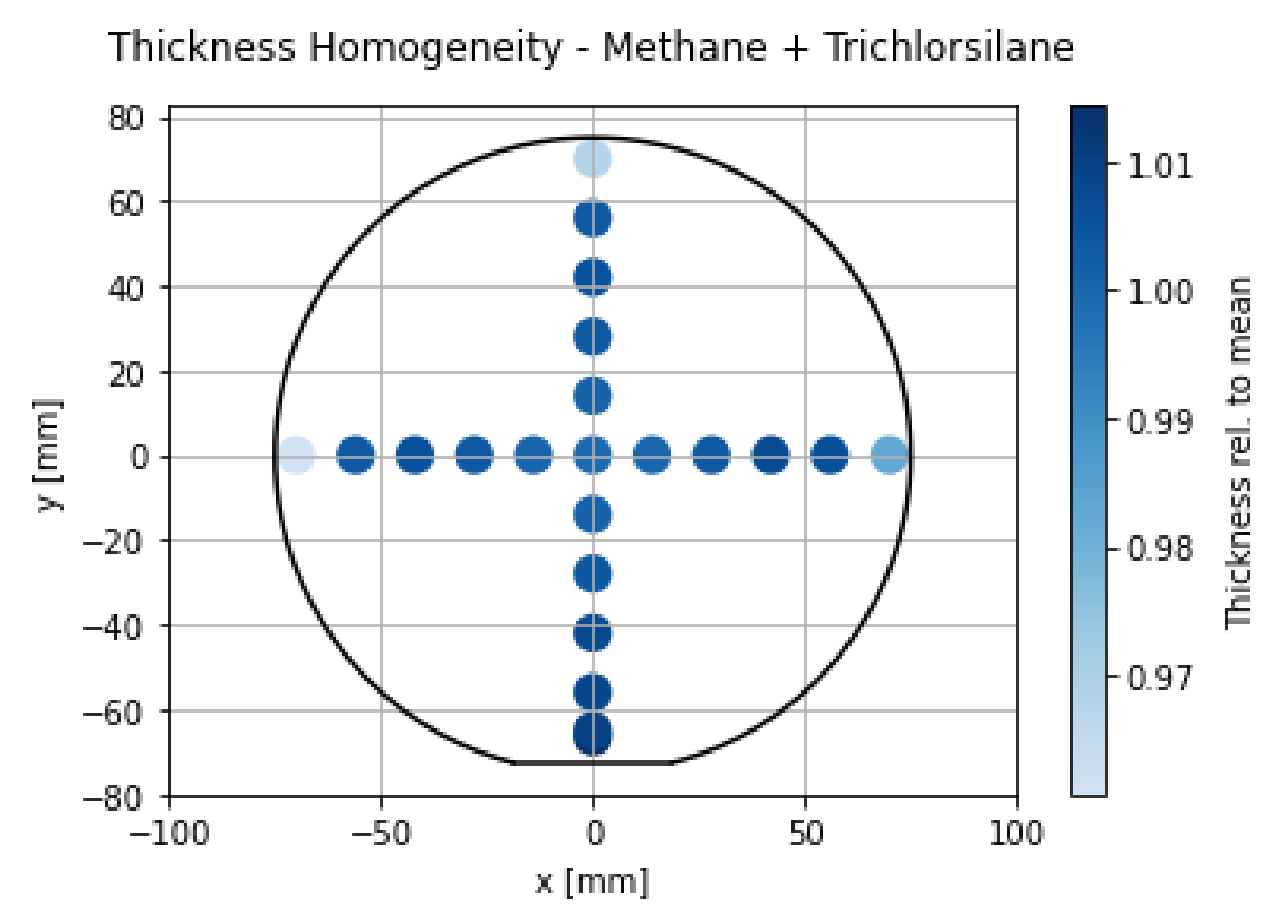
- Epitaxy in AIXTRON planetary reactors (G5WW C, G10-SiC)
- Growth rates of 30 µm/h and 60 µm/h

	SiH ₄	SiCl ₂ H ₂ (DCS)	SiCl ₃ H (TCS)	SiCl ₄
Ethylene	X	X	X	X
Methane	X	/	X	X

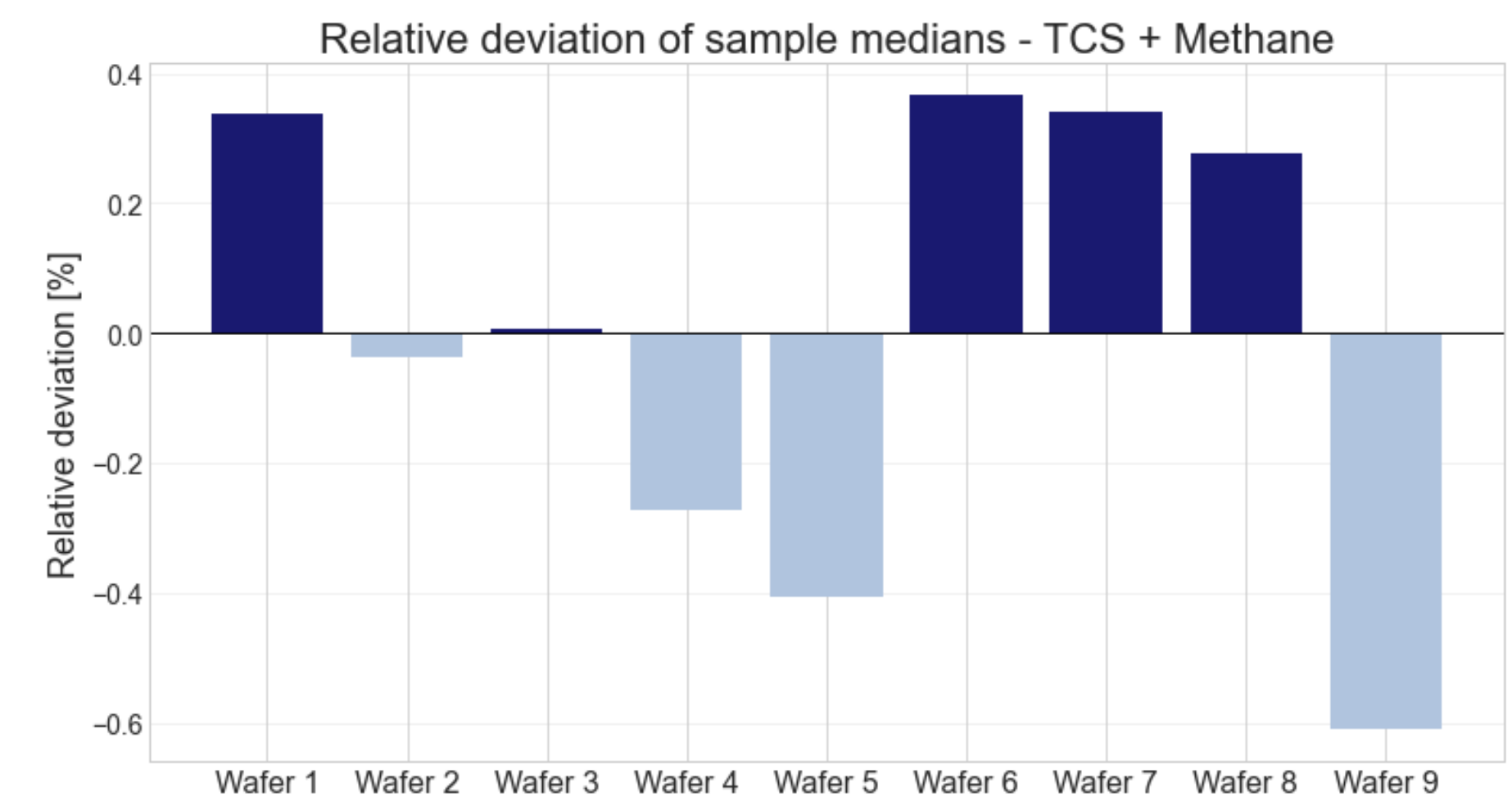
- Post-epitaxy characterization:
 - Epilayer thickness and doping profiles by FTIR-based method and CV
 - Defectivity of the epilayers by UVPL & DIC (Lasertec SICA 88)
 - Carrier lifetime measurements by µ-PCD

3. RESULTS

Homogeneities

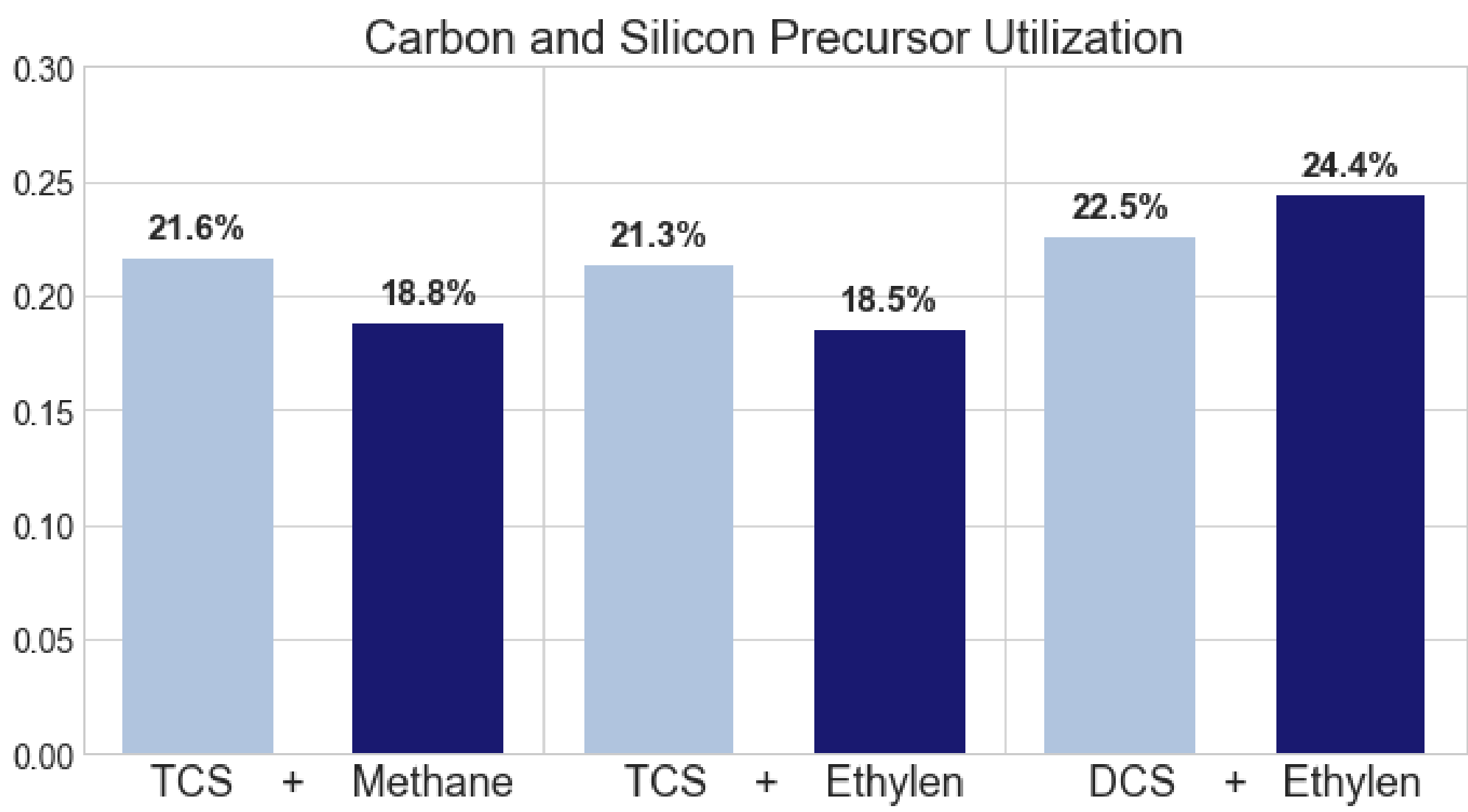


- The epilayer was grown at **~30µm/h** with **trichlorosilane (TCS)/methane** as precursors
- The **thickness distribution is highly uniform** across the wafer. Comparable to standard TCS/ethylene processes
- The relative thickness deviation remains within approximately -2% to +1%, demonstrating good thickness control for the TCS/methane process
- The **doping concentration is uniform** across the wafer, with only minor local variations
- Overall, the relative deviation remains within approximately ±1.5%, demonstrating **good doping control** for the TCS/methane process
- The background doping in intrinsic runs is also not affected by the use of methane as a precursor, it remains below 1×10¹⁴ cm⁻³ (n-type)
- A similar doping range as with TCS has been tested using methane and is achievable



- The sample medians show only minor deviations from the mean median of the run
- Relative deviations of sample medians remain very small, within approximately **±0.6%** of the reference
- Methane with TCS can achieve similar interwafer homogeneities as ethylene with TCS

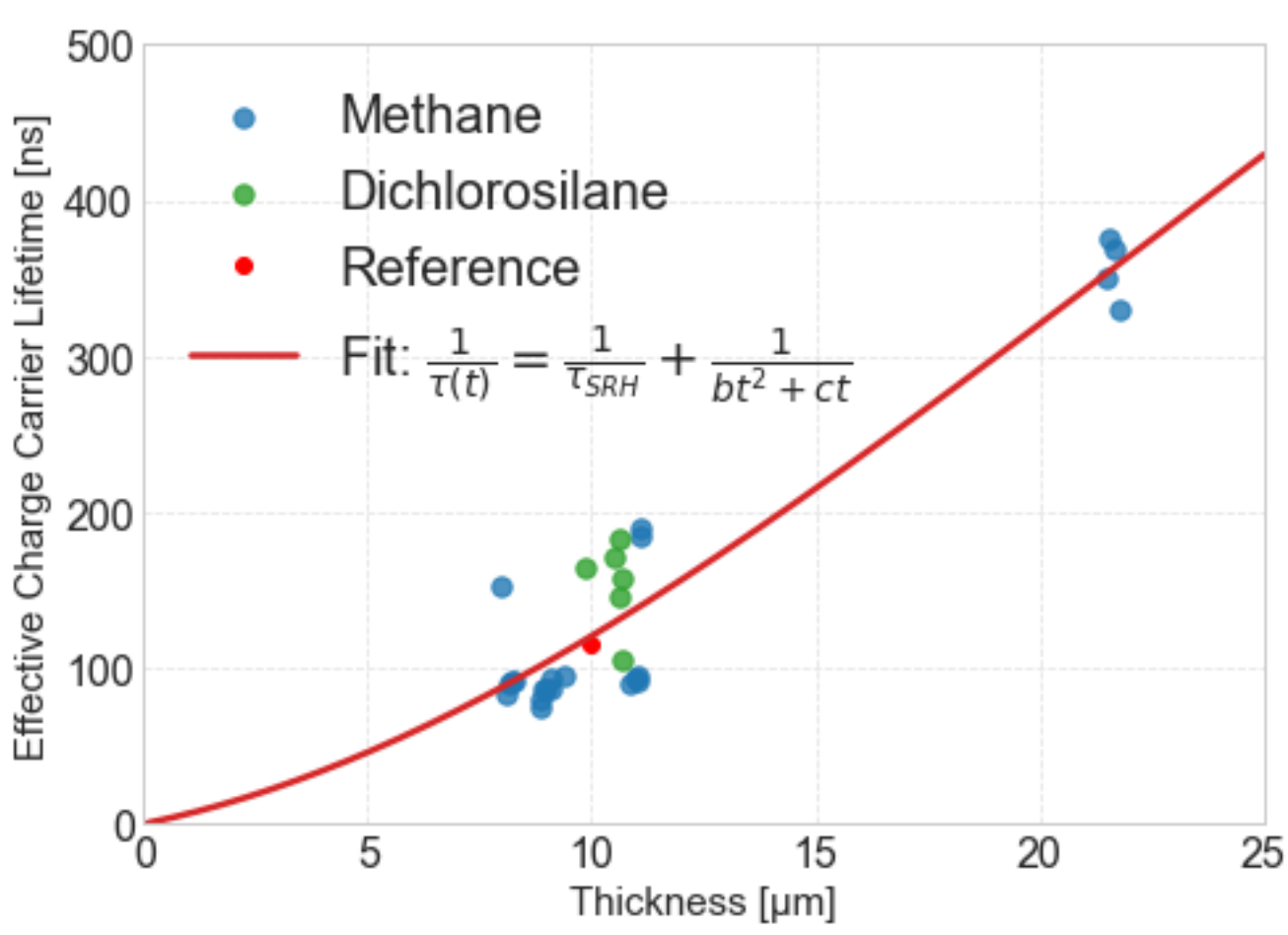
Efficiencies



$$\text{Utilization} = \frac{\text{amount of precursor supplied to the reactor}}{\text{amount of precursor incorporated}}$$

- Values ranged from **18.5% to 24.4%** across all tested conditions
- For TCS, silicon precursor utilization remained nearly constant
- Carbon precursor utilization was lower for the TCS-based processes
- DCS combined with ethylene was the most efficient precursor combination** under the investigated conditions.

Lifetimes



- The methane/TCS and Ethylene/DCS process achieves **majority carrier lifetimes comparable to the reference process**
- Higher lifetimes are in general obtained for thicker epilayers indicating a high influence of the interfaces and the substrate
- Shockley-Read-Hall (SRH) recombination is not a limiting factor for lifetime in these epilayers
- The results indicate a comparable intrinsic and extrinsic defect level for methane/TCS and the established reference process
- These preliminary results have to be proven by DLTS in future work

4.) CONCLUSION AND OUTLOOK:

- Methane being an important precursor for isotopically enriched epi showed promising results
- Next tests will include **²⁸Si** and **¹²C** enriched precursors (Methane + Tetrachlorosilane)
- Further work will focus on evaluating layer thickness and doping homogeneity, defect density, reactor deposition behaviour, and long-term process stability at increased growth rates of up to 60 µm/h.

¹ Milan Yazdanfar et al., „Finding the Optimum Chloride-Based Chemistry for Chemical Vapor Deposition of SiC“, 2014, ECS J. Solid State Sci. Technol. 3 P320, DOI 10.1149/2.0111410jss

² Milan Yazdanfar et al., “On the use of methane as a carbon precursor in Chemical Vapor Deposition of silicon carbide,” 2014, Journal of Crystal Growth, DOI: 10.1016/j.jcrysgro.2013.12.033.

³ Milan Yazdanfar et al., „Brominated Chemistry for Chemical Vapor Deposition of Electronic Grade SiC“, 2015, Chem. Mater., DOI: 10.1021/acs.chemmater.5b00074



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