PSC Technologies
Pure Silicon Carbide

3D Printed Silicon Carbide Alloys

New Massive Polycrystalline Materials in Arbitrary Shapes

EPIC World Photonics Technology Summit
Berlin, 28. August 2019

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Start-Up in Berlin
Disruptive Silicon Carbide Technologies

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- Founded in 2015 for transforming the decade-long experience in silicon carbide of Prof. Greulich-Weber into industrial products
- 2017: five patent applications, first investors
- 2018: laboratories in Berlin-Adlershof
- 2019: The Technology Park Adlershof invites PSC to the LASER fair in Munich as strategic company
- 6 employees today, soon more
- Looking for cooperation partners, customers and investors

Prof. Dr. Siegmund Greulich-Weber gave up his chair at the University of Paderborn to found PSC.
Since the end of the seventies he was involved in perfecting the crystallization of silicon. In the early nineties he turned to silicon carbide.

Silicon Carbide:
Huge potential, little used

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Outstanding properties are known for a long time

Properties of Silicon Carbide (SiC)
- Nearly as hard as diamond, light as aluminium
- Does not melt; evaporates above 2700° C
- Heat resistant up to 2000 degrees
- Highly corrosion resistant
- Excellent heat conductivity
- Very low thermal expansion
- Ideal semiconductor for power electronics
- Raw materials available in abundance

Special features have been a high hurdle for production & processing up to now

Hurdles for use
- No melting, no casting, no massive pieces
- Sintered material is difficult to machine
- High purity only with costly procedures

PSC brings a breakthrough

PSC is a Game-Changer: allows for widespread use of SiC

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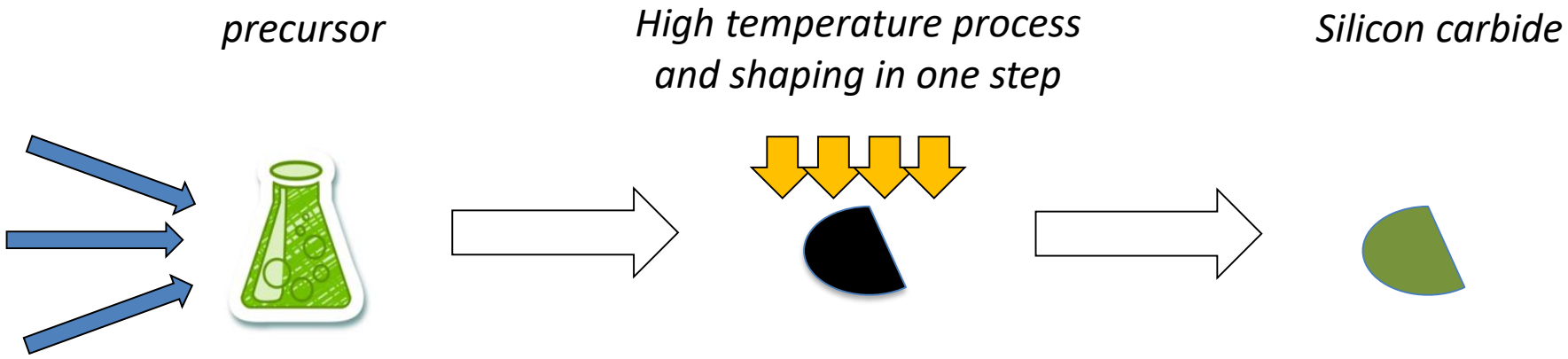
PSC goes a new way

1. Manufacturing of proprietary precursors
2. Transformation into SiC at high temperatures



- **Synthesis and final shaping in one process**
- **Production of a wide choice of SiC alloys**
- **Few process steps, decentralised production**

Our Focus:
3D printing of Silicon Carbide Alloys

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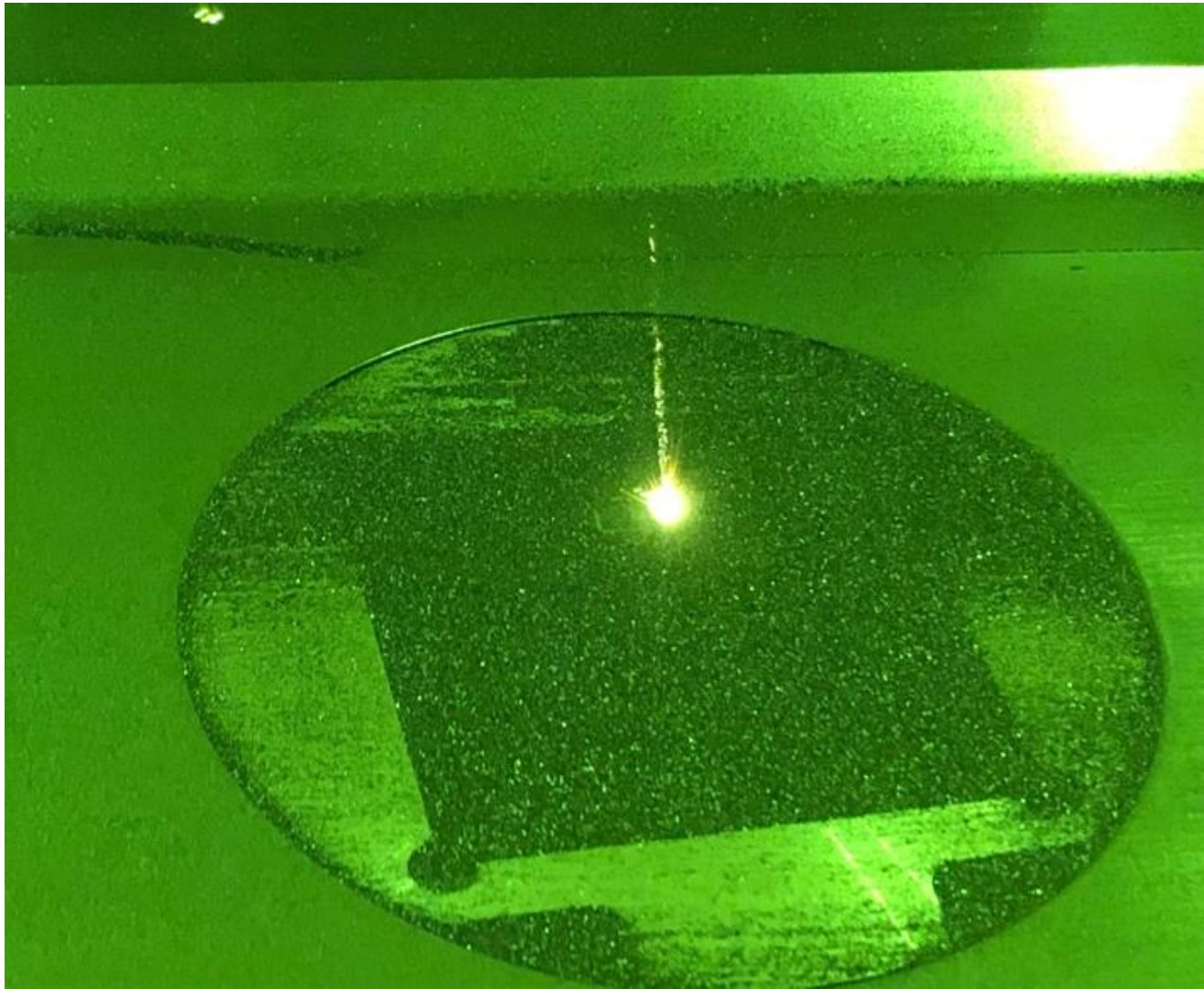
- Material synthesis and shaping in one process
- Laser selectively evaporates precursor powder, immediate local crystallisation
- Customised material properties with alloys
- 3D printing allows for arbitrary geometries



Many applications also beyond photonics: e.g. durable tools

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Main materials used today for high-end tools:

- tool steel
- tungsten carbide (in a Cobalt matrix)
- coated tungsten carbide
- diamond

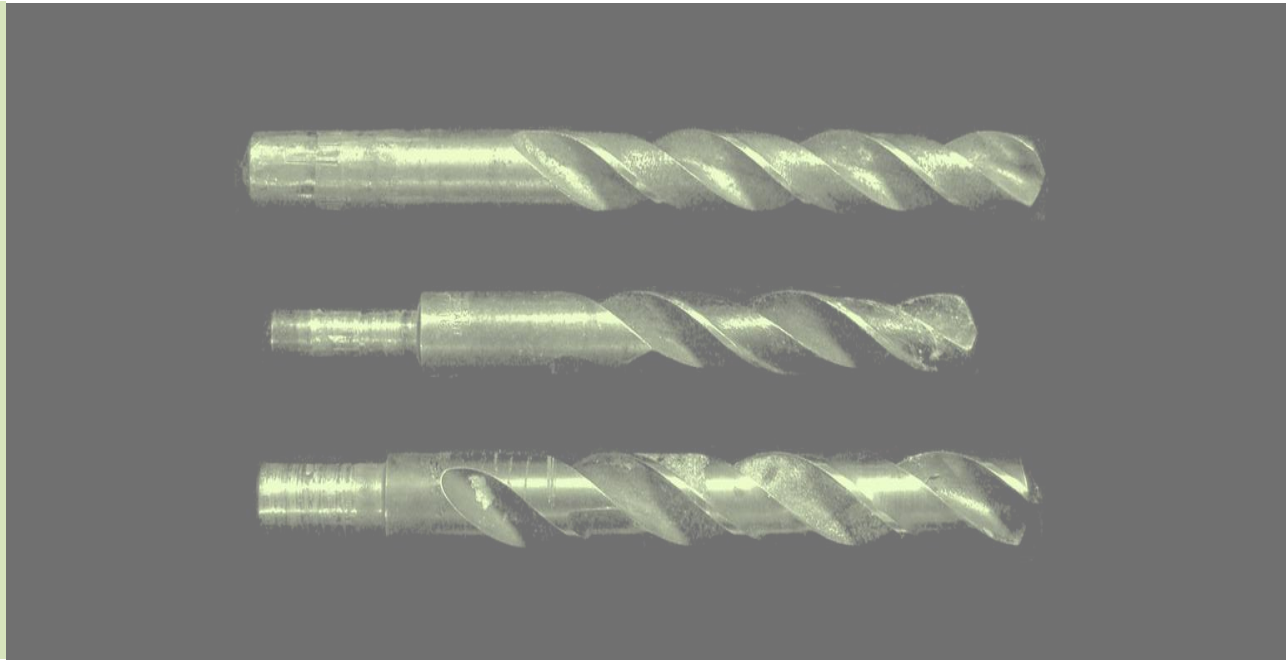
PSC Technologies offers

- job order production:
  small and medium-size series
- custom-specific materials
- later: production at the customers premises

Compared to tungsten carbide
SiC alloys have decisive advantages:

- much harder, light as aluminium
- better heat conductivity and heat resistance
- no matrix: massive alloy
- no problematic raw materials
- easy to produce

→ ***considerably higher lifetime***
→ ***lower lifecycle costs***



Business model:
Disruptive materials as a service

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1. PSC 3D Printing Service Provider

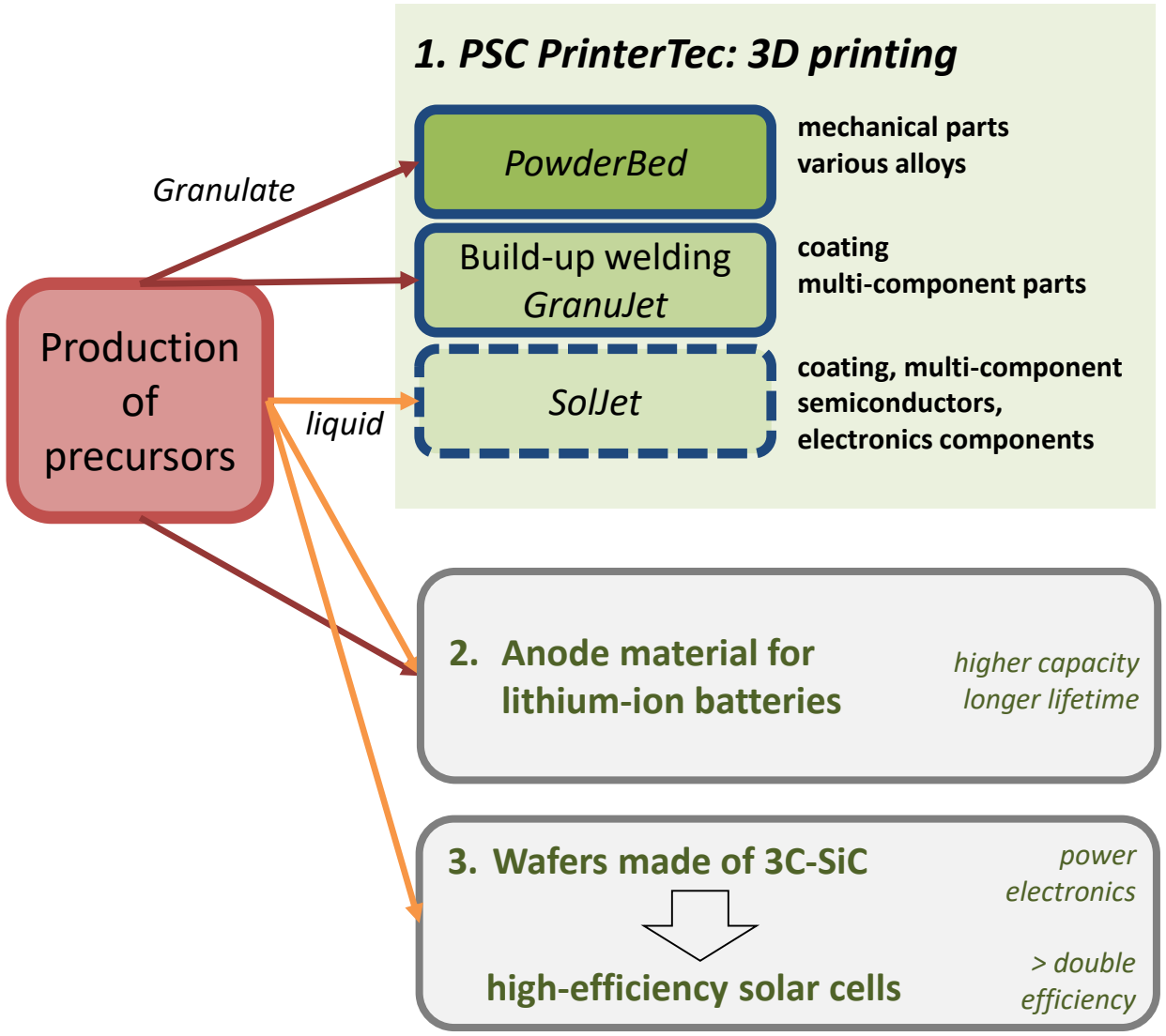
- Contract manufacturing
- Service Model / Licenses
- Customer support construction & design
- Customer-specific material development

2. PSC Development Laboratory

- 3D printing of SiC alloys
- Material for lithium-ion batteries
- Semiconductor wafers / solar cells

3. PSC participations

- Participation in joint ventures using technologies developed in-house
- Management of licenses



Our process for printing SiC:
Selective Synthetic Crystallisation SSC

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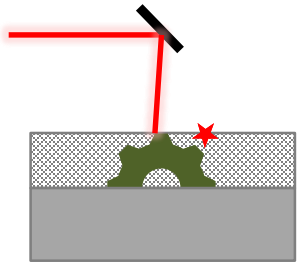
Proprietary precursor material

may contain additives for producing alloys and doped materials

3D printing



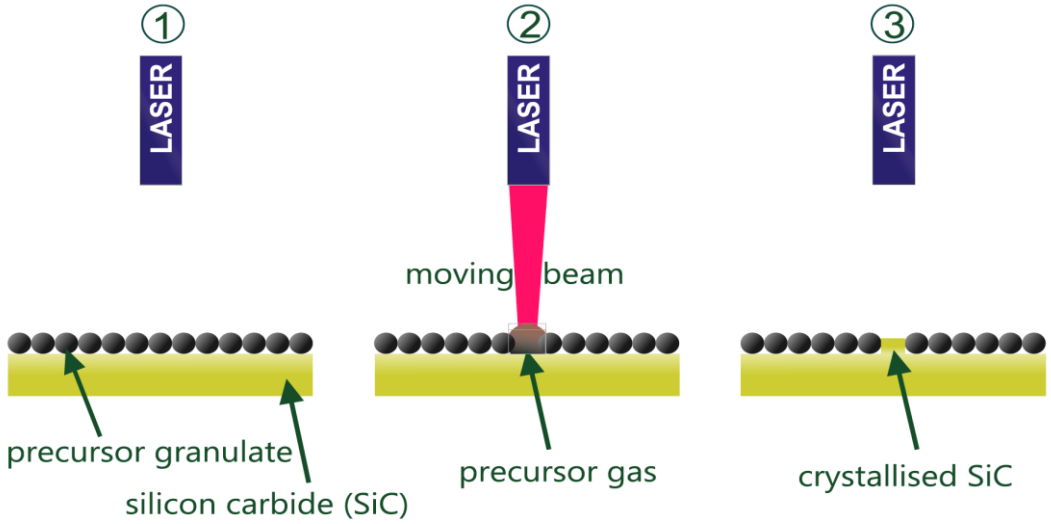
one step process small machine

massive silicon carbide

surface treatment with laser ablation may be integrated in same machine

Mechanical and electrical properties of SiC can be modified in wide range by integrating additives in the lattice structure

Complex combination of several chemical and physical processes with differing time constants and temperature requirements



Starting with a metal printing machine

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- November 2018: start of printing parameter development on a “Laser Metal Fusion” machine by Trumpf
- We found out that compared to metal printing (LMF, SLM …) SiC printing requires:
  - complex scanning strategies
  - longer exposure times
  - much lower laser power
- PSC can now print 3D-SiC with good mechanical characteristics
- However
  - The printing speed is too low
  - The porosity is not yet satisfactory

3D Test Cube: High dimensional accuracy

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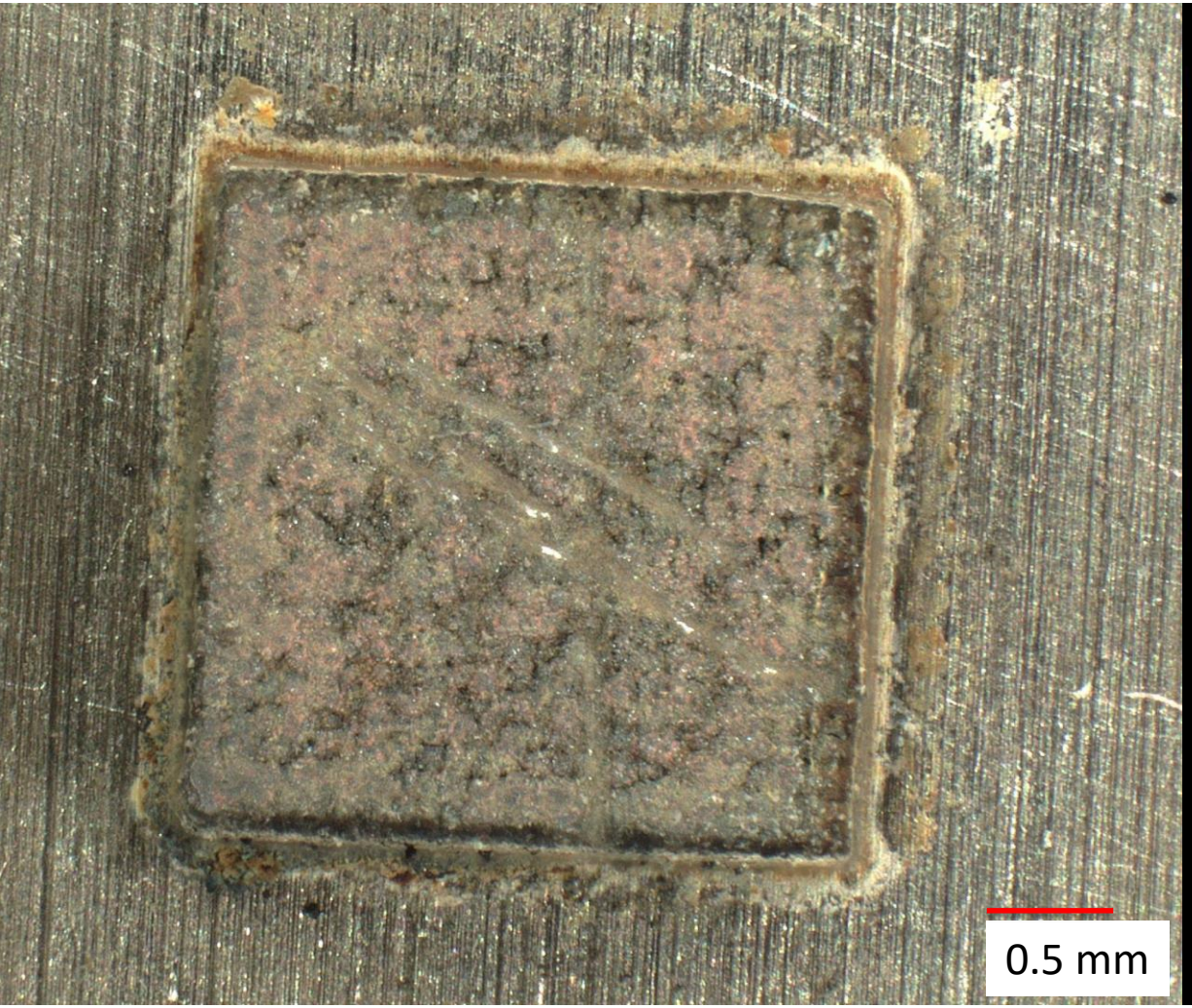

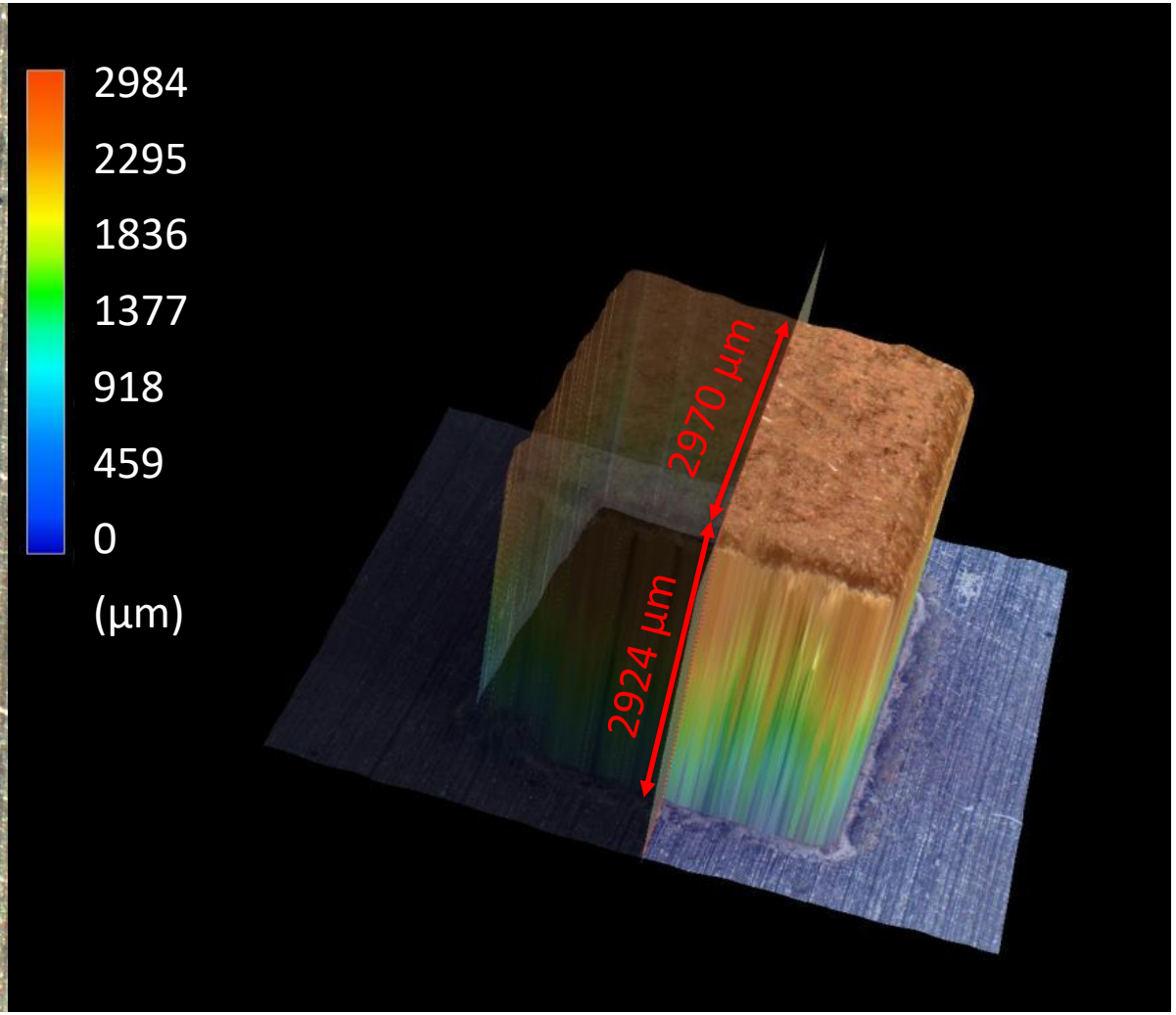

Polycrystalline 3D-SiC

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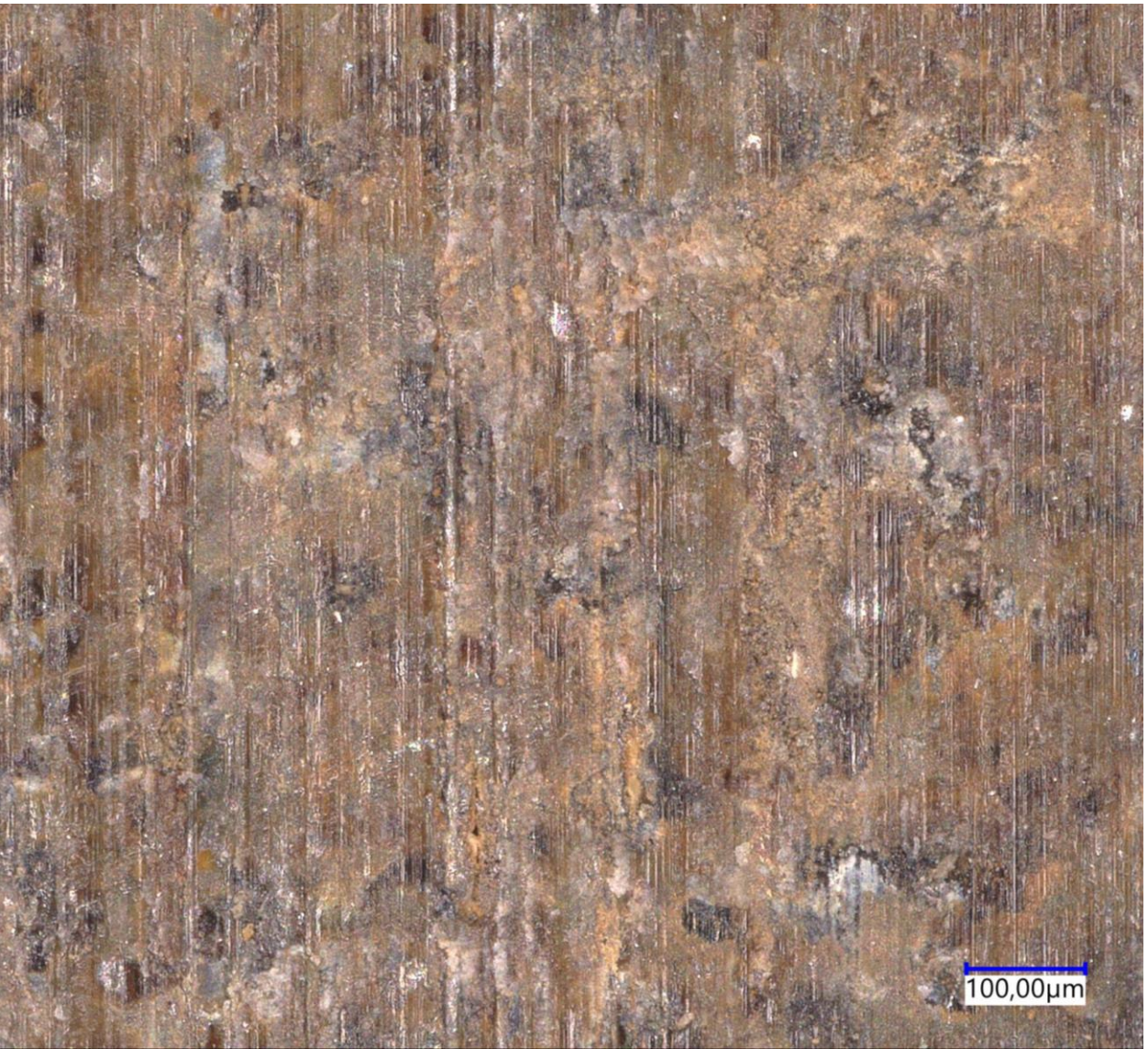

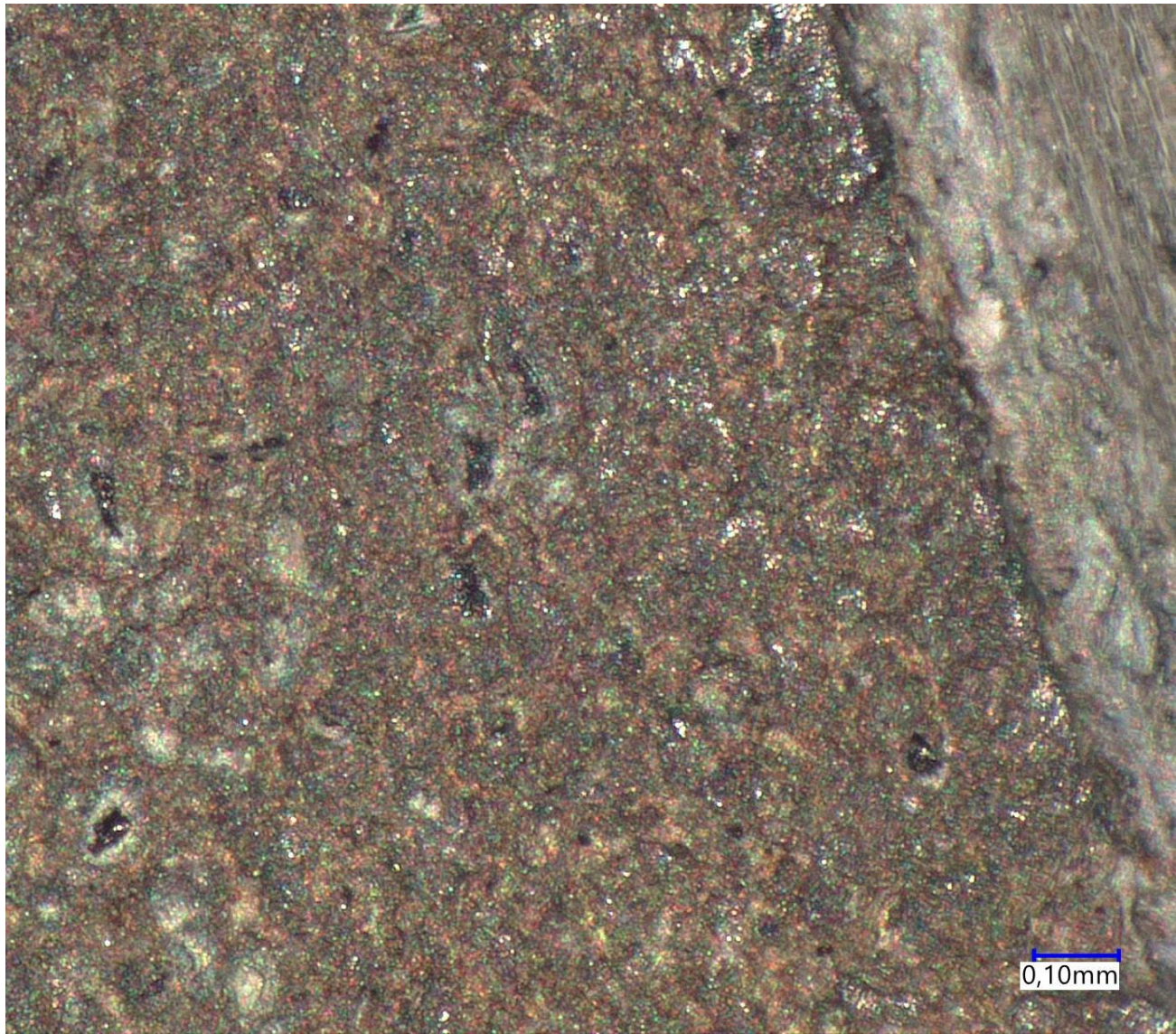

3D Test Cube: Polycrystalline 3C-SiC

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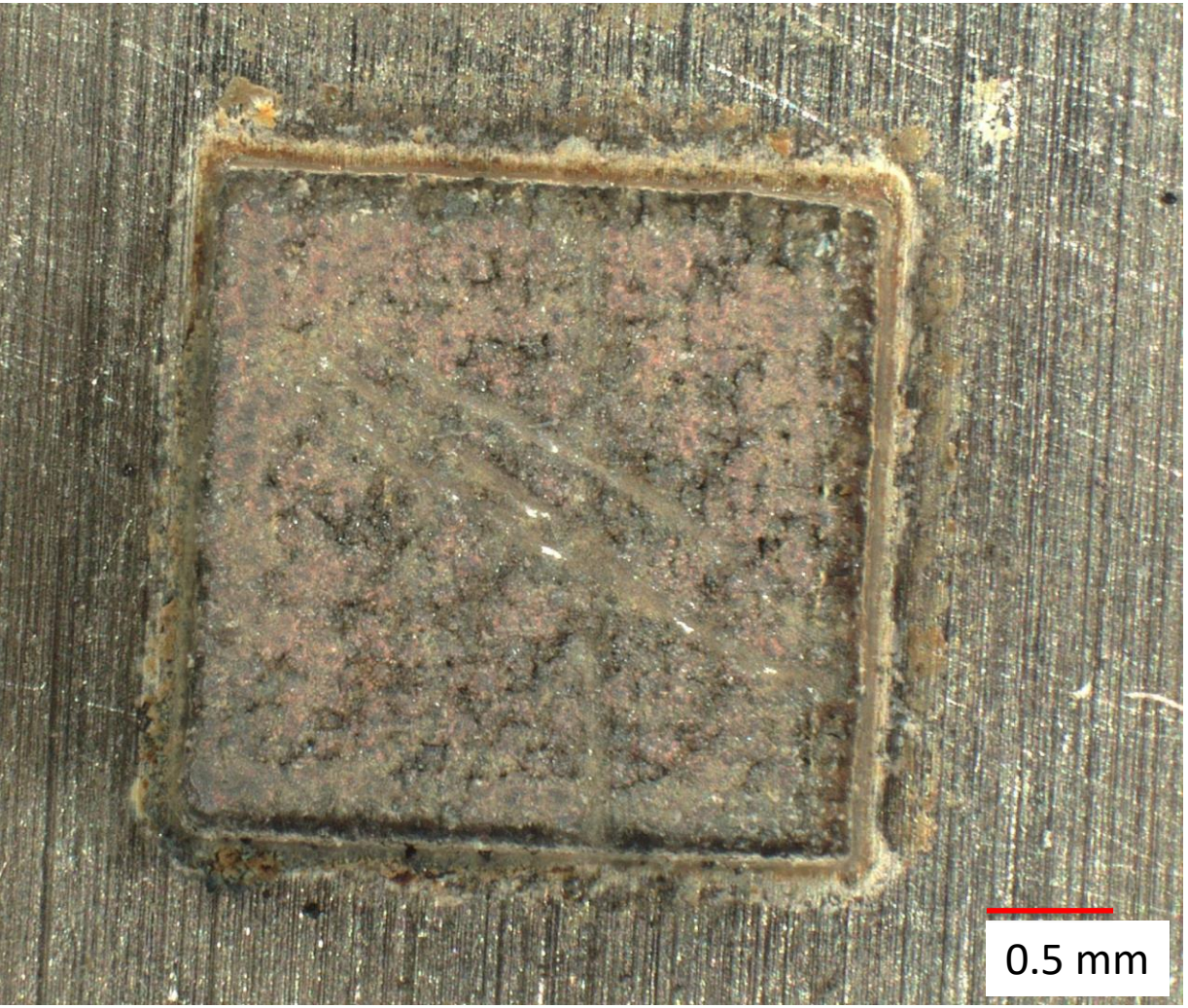

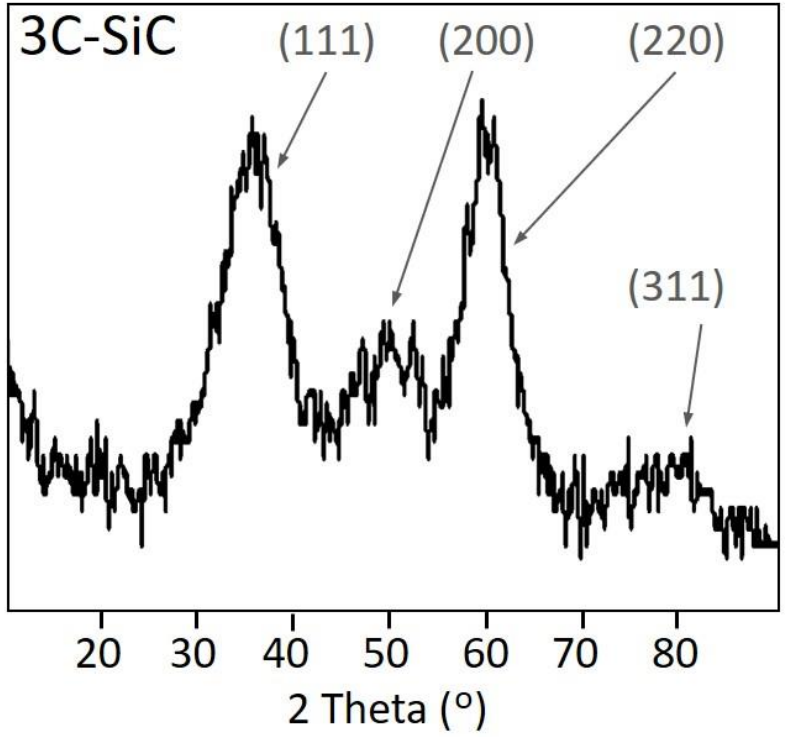

X-Ray Diffraction Result

→ Material: Polycrystalline 3C-SiC

Improving printing speed and quality with new technologies

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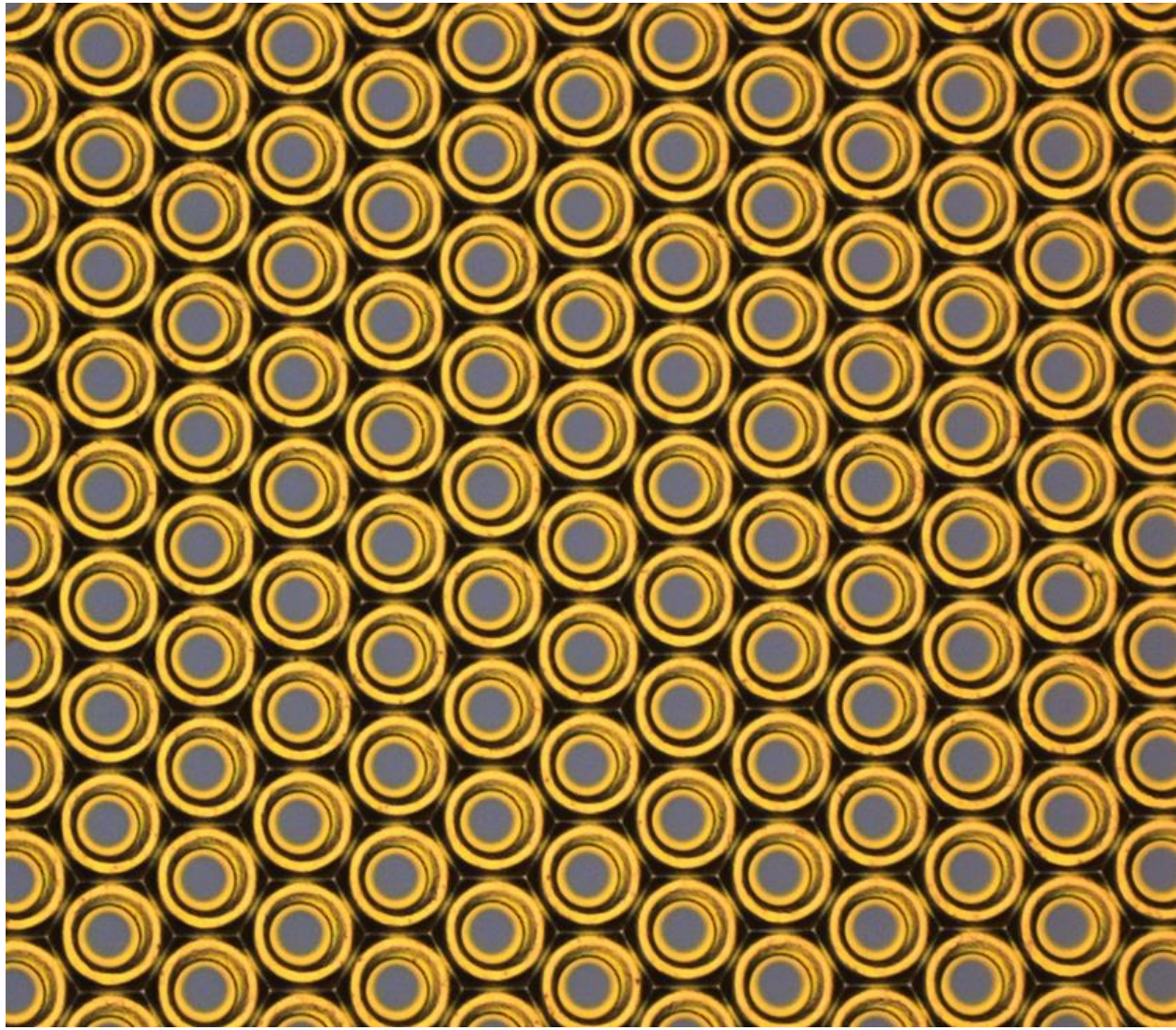
- Modular technologies from consumer markets enter the professional sphere
- New technological options for SiC 3D-printing with low-power lasers:
  - 3D printing technologies for plastics
  - communication laser technologies

CHEAP – MODULAR – FLEXIBLE – DIVERSE

HIGH INNOVATION RATE

- Printing SiC with arrays of thousands of low-power lasers will
  - multiply the printing speed
  - improve heat dynamics → better quality



PSC Technology Upgrade

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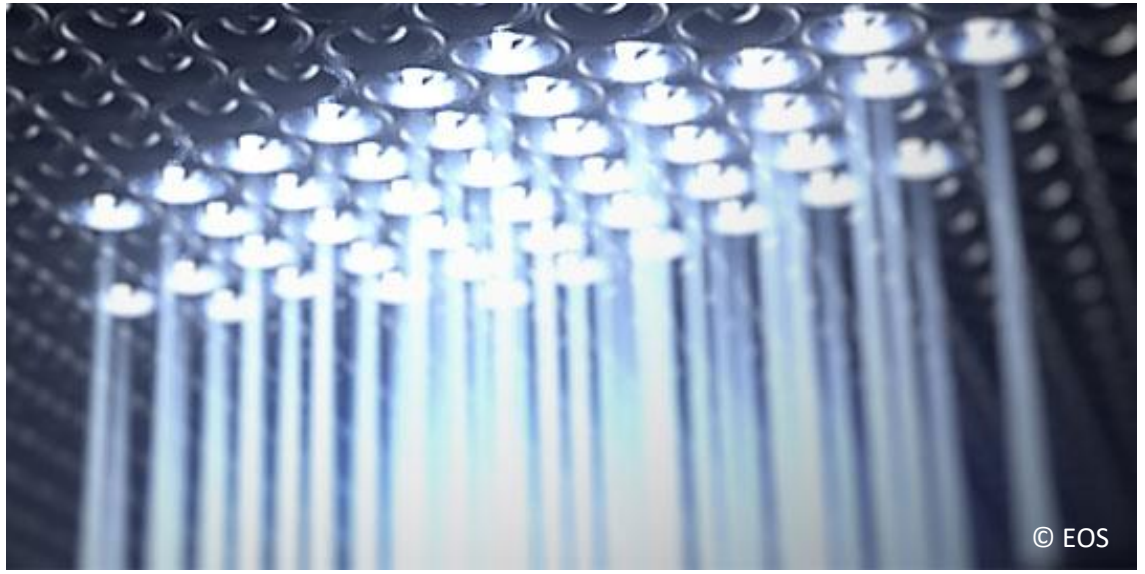
PSC will develop a high-speed SiC-printer prototype with laser arrays until end 2020

SiC printing will be cheaper than metal printing

The printer will not be for sale – In full-service leasing schemes customers will pay per print, including the precursor

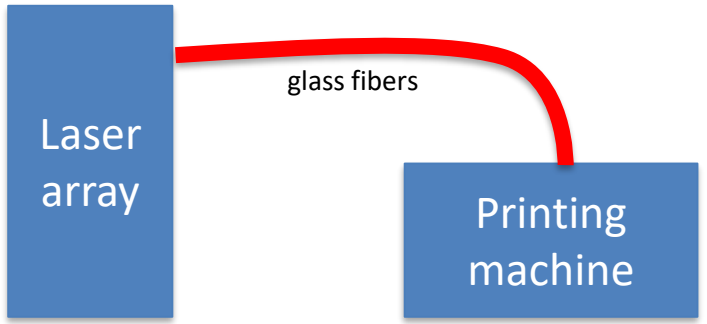
PSC slowly starts delivering samples for product development



EOS has announced a laser array plastics printer for 2021

alternative concept:

avoiding dense laser packaging and weight problems on a moving bar



Developing alloys and new products

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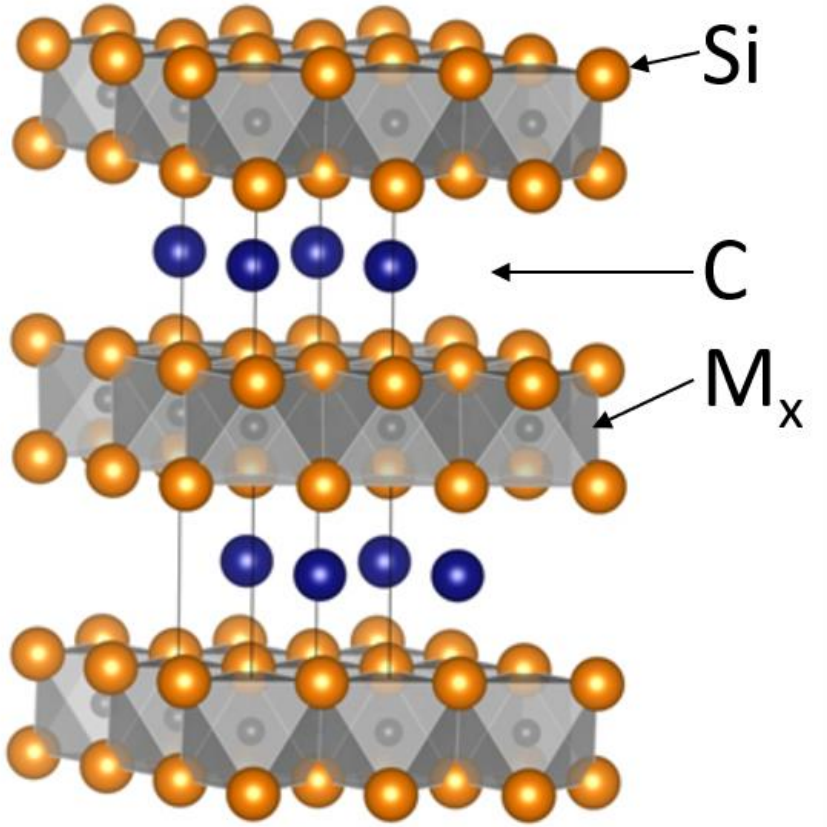
Silicon carbide alloys

- Additives are directly and homogeneously built into the lattice structure – directly modifying intrinsic mechanical and electrical characteristics
- The PSC process dramatically facilitates producing SiC alloys – up to now it was very difficult
- Discovery of this new class of materials starts now
- The range of varieties is probably larger than that of iron alloys i.e. steel
- We have started with vanadium an titanium alloys

Join us now for developing the right material for your new product. Be ready when the new printer is available



The next step:
Multi-component printing

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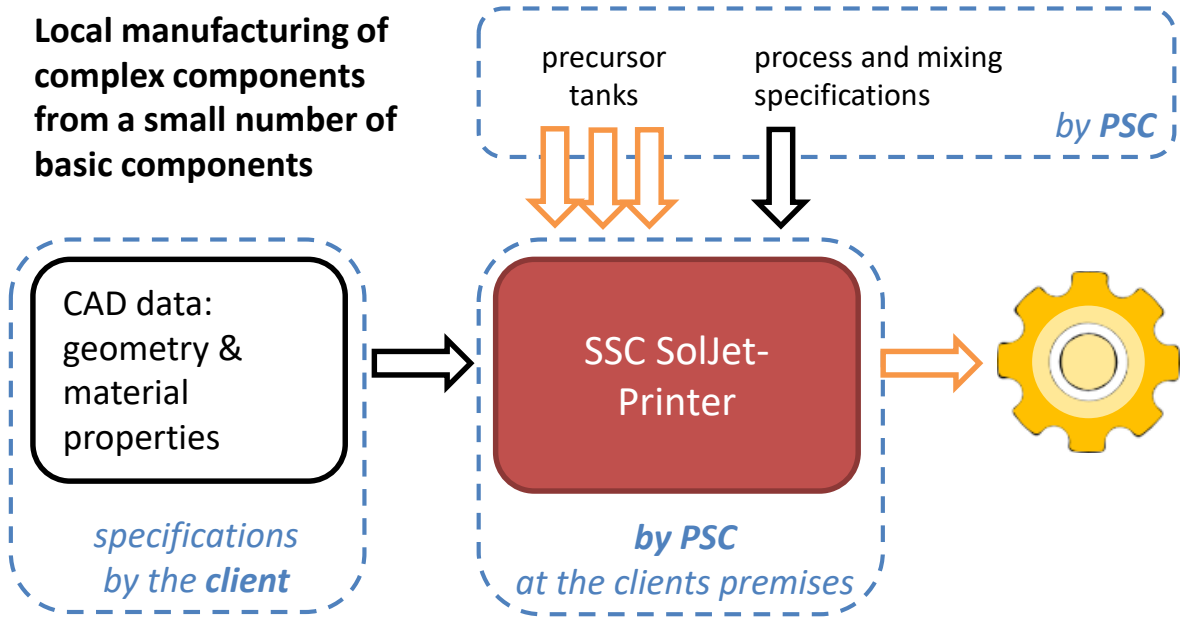
With liquid precursors applied with an ink-jet mechanism multi-component printing will become possible

PSC plans to develop such a “SolJet” printer by 2021. Automatic mixing of liquid precursor components will allow for printing a wide range of alloys

This opens the door to rapid 3D printing of multi-component semiconductor devices for power electronics



Electrical properties:
new options with the PSC process

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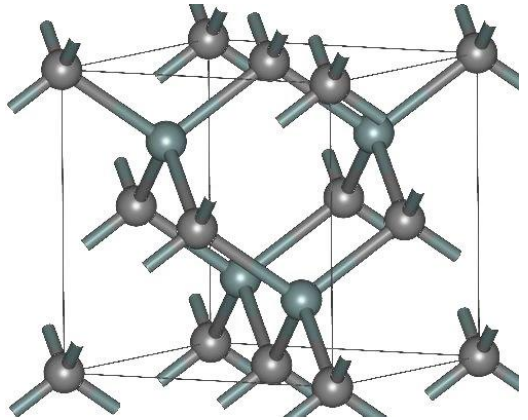
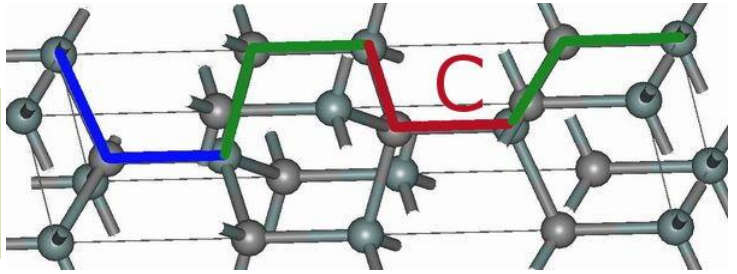
- The PSC process avoids the inclusion of nitrogen and can produce perfectly non-doped, isolating SiC – the perfect basis for a coherent variety of doped materials
- Commercial semiconductor-grade SiC always contains nitrogen – a hurdle for many applications
- The PSC processes allow to produce 3C-SiC with a cubic lattice structure – there is no commercial procedure for this until now
- The 3C-SiC has advantageous electronic properties
- Nitrogen-free 3C-SiC is the precondition for producing intermediate-band solar cells with triple efficiency



3C-SiC

6H-SiC



Mechanical parts for optics and micromechanics

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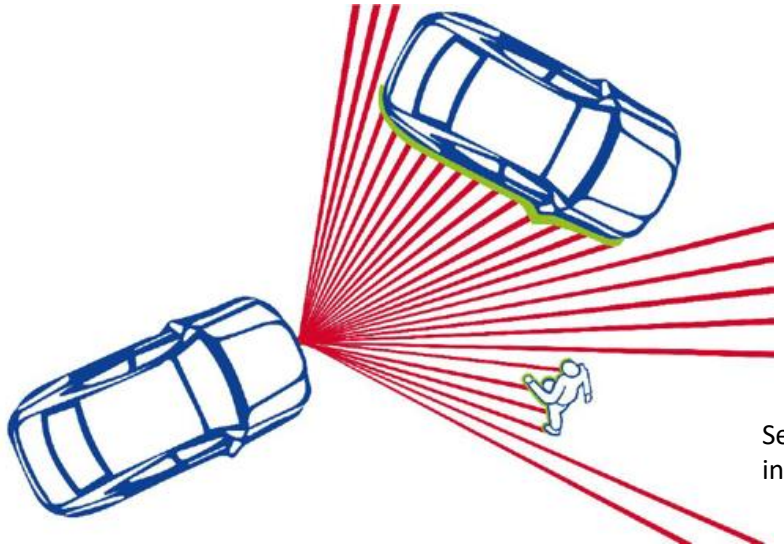
High-tech optics and micromechanics depend on extremely stable materials

- *carriers and casings*
- *bearings and gliders*
- *sensors*

low thermal expansion is key



Sensors must deliver same results independent of ambient conditions

For highest requirements, sintered SiC is already used today

Advantages of PSC 3D-printed SiC over sintered SiC

- easy shaping through 3D printing
- optimized geometry, cooling channels
- higher mechanical & thermal load capacity
- No binder, no sintering
- massive, not porous
- faster production

Also for replacing less sensitive ceramic or metal parts PSC-SiC may be very attractive

Integrating packaging and thermal management

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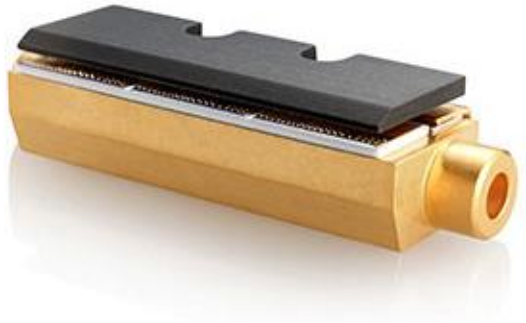
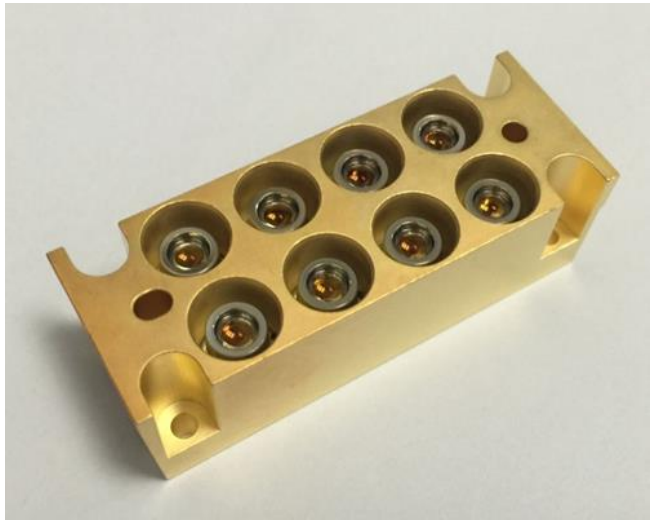
Thermal management today:
Main materials used for heat exchangers and heat sinks:
Aluminium, Steel, Ceramics

New horizons for functional integration:
substrate, packaging and cooling can all be combined in a complex piece

3D printed SiC alloys are technically superior in every respect:

- outstanding thermal conductivity
- arbitrary geometries, cooling channels
- **electrical insulator**
- corrosion resistant
- high mechanical load capacity
- significant weight saving





Applications in Photonics: Coating

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Coatings of SiC alloys on a wide variety of materials:

- Steel, Aluminium, Copper
- Silicon, Glass, Ceramics

Interesting for a wide range of applications:

- wear parts, gliders
- corrosion protection
- electrical insulation, heat transfer
- optical technologies
- sensors

Technological perspective

- structured coating of curved surfaces with build-up welding technologies

Please contact us

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PSC is looking for:

Customers engaging in product development projects

Technology suppliers for our new printers

Investors

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This presentation was presented at EPIC World Photonics Technology Summit 2019

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