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mi2-factory

MATCHED ION IMPLANTATION

Energy-Filter For Ion Implantation - EFII©

OUR CORE TEAM...

...WORKING TOWARDS A BETTER WORLD

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Learn More About Our Innovation

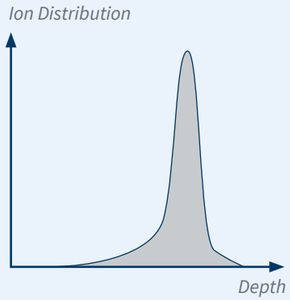
TECHNOLOGY INNOVATION FOR PRECISION DOPING

Energy-Filtered Ion Implantation

Using an energy-filter (EFII©) for ion implantation enables conversion of a monoenergetic ion beam to that with a **continuous energy spectrum**, thereby **enabling depth-distributed and highly homogeneous doping**.

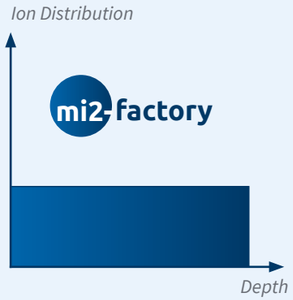
Conventional Ion Implantation

The conventional method only permits a Gaussian distribution with no deep drive-in.



Energy-Filtered Ion Implantation

Our technology facilitates both depth-distributed box & customized doping profiles.



"[…] the standard doping process, by adding dopants during chemical vapour deposition, lacks precision and thus results in large doping variations across the wafer and from wafer to wafer."

A. Bauer, Fraunhofer IISB, Erlangen, Germany

mi2-factory

Patented Energy-Filter Technology

Substrate

Energy-Filtered Ion Beam

Monoenergetic Ion Beam

Hardmask On Substrate

Triangular Silicon-Based Filter Structure

SIC SUPERJUNCTION MOSFET

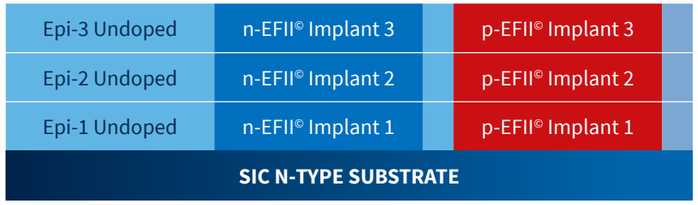
APPLICATIONS & BENEFITS

Enabling SiC Superjunction Structures

1.2kV SiC superjunction (SJ) MOSFETs are superior in cost-performance compared to conventional MOSFETs. But how to manufacture a SJ structure in SiC? Our approach: multiepitaxy with masked EFII© p- and n-implant.
We enable cost reduction, design innovation & performance boost for your microchips.

Manufacturing Approach

Our technology enables specialized implantation and undoped epi regrowth.

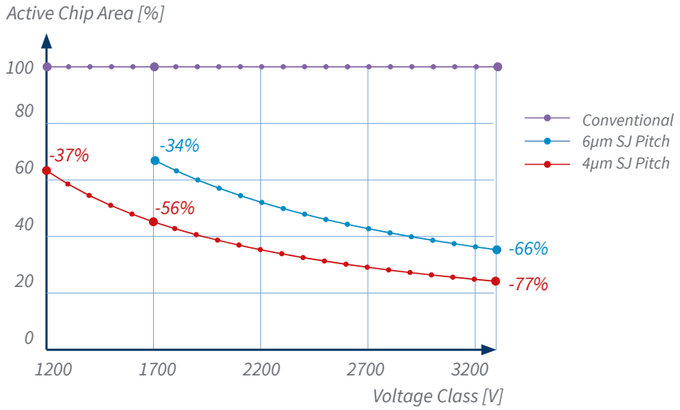


Applications

SiC SJ MOSFET:

- 1200V
- 1700V
- 3300V
- Shrink and yield

Active chip area reduction afforded by SiC SJ MOSFET relative to conventional SiC MOSFET is visualized on the right.



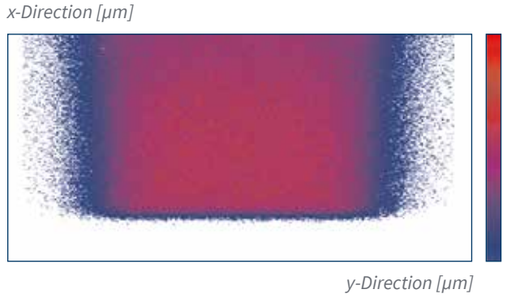
Tatsuhiko Fujihira: „Theory of Semiconductor Superjunction Devices“, Japanese Journal of Applied Physics, Volume 36, Part 1, Number 10, 1997

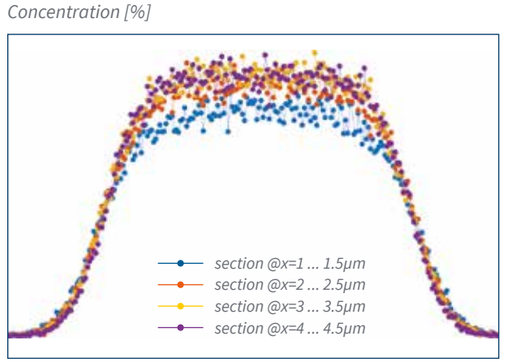
Masked Energy-Filtered Monte Carlo Simulation

A simulation tool kit called EFIIS© (Energy Filtered Ion Implantation Simulator) has been developed which allows to investigate the exact shape of 3-dimensional doping structures. EFIIS© is based on the ion implantation Monte-Carlo simulator GEANT4. Any desired setup of ion beams, energy-filter designs, mask designs etc. can be tested. **EFIIS© allows for exact characterization of lateral and vertical doping profiles.** The simulation results can be imported into TCAD software to provide for device simulation which are as accurate as possible.

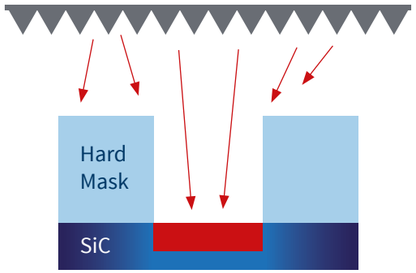
AGOSTINELLI, Sea, et al. GEANT4 -a simulation toolkit. Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2003, 506. Jg., Nr. 3, S. 250-303

Implantation Profile





Simulation Design



SIC DIODE DRIFT ZONE
APPLICATIONS & BENEFITS

Advantages And Properties

Our cutting-edge EFII© technology provides **exceptional n-type drift zone doping** for 600V-1200V SiC power devices. **We recommend using undoped epitaxial layer formation followed by the EFII© process** to manufacture n-type drift zones. This method will help realize previoulsy unattained levels of doping uniformity (3%). Positive side effect: Deposition of undoped SiC epitaxial layers leads to improved thickness uniformity.

Benefits

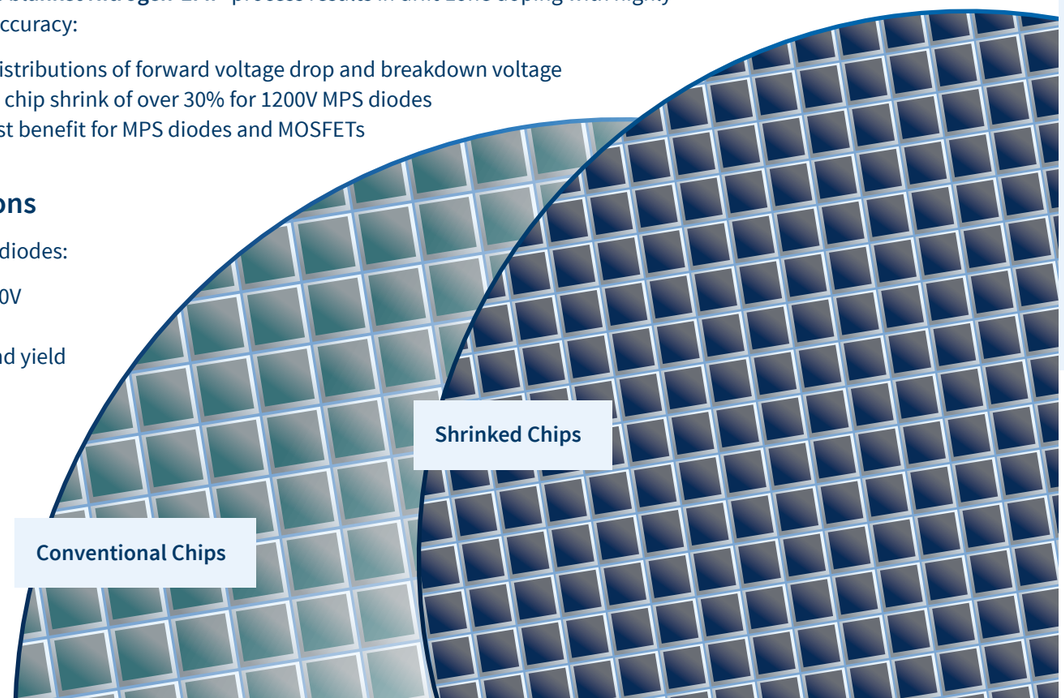
mi2-factory's blanket Nitrogen-EFII© process results in drift-zone doping with highly augmented accuracy:

- Tighter distributions of forward voltage drop and breakdown voltage
- Potential chip shrink of over 30% for 1200V MPS diodes
- Direct cost benefit for MPS diodes and MOSFETs

Applications

SiC Schottky diodes:

- 600V / 650V
- 1200V
- Shrink and yield



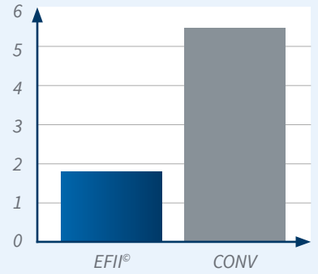
Proof Of Our Technology

Our test vehicle - the 650V SiC MPS diode from Infineon Technologies - has provided robust and compelling **proof of the EFII© technology's succesful translation to and suitability for commercial settings and applications.**

Packaged Chip Data

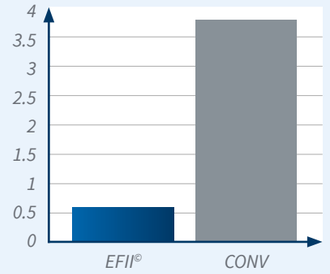
Differential Resistance R_{Diff}

Interquartile range / Median [%]



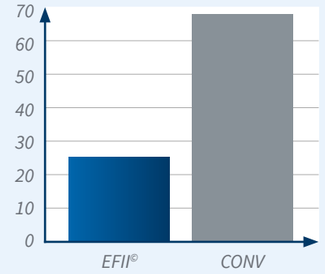
Blocking Voltage V_R

Interquartile range / Median [%]



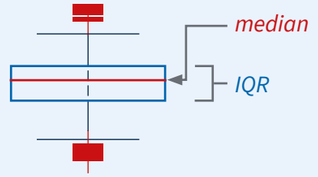
Leakage Current I_R

Interquartile range / Median [%]



Result

The IQR/median value of packaged diodes is much smaller for EFII© chips than for conventional chips. *(Data from joint project IFX-mi2-factory, 2015)*
Forward characteristics up to 10x 12A.



Alternative highly homogenous drift layer doping for 650 V SiC devices
R. Rupp et al, Materials Science Forum, ISSN: 1662-9760, Vol. 858, pp 531-534

SIC EPI DOPING

HIGHLY PRECISE TECHNOLOGY

[…] the energy-filter technology […] is highly innovative and exceeds the state of the art. There is no comparable product on the market.

A. Bauer, Fraunhofer IISB, Erlangen, Germany

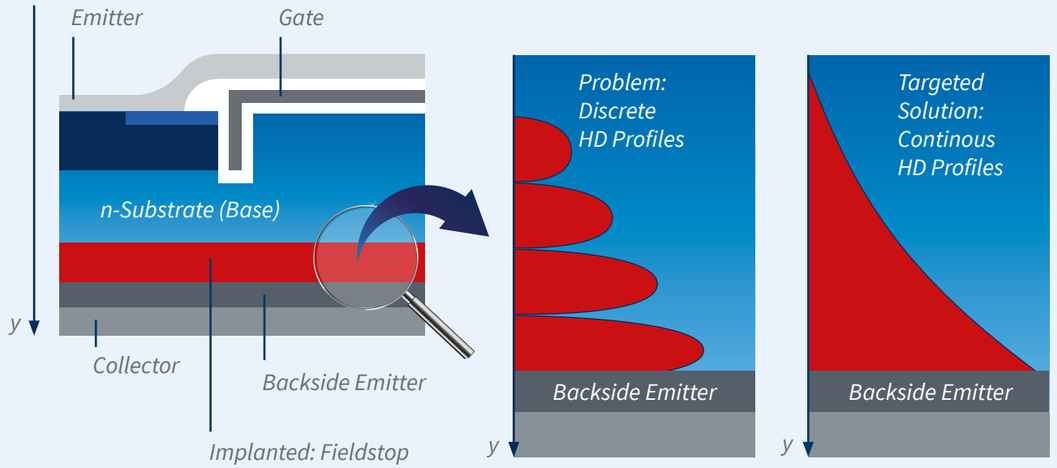
Our technology guarantees high precision epi layer doping and improved thickness uniformity. Chip manufacturers are guaranteed higher device yield and quality alongside substantially improved cost efficiency.

SI IGBT FIELD STOPP

APPLICATIONS & BENEFITS

Advantages And Properties

mi2-factory offers customers **unprecedented flexibility in lifetime management.** Our EFII© technology enables continuous hydrogen-donor (HD) related n-doping.



Benefits

Enabling Si IGBT performance increase

- Improved electric field distribution
- Optimized field stop for reduced static and dynamic losses

Applications

Si IGBT

- n-doping
- lifetime-management
- performance

ENERGY-FILTER

FEATURES

Doping Specification

- Concentration variation wafer to wafer < ± 3%
- Concentration variation center / edge < ± 3%
- Depth range variation < ± 3%

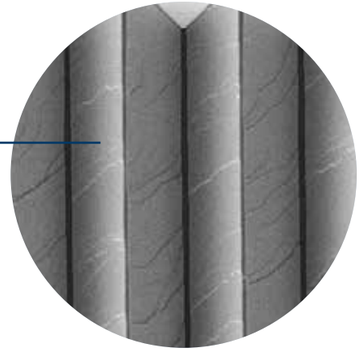
Defect And Contamination Control

- Contamination: Silicon-based filter results in low contamination levels
- Defects: No observation of detrimental material defects for 1E16cm^{-3} N concentrations

Lifetime And Quality Control

- Over 60 wafers (6“) can be processed with one filter when keeping the filter‘s temperature below 500°C
- mi2-factory is ISO 9001 certified since Q4/2017
- Our implantation facilities and MEMS suppliers are all ISO 9001 certified

No degradation occurs after 66 implanted wafers.
Dose on each wafer: ~1E13cm^{-2}, N, with 1 energy-filter (at T < 500°C)



We Support You With Our Products & Services

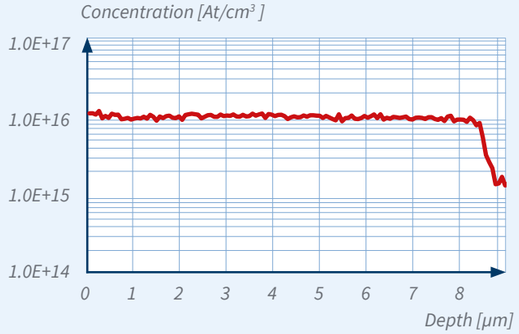
DOPING PROFILE

FEATURES

Our standard products are N for n-doping and Al for p-doping.
Special parameter sets are available on request.

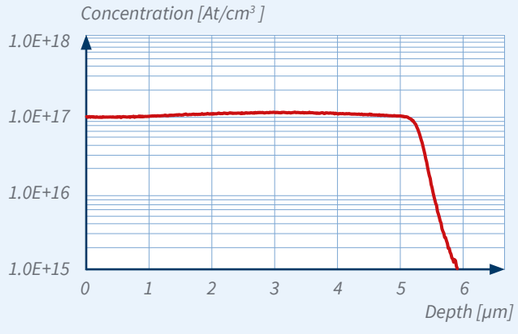
Nitrogen-Box, Dopant: N, 600V-1200V

SUBSTRATE	TARGET CONC.	DEPTH	PROFILE
SiC: 3“-6“	5E15cm^{-3} up to 3E16cm^{-3}	up to 8µm	Box, Blanket I^2 or Masked



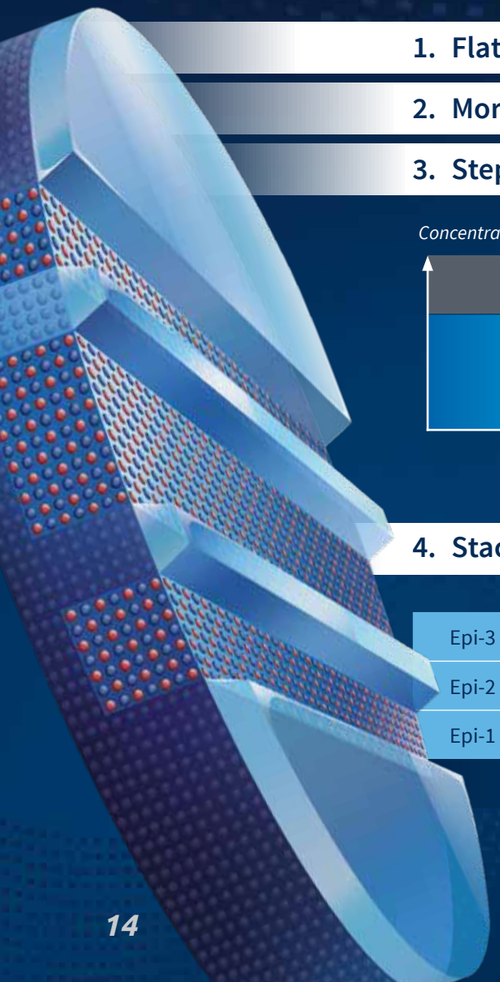
Aluminium-Box, Dopant: Al

SUBSTRATE	TARGET CONC.	DEPTH	PROFILE
SiC: 3“-6“	5E15cm^{-3} up to 3E16cm^{-3}	up to 5µm	Box, Blanket I^2 or Masked

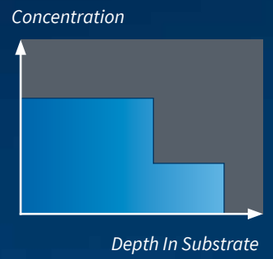


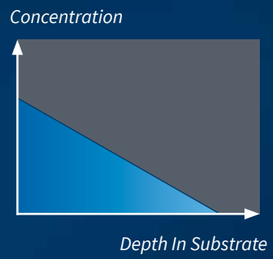
Our Innovation Enables Great Opportunities

OPTIMAL CUSTOMIZED SOLUTIONS FOR SPECIAL DOPING TASKS



1. **Flat or ultra deep profiles**
2. **More elements like H, He, Boron, Phosphorous**
3. **Stepped and graded profiles**





4. **Stacked profiles for superjunction devices**

Epi-3 Undoped	n-EFII© Implant 3	p-EFII© Implant 3
Epi-2 Undoped	n-EFII© Implant 2	p-EFII© Implant 2
Epi-1 Undoped	n-EFII© Implant 1	p-EFII© Implant 1
SIC N-TYPE SUBSTRATE		

We Offer Various Benefits For Our Customers

KEY BENEFITS OF EFII© TECHNOLOGY

THE EFII© TECHNOLOGY ENABLES COST REDUCTION, DESIGN INNOVATION & PERFORMANCE BOOST FOR YOUR MICROCHIPS!

Benefits

1. Excellent concentration control
2. Excellent homogeneity
3. Excellent reproducability
4. Free choice of dopant

Customers

- SiC device manufacturers
- Implant facilities
- Substrate-/epi providers
- Academic and university

	CHAIN IMPLANT	EFII©
NECESSARY ION ENERGIES	Several different energies necessary	Only a single ion energy
NUMBER OF NECESSARY ACCELERATORS	Several, owing to high variability from few keV to several MeV	Only one, since only a single MeV energy necessary
DEPTH PROFILE QUALITY	No entirely homogenous doping profile possible	Highly homogeneous
PROCESS CONTROL AND WAFER LOGISTICS	Complicated and highly error-prone	Robust, straight-forward and reliable
TOTAL IMPLANTATION TIME	High implantation time due to energy adjustment	Significantly reduced implantation time
IMPLANTATION COST	High cost	Reduced cost

MI2-FACTORY'S ION IMPLANT FACILITY PARTNERS

HZDR Innovation GmbH

- Accelerator: 6MV and 3MV Tandetron
- DIN EN ISO 9001 certification
- Experienced manufacturing for major semiconductor companies

rubitec – Gesellschaft für Innovation & Technologie der Ruhr-Universität Bochum mbH

- Accelerator: 4MV Tandetron
- DIN EN ISO 9001 certification
- Experienced manufacturing for major semiconductor companies
- 10,000 semiconductor wafers per year processed for industry

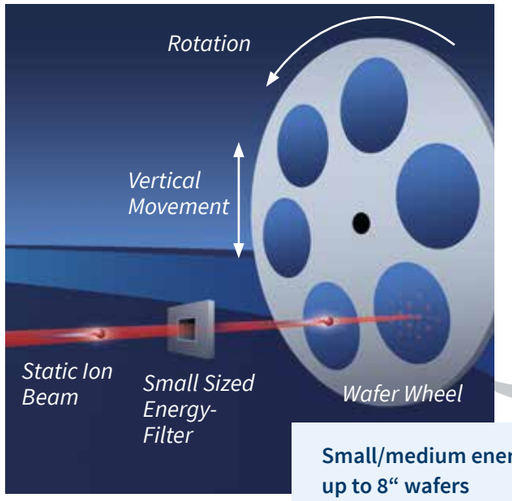
Brookhaven National Laboratory

- Accelerator: 15MV Tandetron
- Experience in industrial application of ion implantation

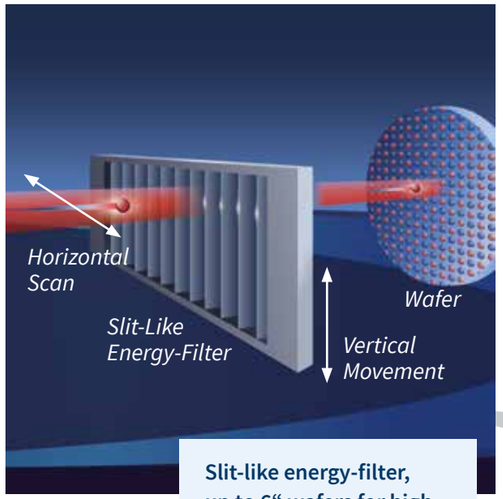
IMPLANTATION SETUPS

Elements And Substrates

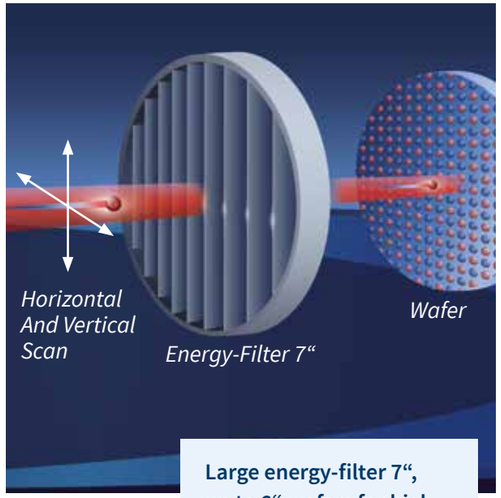
- N, Al as common dopants in SiC can be implanted with EFII©
- More elements possible: H, He, B, P, etc.
- Substrates: Si, SiC and others
- Masked / blanket implantation



Small/medium energy-filter, up to 8“ wafers

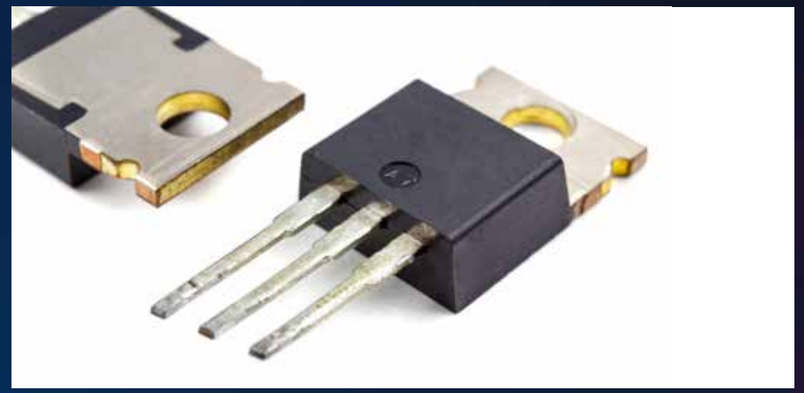


Slit-like energy-filter, up to 6“ wafers for high throughput flexibility



Large energy-filter 7“, up to 6“ wafers for high throughput

APPLICATIONS TOWARDS A GREENER FUTURE



Together with you we are working for a sustainable future!

OUR VISION

Device

EFII© will be established as enabling technology for superjunction MOS transistors for wind power, photovoltaic, electric vehicle, thus contributing to achieve climate targets.

Process Technology

EFII© will be established as a standard SiC specific industrial processing technique, like capped annealing gas phase wafer growth.

Implantation Equipment

EFII© will foster the industrial application of high energy ion implantation by allowing simplified equipment.

mi2-factory

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Freistaat Thüringen — Thuringian Ministry for Economic Affairs, Science and Digital Society

ZIM Zentrales Innovationsprogramm Mittelstand

EFRE EUROPE FOR THURINGIA EUROPEAN REGIONAL DEVELOPMENT FUND | EUROPEAN UNION

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

ESF EUROPE FOR THURINGIA EUROPEAN SOCIAL FUND | EUROPEAN UNION European Social Fund

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