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Back side ohmic contact in 4H-SiC Power Devices

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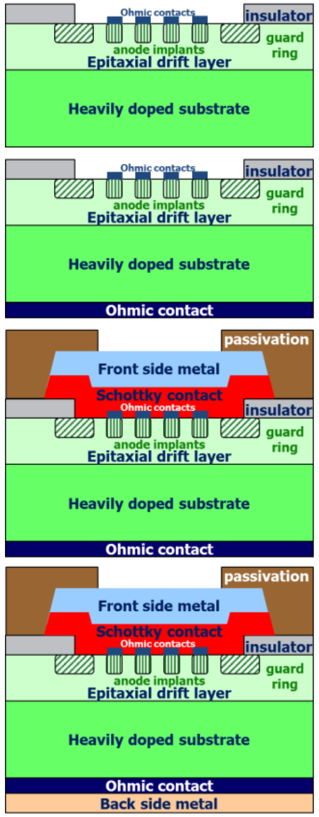
Outline

- Back-side Ohmic contact formation by Laser Annealing process
  - Resistive contributions to the total R_{ON}
  - Morphological, XRD, AFM analysis
  - Sheet resistance and threshold laser fluence
- V_f of a Schottky Barrier Diode:
  - as a function of Ni thickness
  - as a function of the laser fluence
- Conclusions and future perspectives

Laser annealing process: why?

STD flow

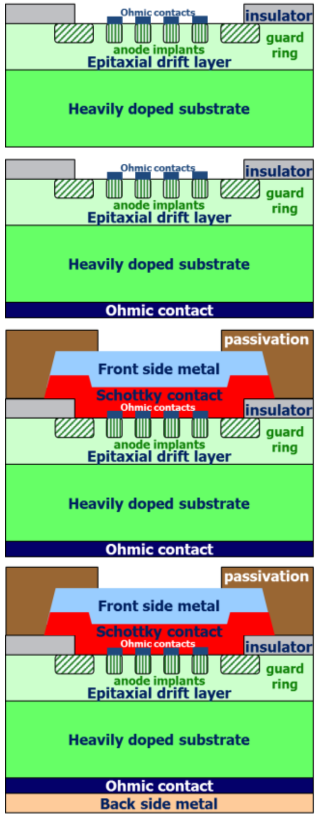


standard back side ohmic contact formation process

T > 980° C

Laser annealing process: why?

STD flow



standard back side ohmic contact formation process T > 980° C

- ❑ Complex process flow integration
- ❑ Reliability of long exposed back side ohmic contact

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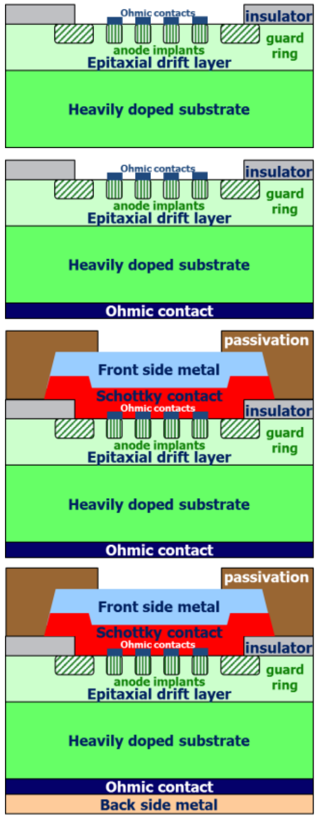
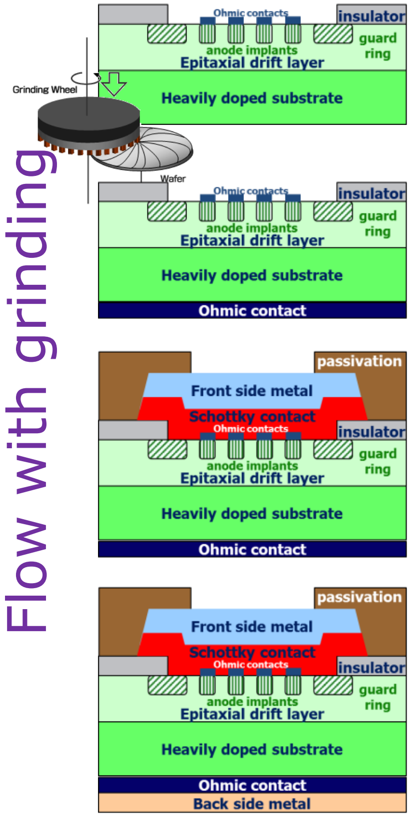


Flow with grinding



- ❑ Complex process flow integration
- ❑ Reliability of long exposed back side ohmic contact
- ❑ Lithography steps limitation after the grinding
- ❑ Risk of wafer breakage

Laser annealing process: why?

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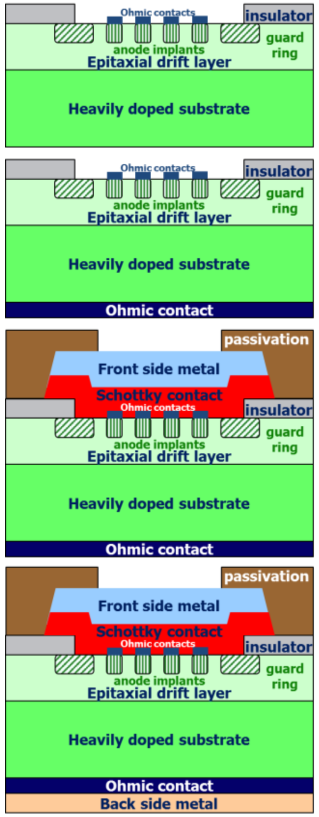

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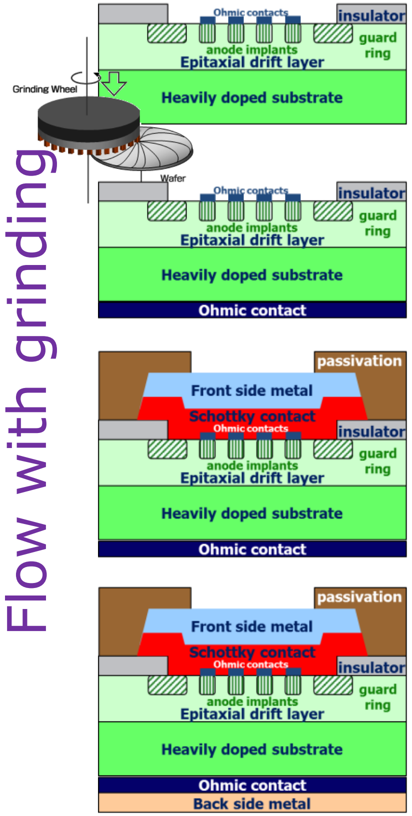
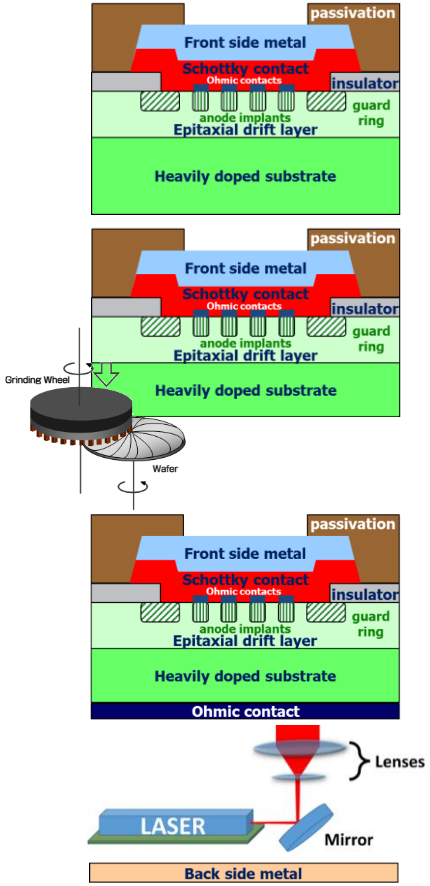
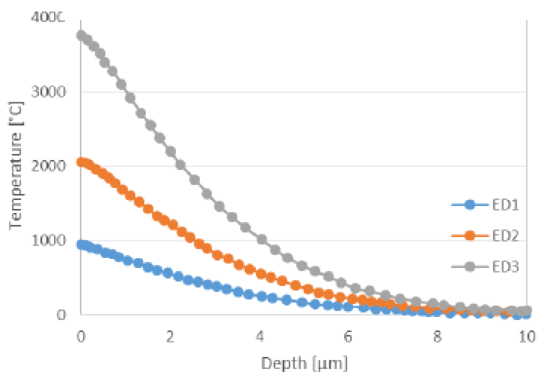


LA flow with grinding



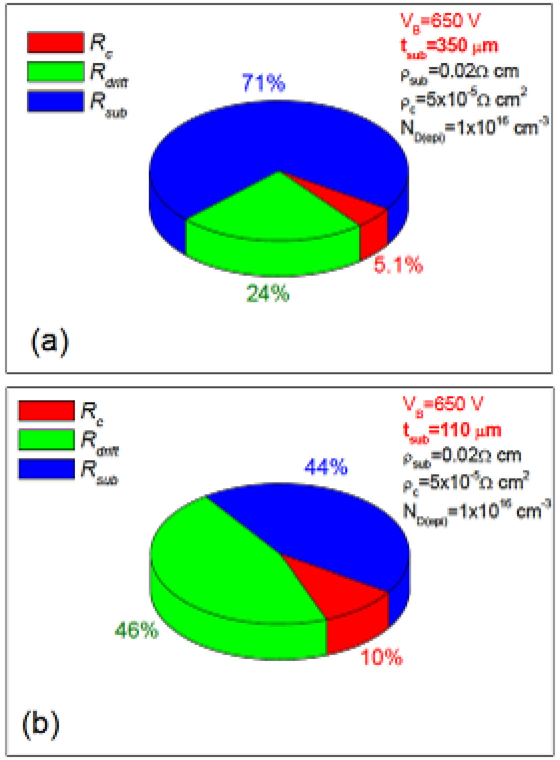


F. Mazzamuto, S. Halty, H. Tanimua, Y. Mori, Mater. Sci. Forum 858, 565 (2016)

- ❑ Complex process flow integration
- ❑ Reliability of long exposed back side ohmic contact
- ❑ Lithography steps limitation after the grinding
- ❑ Risk of wafer breakage

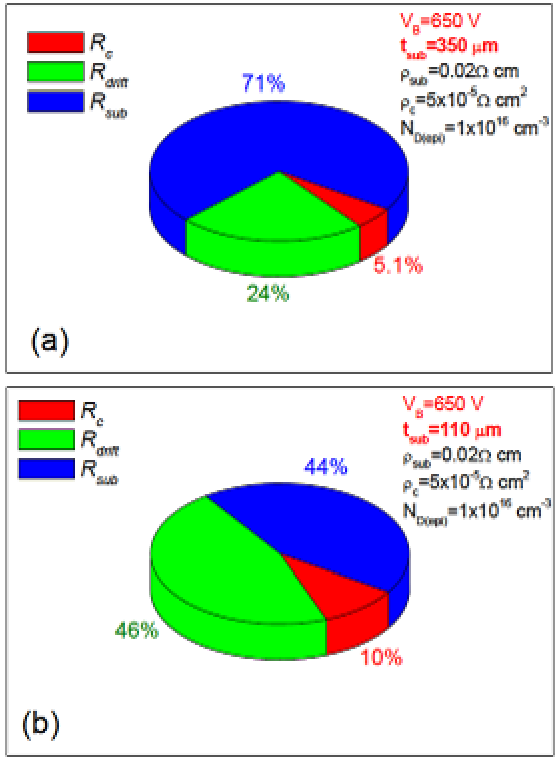
- ✓ Easy process flow integration
- ✓ No exposed back side ohmic contact
- ✓ Minimized risk of wafer breakage
- ✓ No lithography steps after the grinding
- ✓ Big reduction of substrate resistive contribution

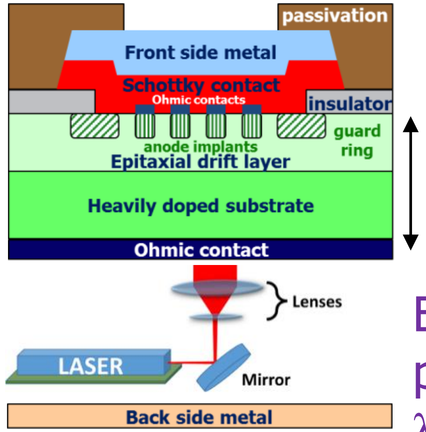
Resistive contributions to the total R_{ON}



Resistive contributions to the total R_{ON} in a 650V 4H-SiC Schottky diode for two different substrate thickness of 350 μm and 110 μm

Resistive contributions to the total R_{ON}





110µm

E.D. 4.7 J/cm², scan 5X, pulse duration=160 ns, λ = 308 nm

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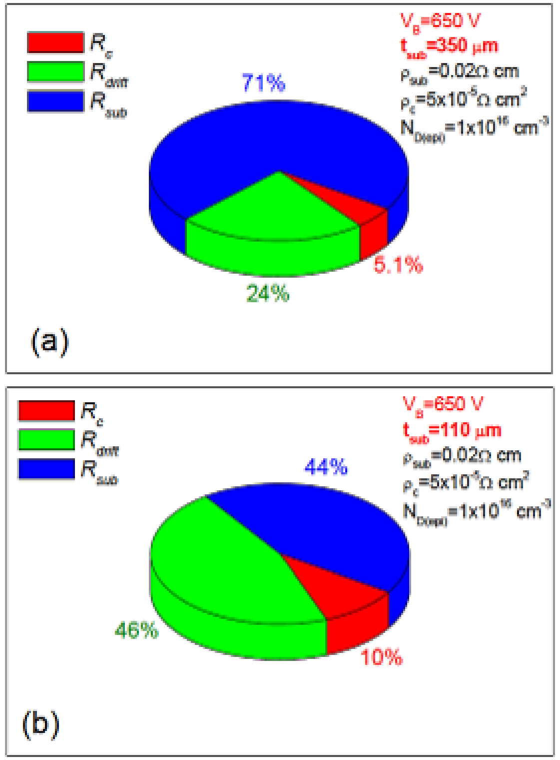
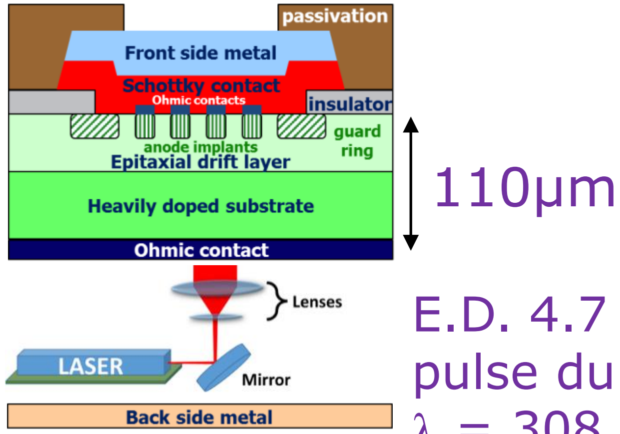
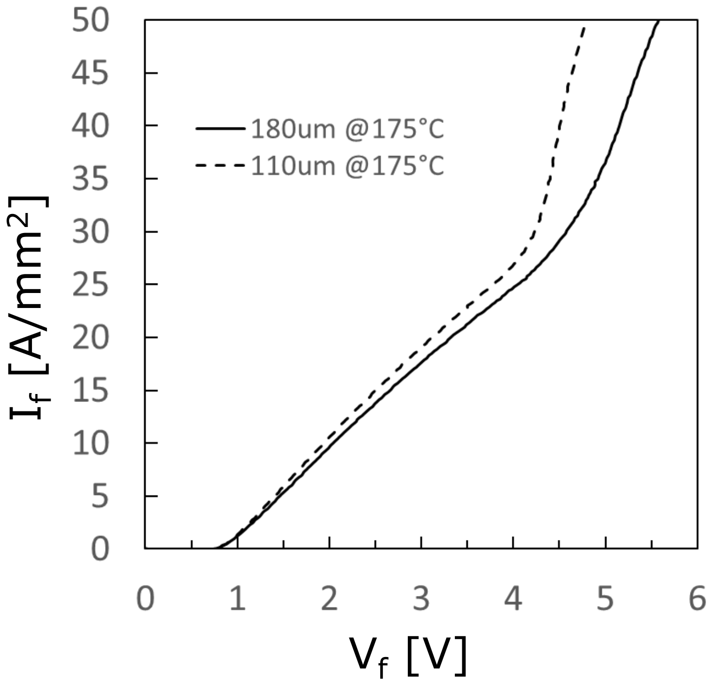


Resistive contributions to the total R_{ON} in a 650V 4H-SiC Schottky diode for two different substrate thickness of 350 µm and 110 µm

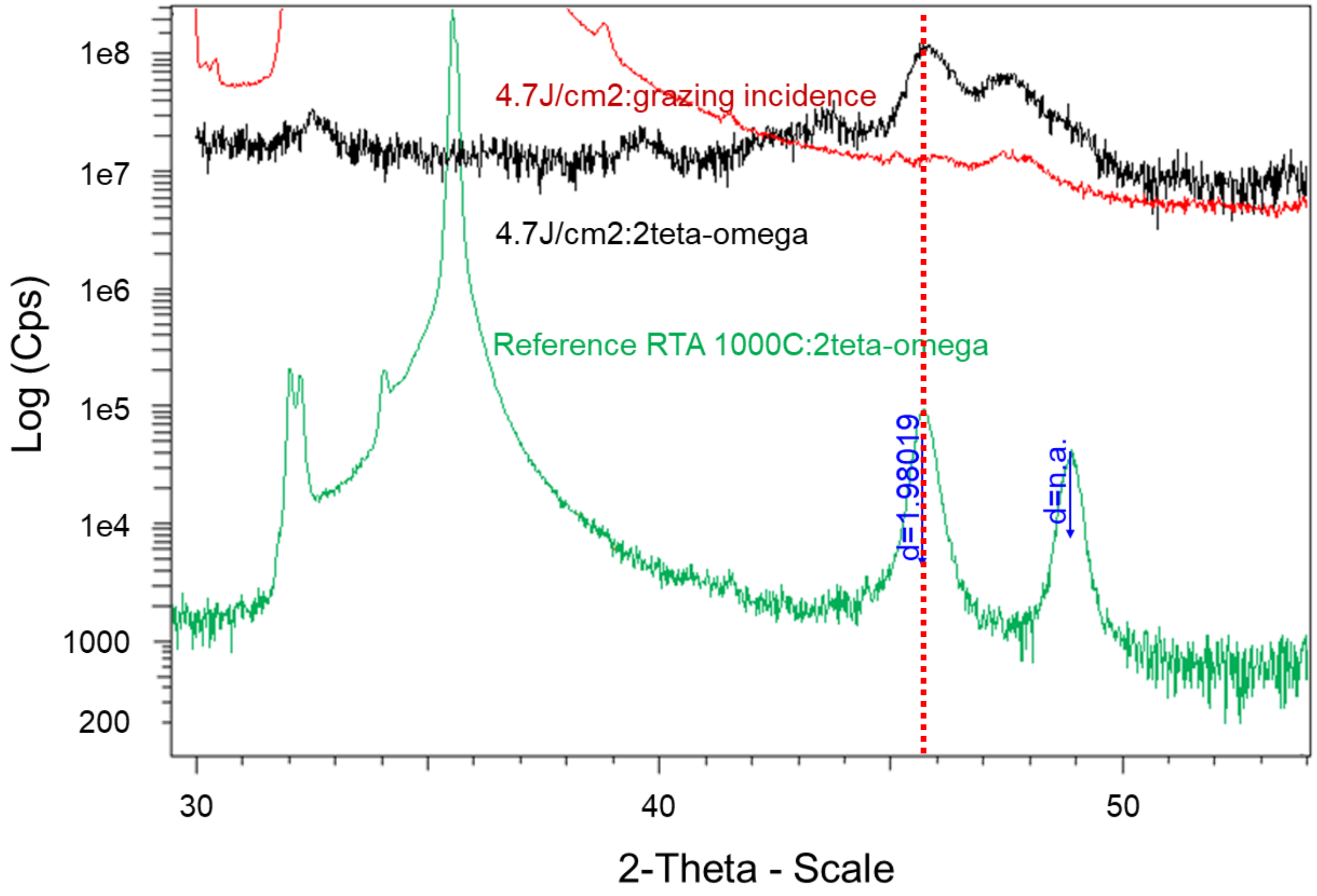


E.D. 4.7 J/cm^2, scan 5X, pulse duration=160 ns, λ = 308 nm

Forward IV characteristic of 650 V JBS diodes for 180 µm thinned wafer with std RTA process and 110 µm thinned wafer with Laser annealing process



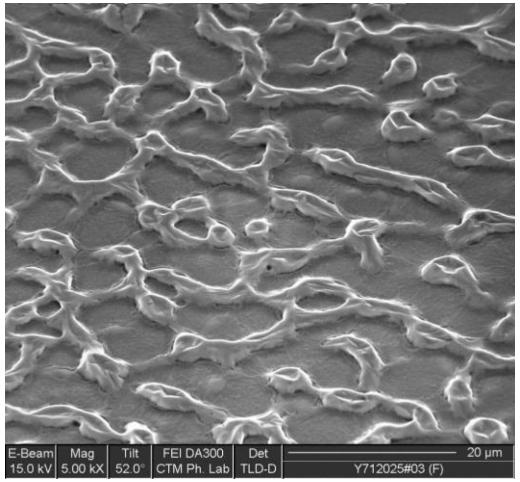
XRD analysis



The labelled peak identifies the orthorhombic Ni_2Si phase.

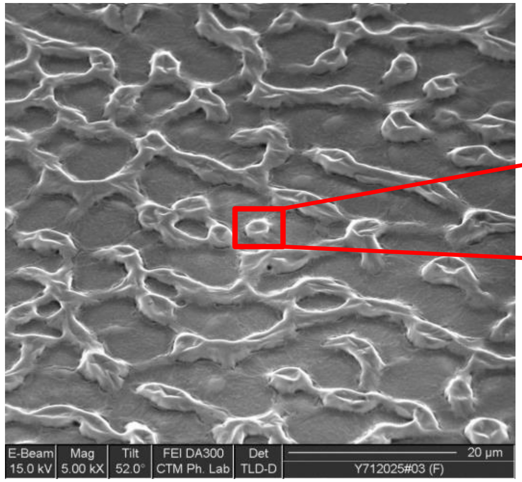
Being present in the reference sample (RTA), it is considered as a marker for the targeted reaction path.

Morphological analysis



SEM plan view of back side layer after 100 nm Ni sputtering and 308 nm laser treatment at a fluence of 4.7 J/cm^2.

Morphological analysis



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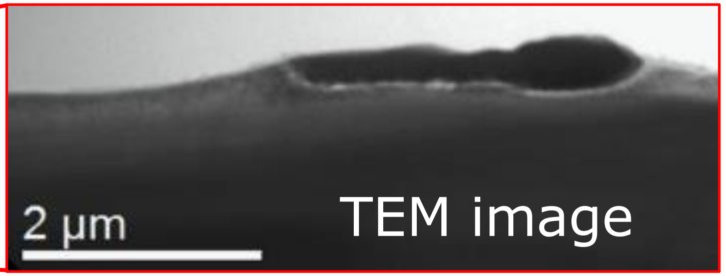

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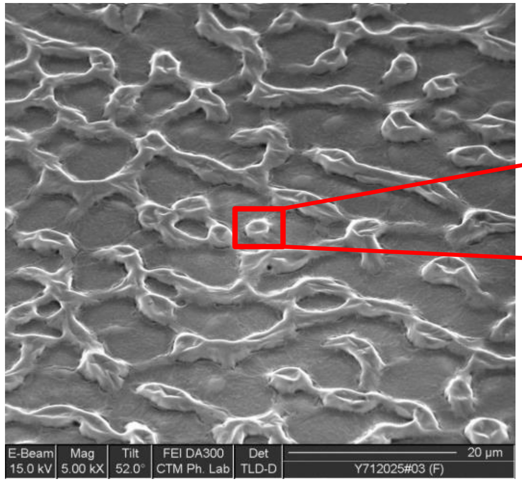

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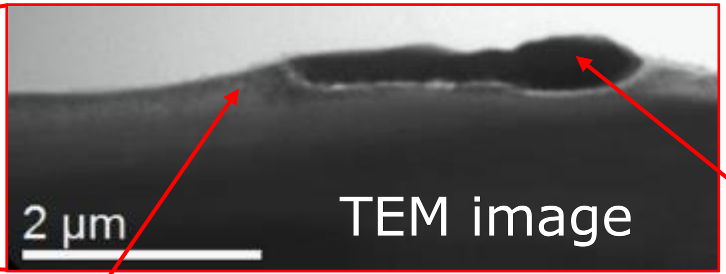
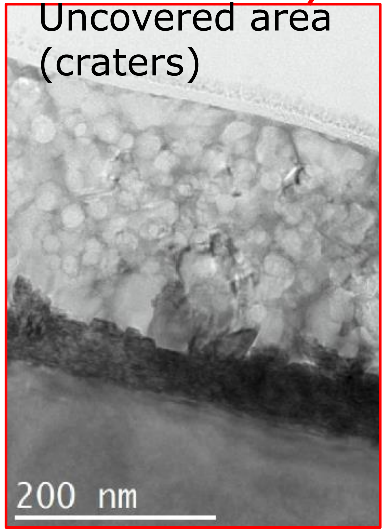
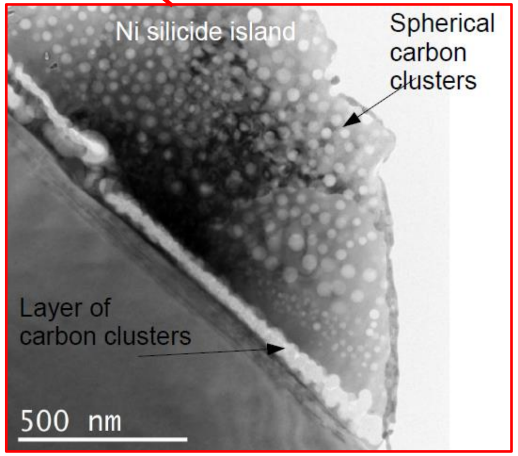




Ni silicide island (curbs)



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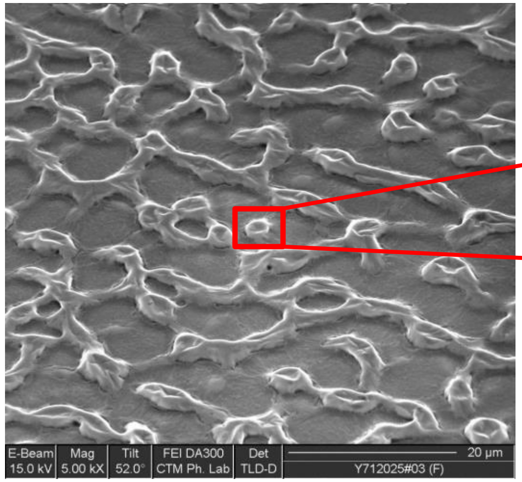
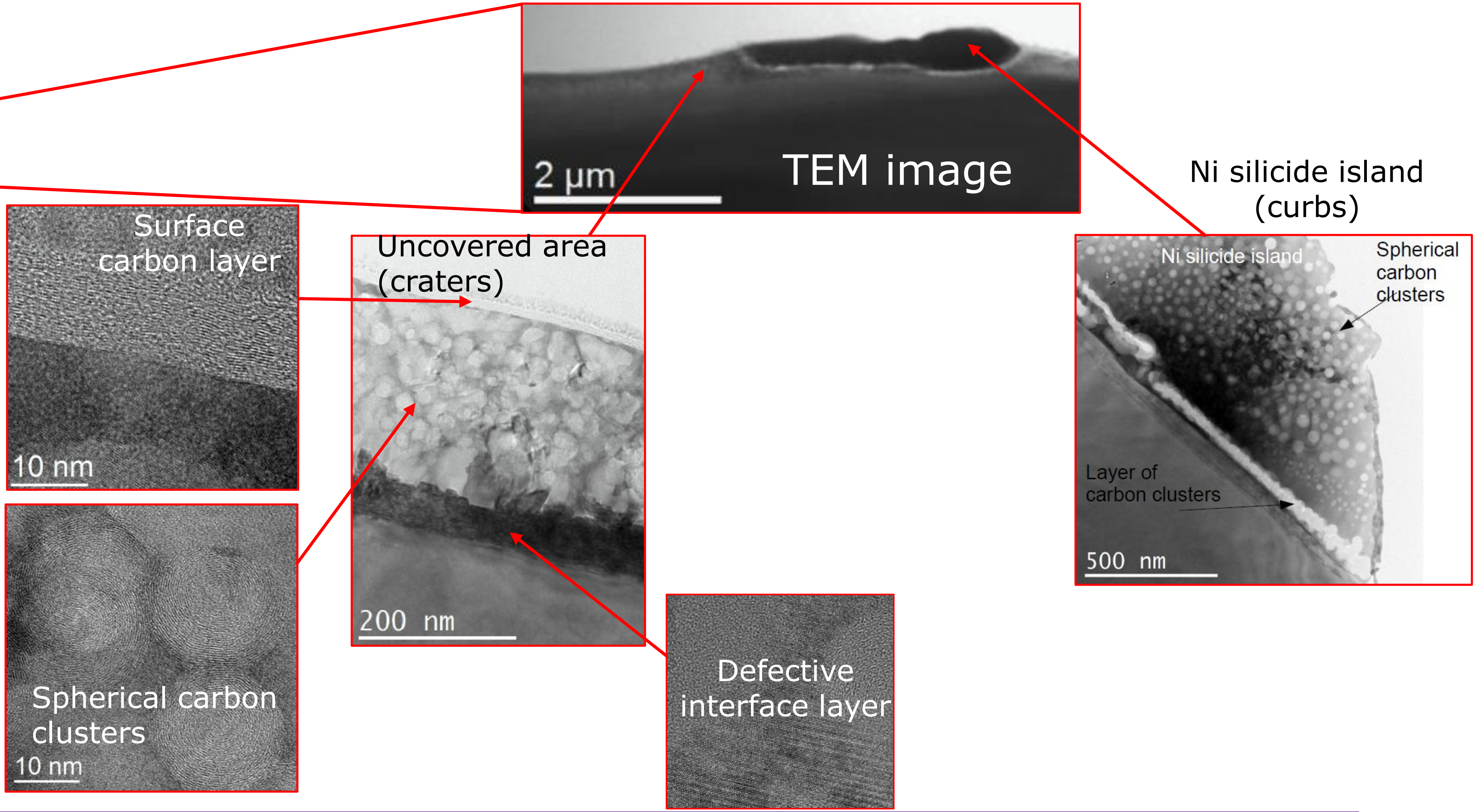


SEM plan view of back side layer after 100 nm Ni sputtering and 308 nm laser treatment at a fluence of 4.7 J/cm².



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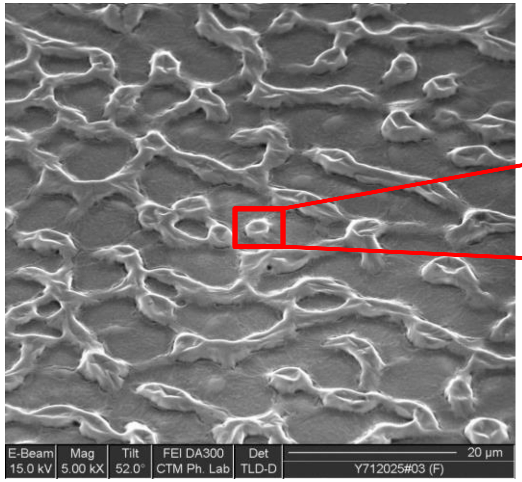

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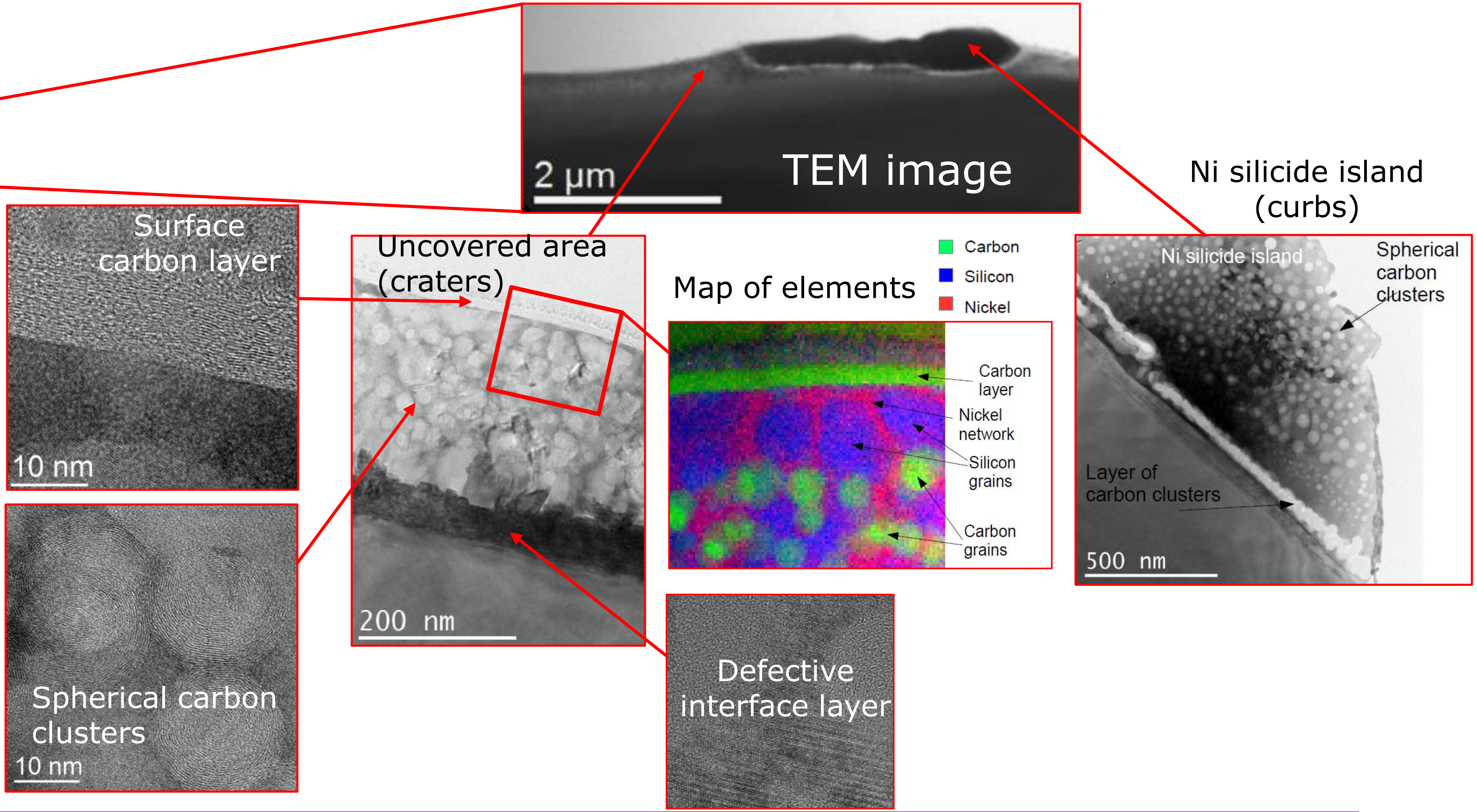
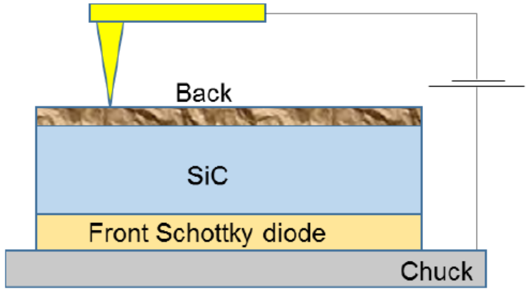
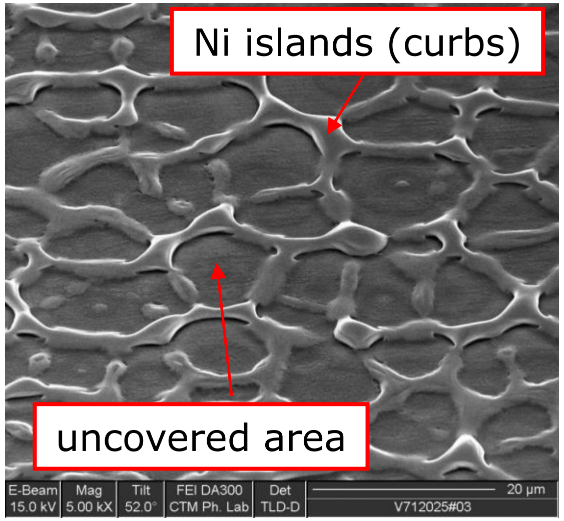
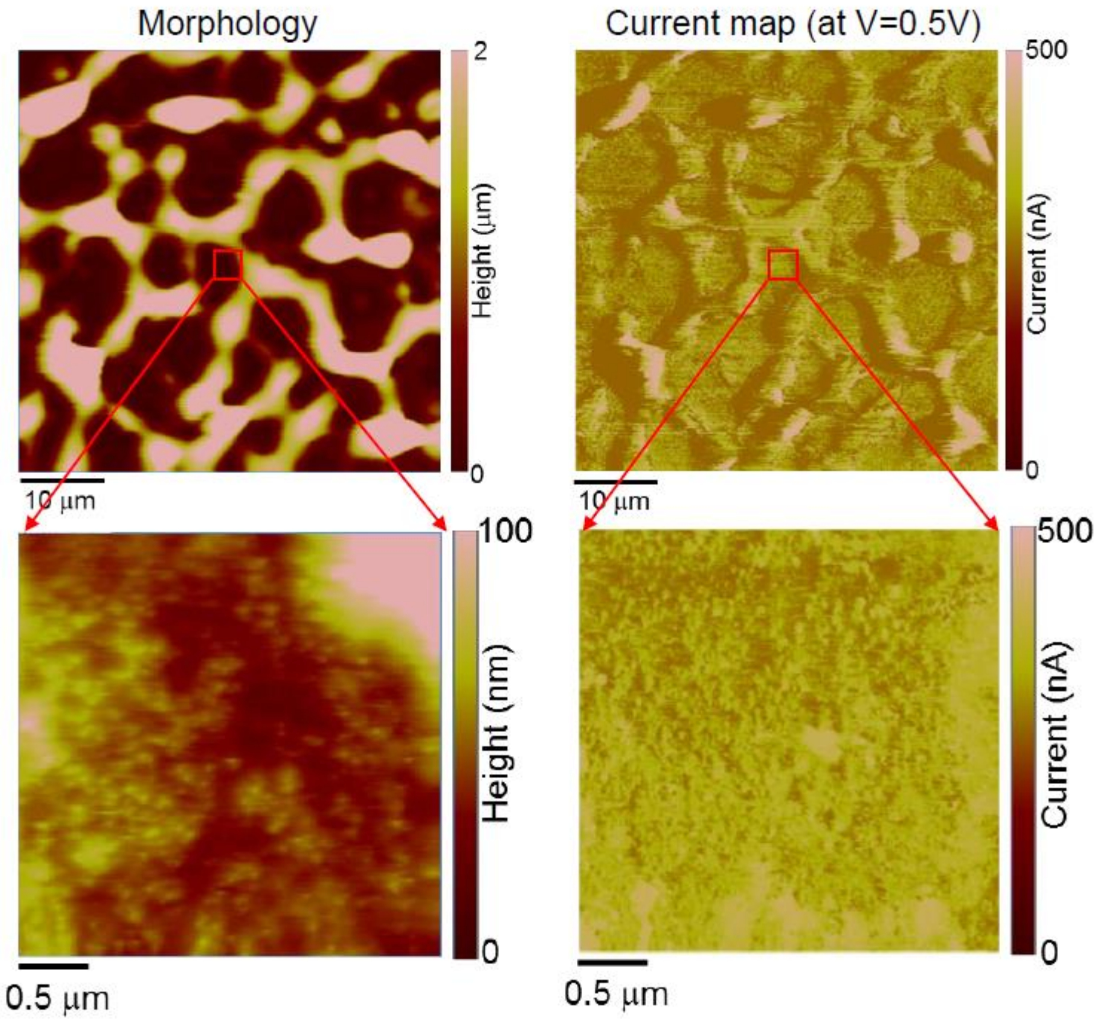


Conductive AFM analysis

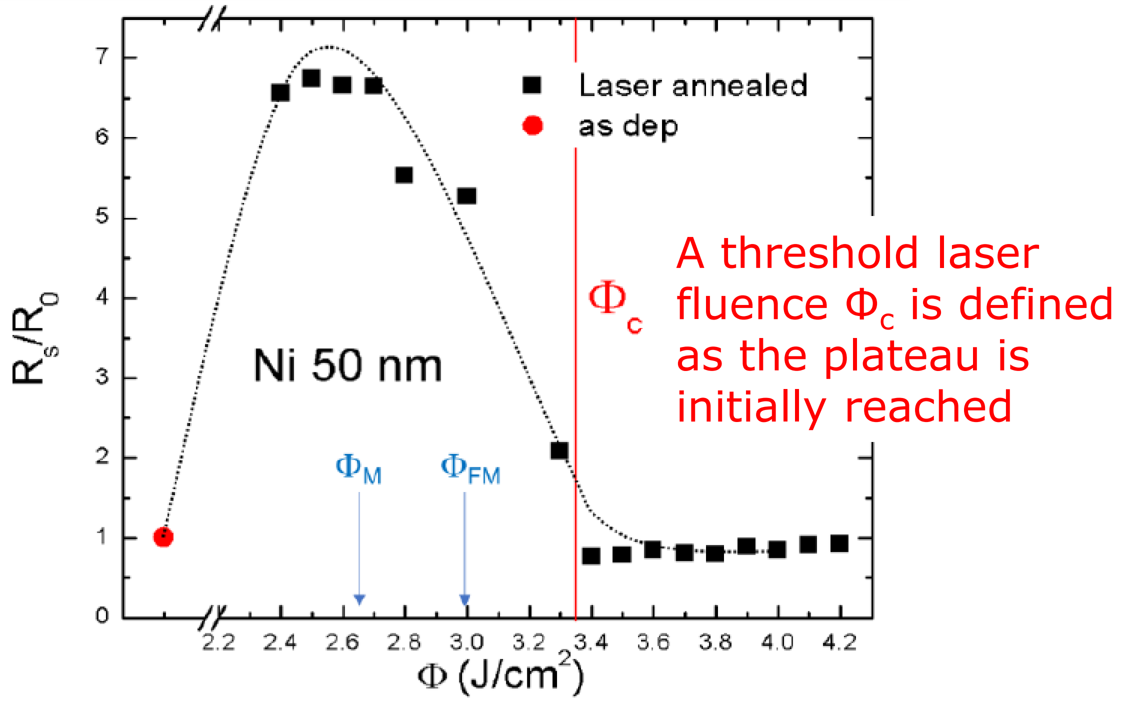




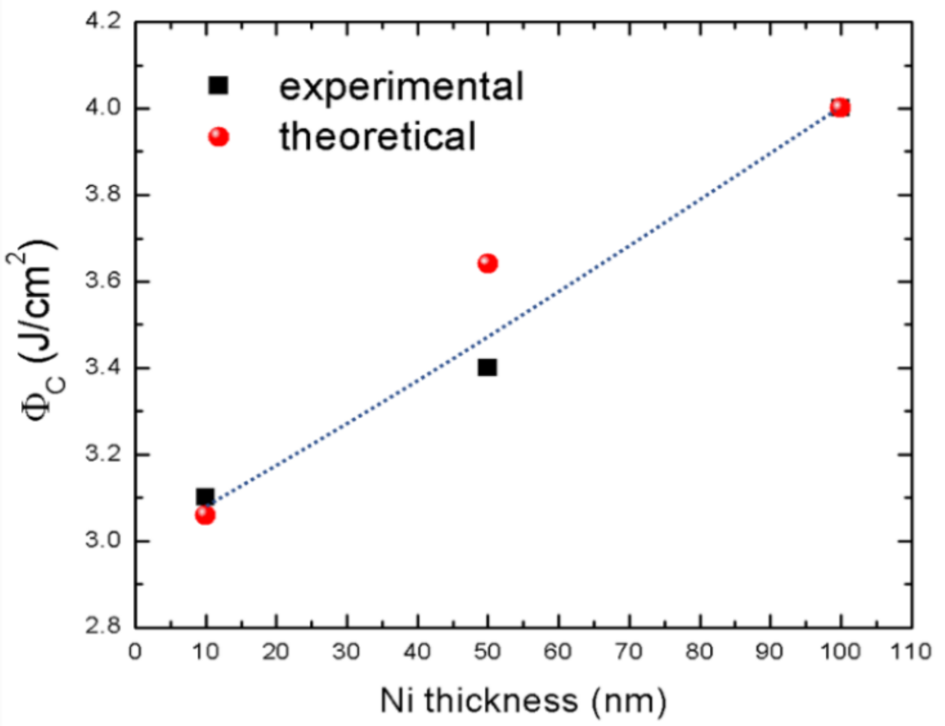
Uniform current injection in the regions uncovered by Ni (craters)



R_s and threshold laser fluence (Φ_c)

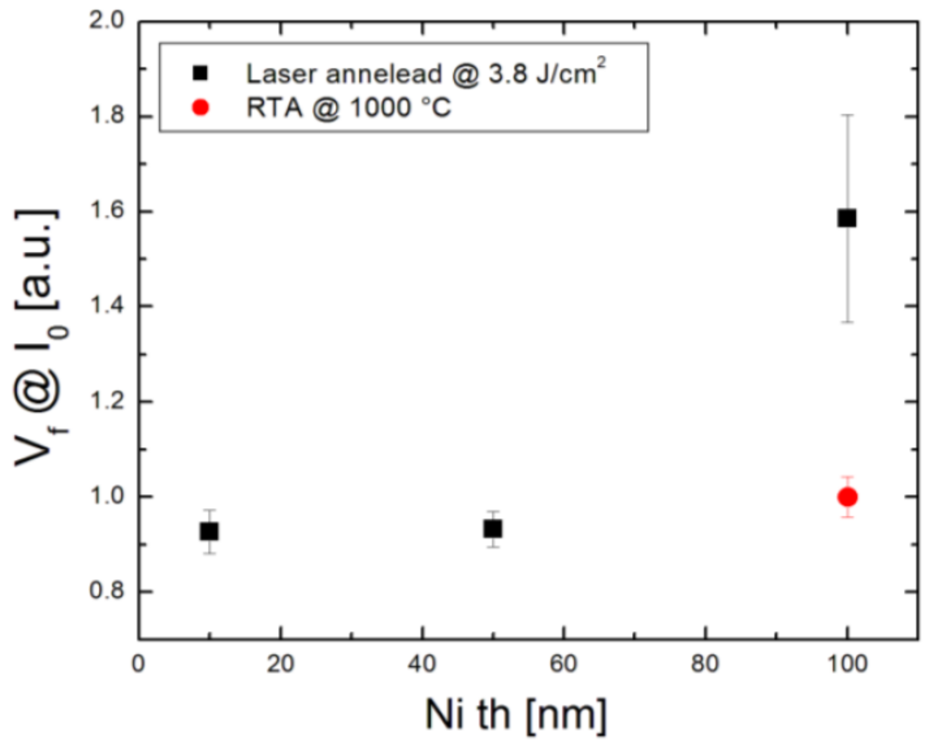


Sheet resistance values normalized to the as deposited sample for a starting Ni thickness of 50 nm

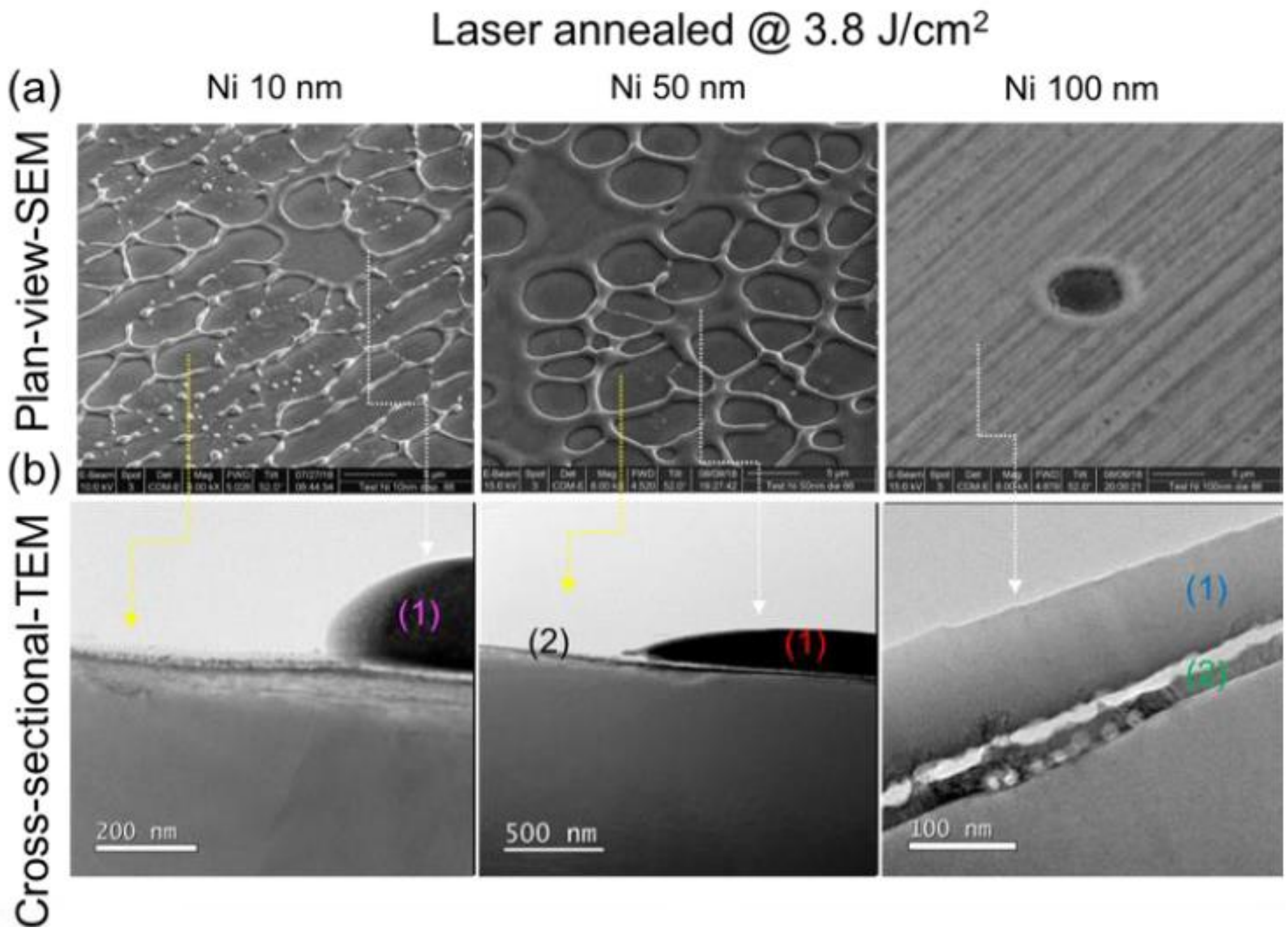


Φ_c linearly increases with Ni thickness

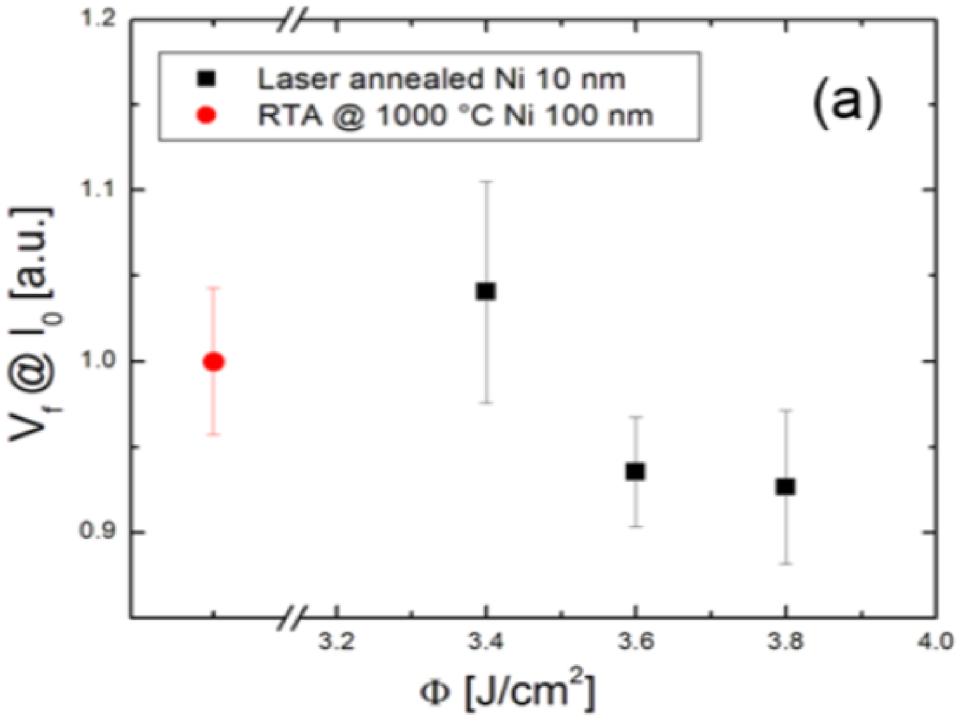
V_f of a SBD as a function of Ni thickness



100 nm thick Ni layer has the highest V_f



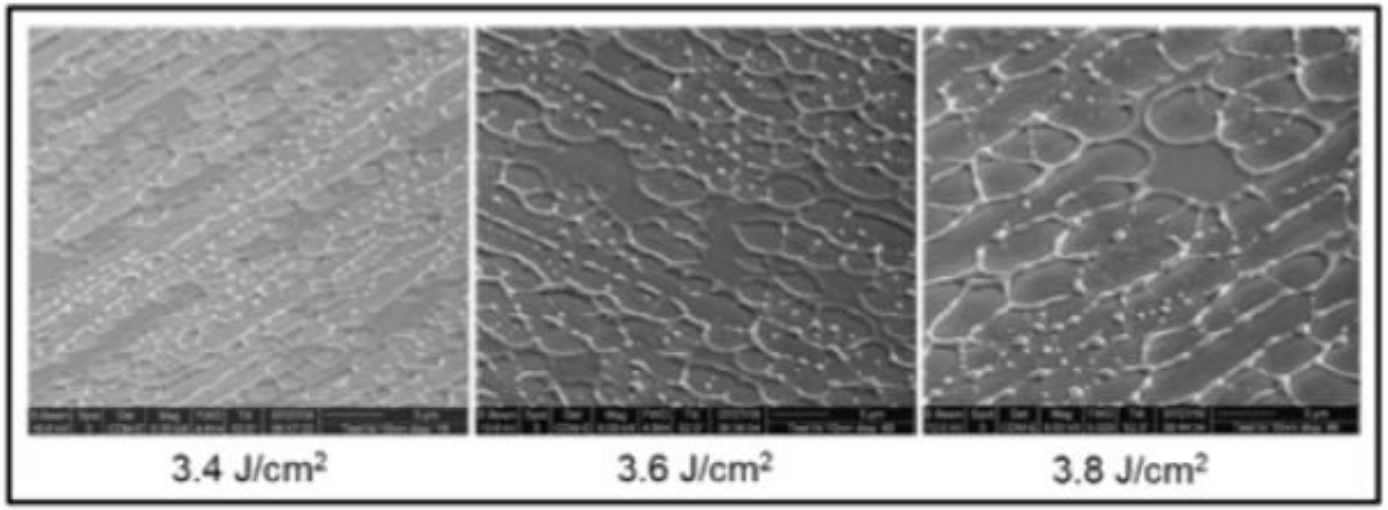
V_f of a SBD as a function of the laser fluence



V_f decreases when the energy density increases from 3.4 J/cm^2 to 3.8 J/cm^2

Nickel thickness 10 nm

Plan view SEM



@ different laser fluences

The lowering of V_f measured on diodes is related to the observation that exposed area (craters) progressively increases

Conclusions and future perspectives

- The use of Laser Annealing technology for the back-side Ohmic contact formation is justified by the possibility to use grinding process down to 110μm
- The back-side Ohmic contact on heavily doped 4H-SiC substrate has been formed by a laser process with energy density of 4.7 J/cm^2 and pulse duration of 160 ns
- Ni based agglomeration (curbs) and areas uncovered by nickel (craters) on the back-side surface have been observed and analyzed after the laser treatment as an indication that SiC melting point has been locally reached.
- Morphological and structural properties of the reacted layers have been characterized revealing a pivotal role of the thickness of the as deposited Ni Layer (balance between the initial Ni atomic amount and Si atoms realised from the 4H-SiC substrate during laser annealing)
- Laser annealing process can be suitably tailored to represent a viable solution for the formation of high-performing back-side Ohmic contact on 4H-SiC power devices

Acknowledgements

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