

Optical defect spectroscopy of wide-band-gap semiconductors using continuous spectra monochromator

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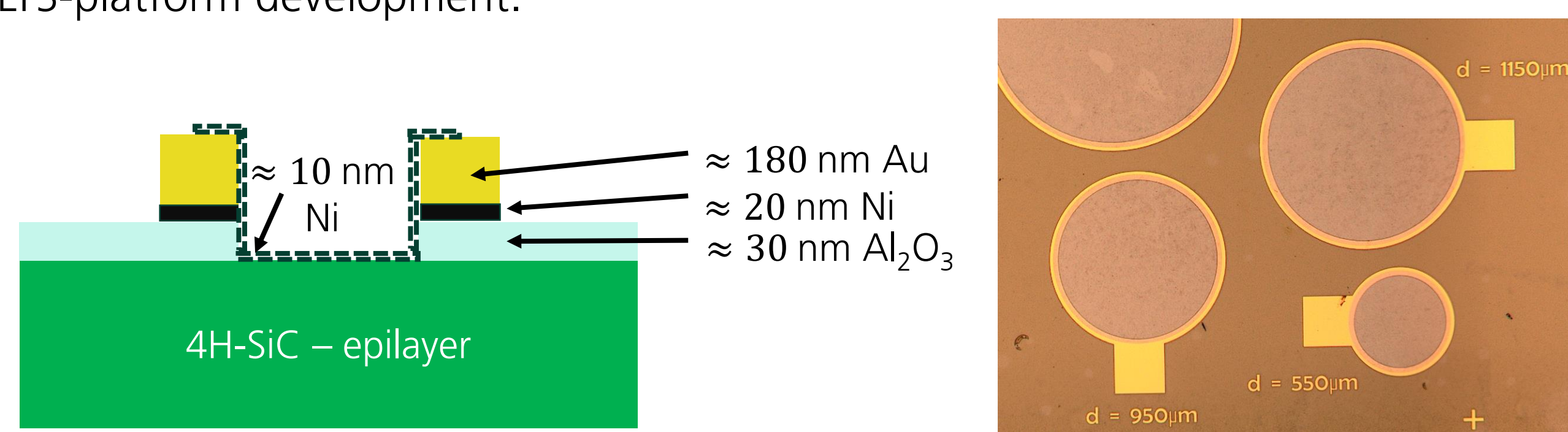
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Motivation

Deep-Level Optical Spectroscopy (DLOS) enables the characterization of electrically active defects across the semiconductor bandgap. However, applying DLOS to wide- and ultra-wide-band-gap semiconductors requires optical excitation extending into the deep ultraviolet while maintaining high spectral purity. This places demanding requirements on the light source and wavelength-selection system. Here a preliminary MCTS measurement on 4H-SiC is presented as the first stage of the optically-enabled DLTS-platform development.

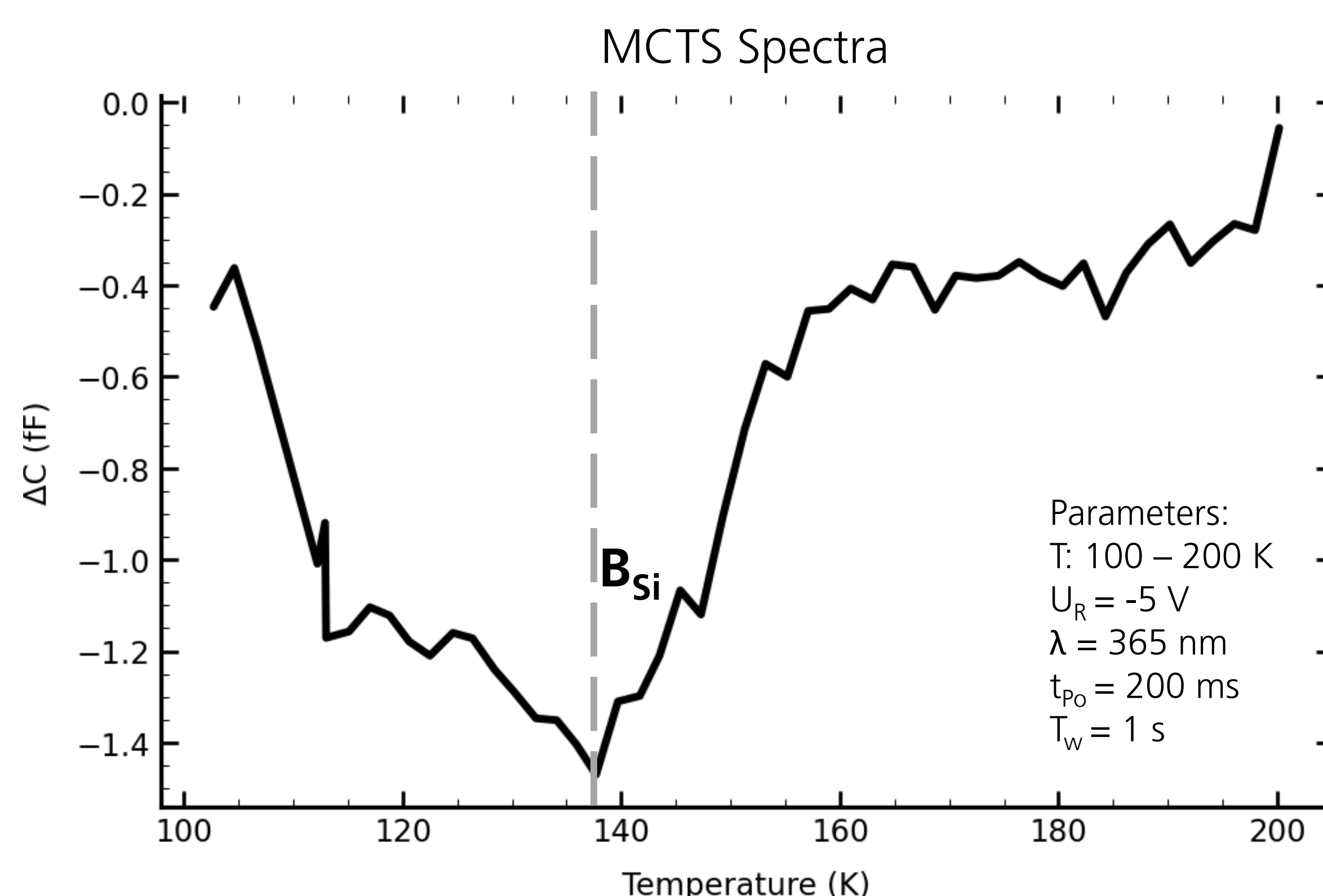


Semi-transparent sample design and top view in a microscope

Sample design

Unlike conventional DLTS, MCTS and DLOS samples require a special preparation to enable optical excitation of the deep levels. The semiconductor material has to be exposed to the irradiation via a window and have an ohmic contact to apply bias.

We have designed and tested specialized semi-transparent samples with a Ni-capped window surrounded by an Au ring with a pad for bonding of the sample. The transmission at 365 nm wavelength is 35% as measured.



MCTS temperature scan of the 4H-SiC sample. The amplitude is obtained via the first sine coefficient b1

Results

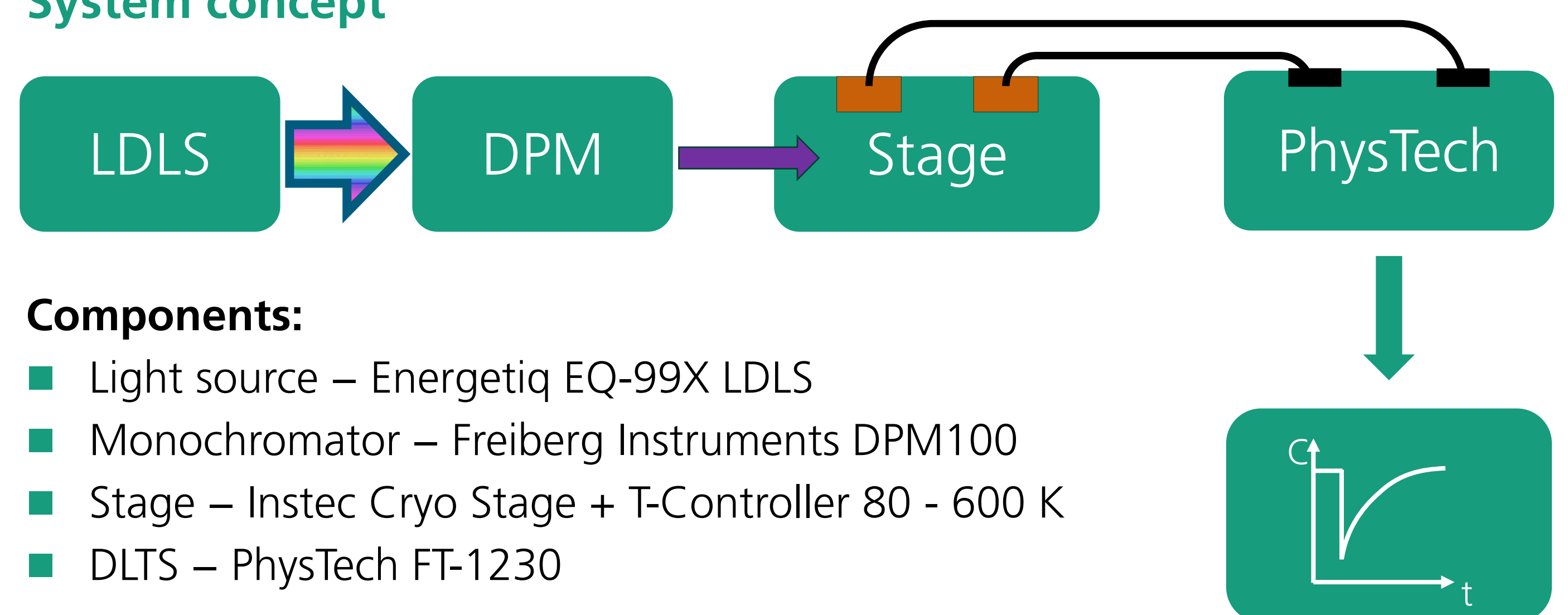
A MCTS temperature scan measurement on a Schottky 4H-SiC diode was performed as an initial end-to-end commissioning test of optical excitation, pulse synchronization, and transient acquisition. The single observed peak at just below 139 K is a well-described B_{Si} minority-carrier trap in 4H-SiC [1,2, 3]. It originates from implantation damage and corresponds to a substitutional B atom in Si.

First development stage of an optically enabled DLTS platform has been completed successfully as demonstrated by a fixed-wavelength MCTS benchmark on 4H-SiC.

References:

- 1 Capan I. et al., *Majority and Minority Charge Carrier Traps in n-Type 4H-SiC Studied by Junction Spectroscopy Techniques*, Electr. Mat., 3.1, **2022**, 115-123
- 2 Barthen M. E. et al, *Impact of carbon injection in 4H-SiC on defect formation and minority carrier lifetime*, Mat. Sci. and Semicon. Process., 176, **2024**, 109316
- 3 Feiler P.U. Masterarbeit: *Charakterisierung von tiefen Störstellen in SiC mit optisch stimulierter Kapazitätsspektroskopie*, TU Bergakademie Freiberg, Institute of Applied Physics, **2025**

System concept



Components:

- Light source – Energetiq EQ-99X LDLS
- Monochromator – Freiberg Instruments DPM100
- Stage – Instec Cryo Stage + T-Controller 80 - 600 K
- DLTS – PhysTech FT-1230



Wavelength: 175 – 3100 nm
Energy: 0.5 – 7.3 eV
 10^8 stray-light suppression

Double Prism Monochromator developed by Freiberg Instruments

Setup

Double prism monochromator enables continuous wavelength scanning and allows performing DLOS with desired spectral resolution. The developed system includes a software layer between the DPM and the PhysTech measurement software, that enables direct control of the optical system by the DLOS-enabled measurement algorithm, enables intensity control to keep a constant photon flux and serves as an intermediate monitoring surface and measurement log record.

At the current development stage, the setup is capable of measurements in the range of 0.5 – 4.4 eV. To enable full range, the system has to be equipped with a nitrogen gas purging system to eliminate oxygen from the atmosphere and ozone build-up during LDLS operation that attenuate wavelengths in the DUV range and prevent study of UWBG-materials.

Summary

- Designed a DLOS-enabled system with a wide range Monochromator as primary Light Source, targeting UWBG-materials
- Integrated a new FI Monochromator into the existing DLTS system
- Established semi-transparent contact fabrication solution
- Performed a MCTS measurement on 4H-SiC as an initial benchmark of the integrated optical system

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