Electronics and
Computer Science

ELEC2208 Power Electronics and Drives

Extra slides

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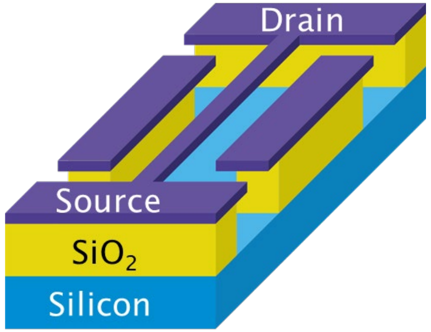
My research link with Power Electronics

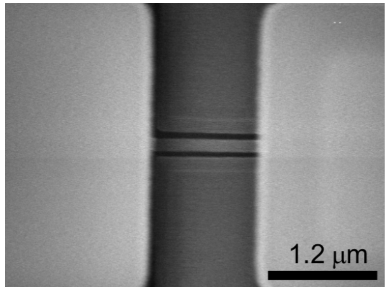
Topic

Nanoelectromechanical Systems (NEMS)

NEMS Resonator

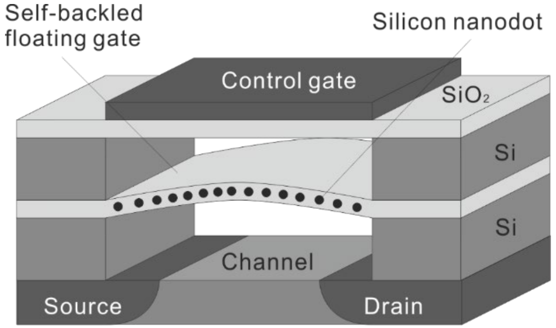
Y. Tsuchiya et al., IEEE MEMS2018

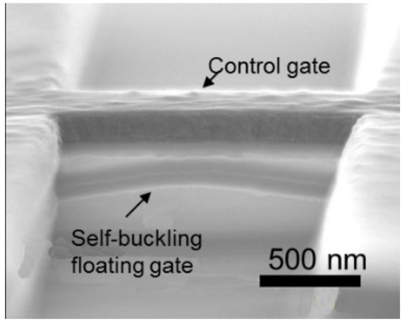




NEMS memory

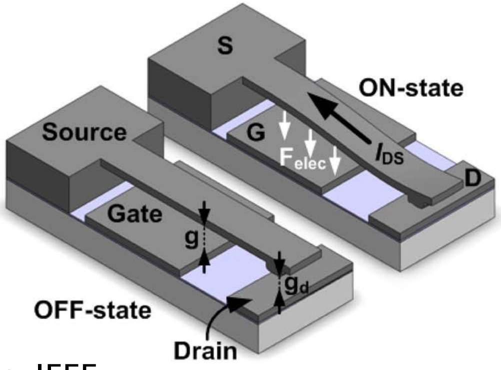
Y. Tsuchiya et al, JAP 2006



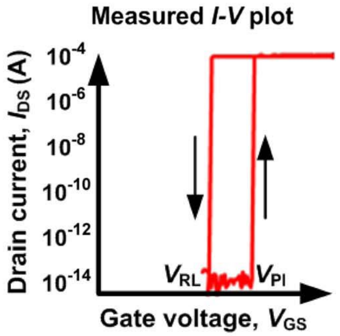


MEMS/NEMS switches for power management ➡ Towards "Ideal switch"!

Contact switches



(a)

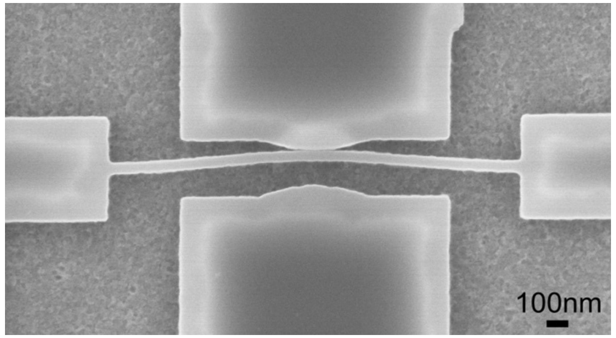


(b)

V. Pott et al., Proc. IEEE 98, 2076 (2010).

Energy-reversible low-power NEMS switches

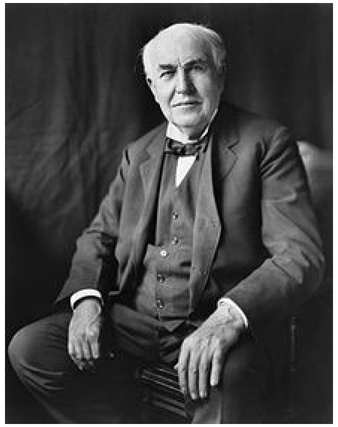
Boodhoo, Tsuchiya *et al.*, Microelec. Eng. 2015.



Diode – History

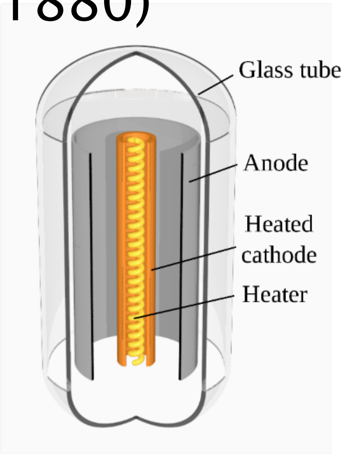
Topic

F. Guthrie
British physicist
(1873)



T. Edison
American inventor
(1880)

Vacuum tube diode



K. F. Braun
German engineer
(1874)

J. C Bose
Indian scientist
(1894)

Solid state diode

Contact between metal and mineral/crystal

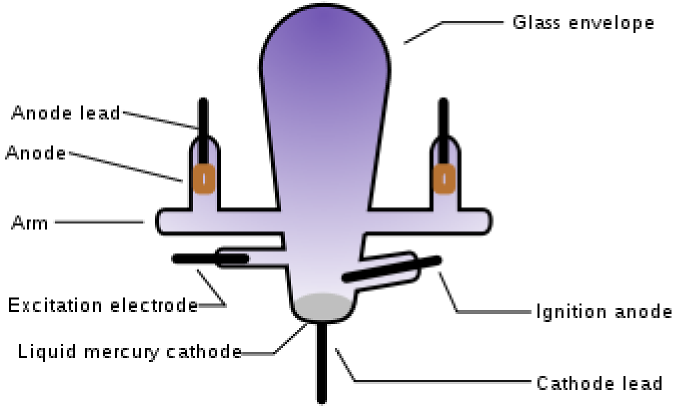
https://en.wikipedia.org/wiki/Diode https://www.idc-online.com/technical_references/pdfs/electronic_engineering/History_of_diode.pdf

Rectifier – History

https://en.wikipedia.org/wiki/Rectifier

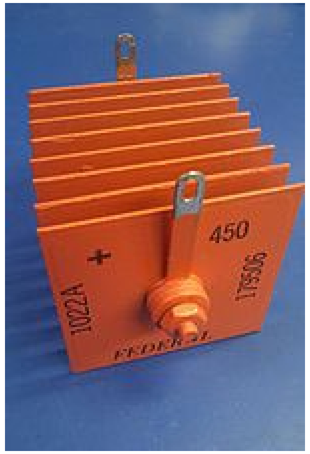
Topic

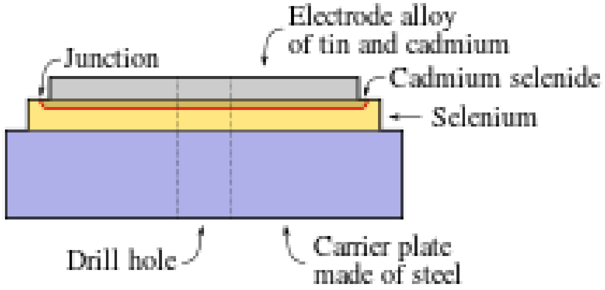
Mercury-arc rectifier



- Invented by American engineer Peter Cooper Hewitt in 1902.
- Cold cathode gas-filled tube.
- For high-voltage and high current.

Selenium rectifier





- Manufactured from 1930s
- Metal (CdSe) – Semiconductor (Se) junction

Then superseded by silicon rectifier in 1970s.

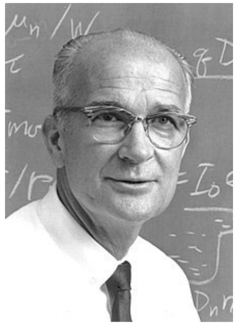
Thyristor - History

Topic

https://en.wikipedia.org/wiki/Thyristor

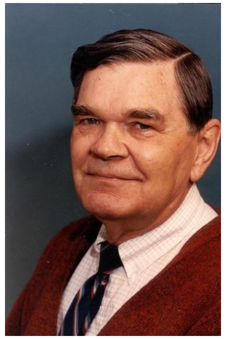
https://www.tdworld.com/digital-innovations/hvdc/article/20969683/a-short-history-on-the-thyristor-valve

- PNPN switches developed at Bell laboratories.



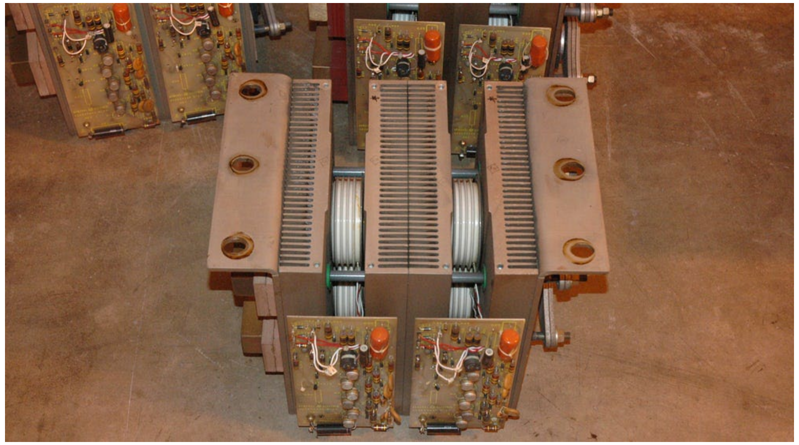
Proposal

W. Shockley



Team leader

J. Moll



- Commercialised by General Electric (GE) in 1957.
- "Thyratron" + "Transistor" = "Thyristor"
- Dawn of "Power Electronics"

Frank "Bill" Gutzwiller

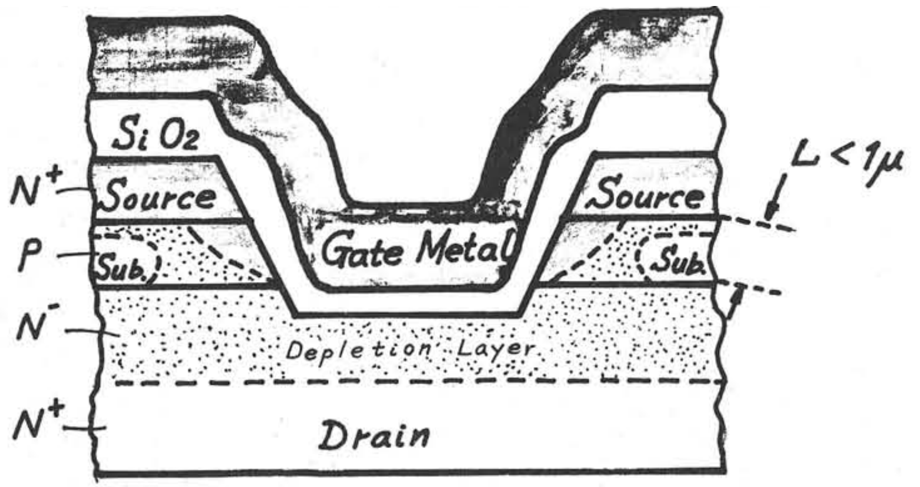
Power MOSFET - History

Topic

MOSFET was invented by Atalla and Kahng at Bell Labs, US in 1959.

https://en.wikipedia.org/wiki/Power_MOSFET

Tarui et al., SSDM 1969

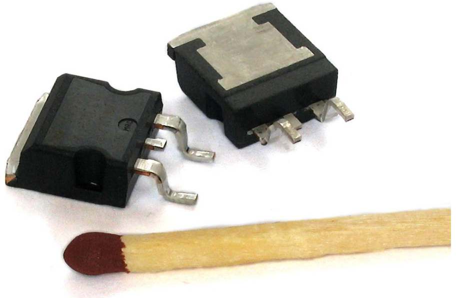


Power MOSFET was invented in 1969

- Hitachi invented a basis of VMOS (Vertical MOS)
- Yasuo Tarui et al (ETL, Japan) invented DDMOST (Double-Diffused MOS Transistor)

Commercialisation

Siliconix (UK) delivered VMOS in 1975 as the first power FET in the marketplace.



https://www.electronicdesign.com/content/article/21188215/then-and-now

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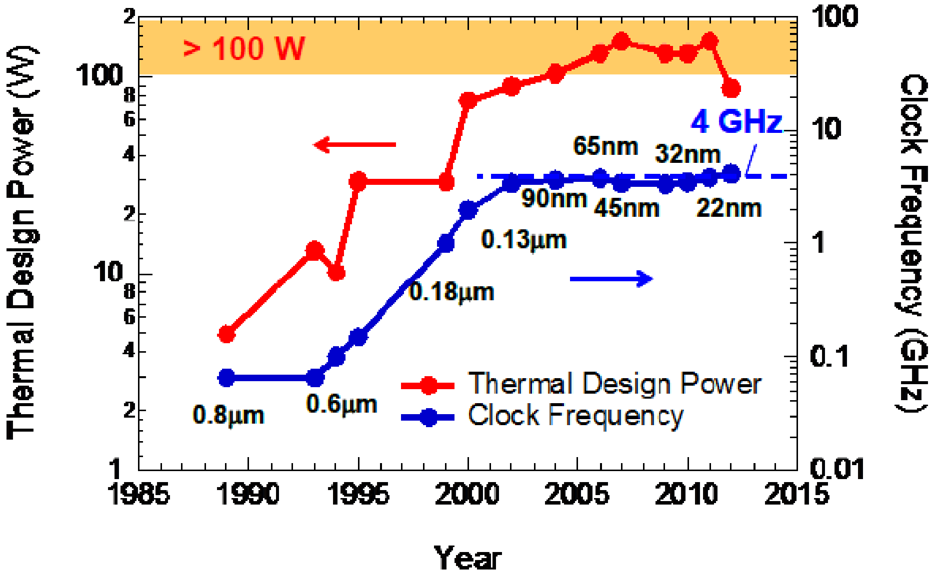
My research link with Power Electronics

Topic

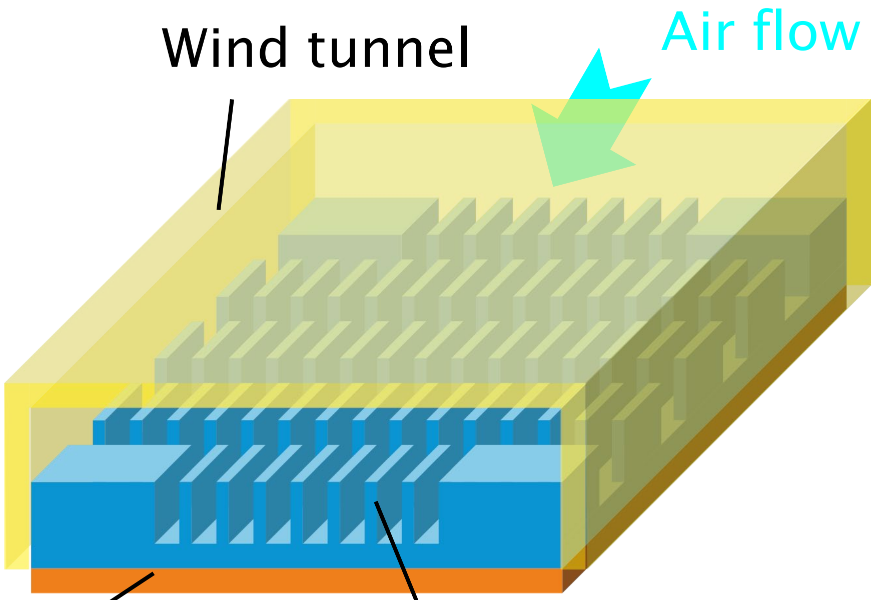
TDP vs Frequency in ICs



- CPU clock frequency capped since early 2000.
- **The performance is limited by heat generation.**

Silicon surface modified heat sinks

Y Zhang, Y Tsuchiya *et al.*, MNE2017, ICAN 2019



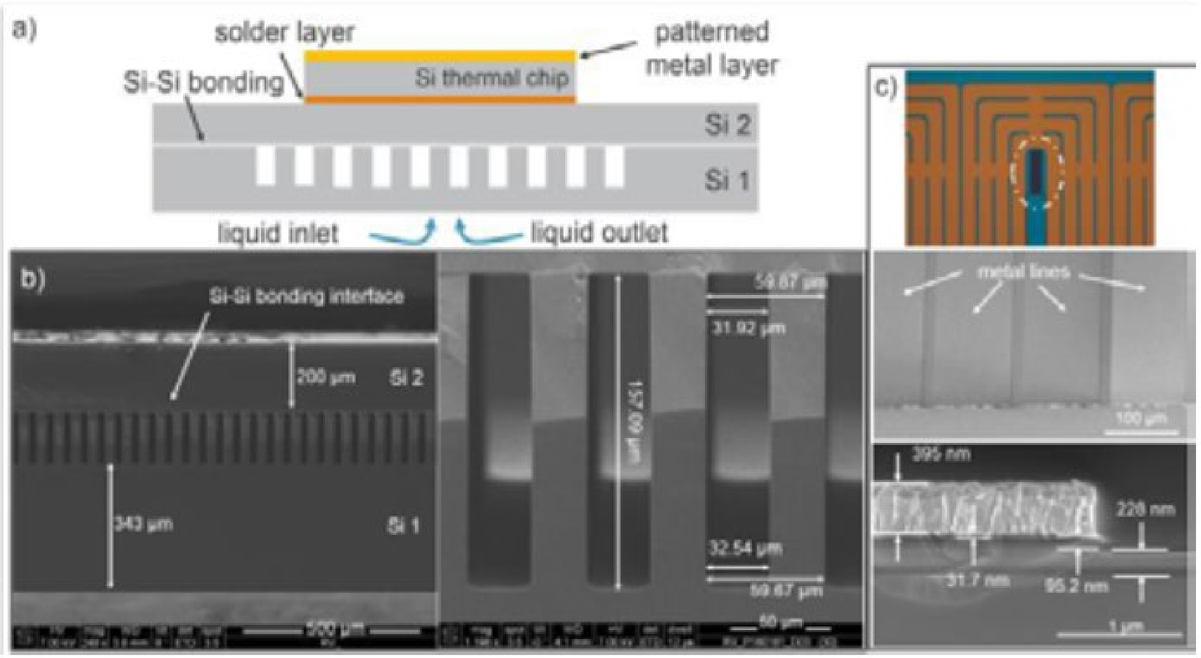
- Surface modification via micro- and nanofabrication technology to reduce the thermal resistance $R_{\theta(s\text{-}a)}$.

Embedded cooling trends

Topic

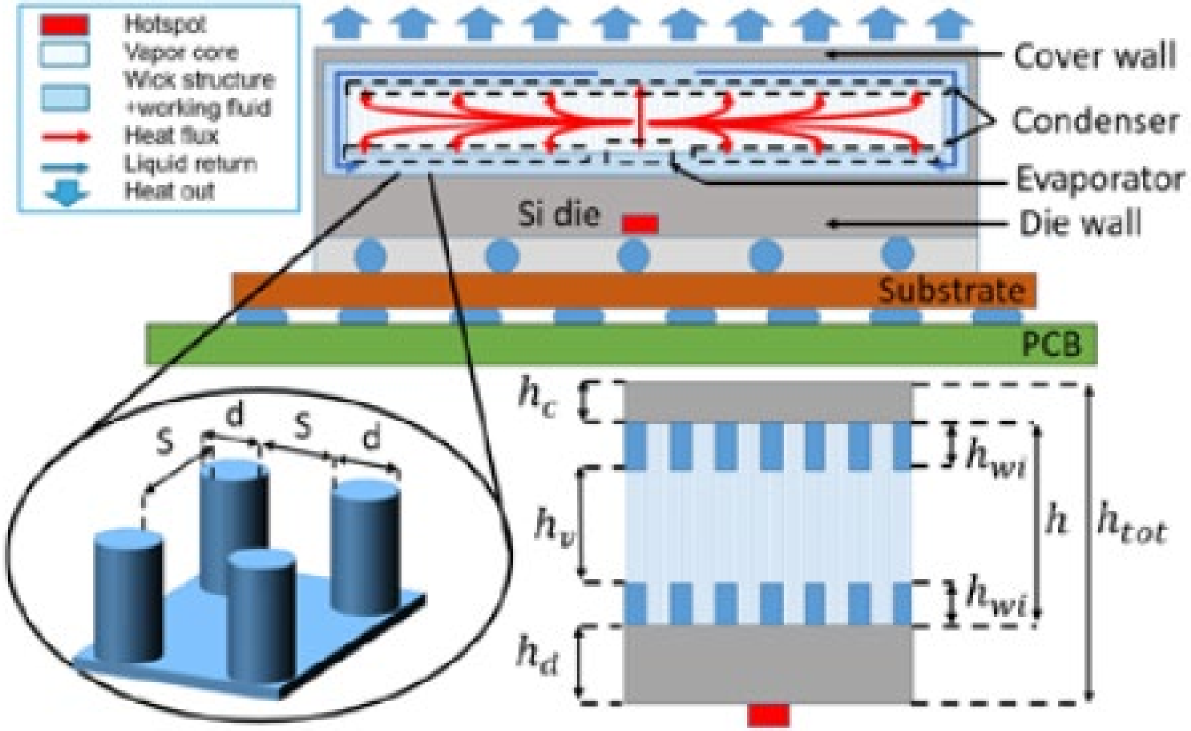
Si microchannels

L Zhang *et al.*, Therminic 2018



Si vapor chamber

Q Struss *et al.*, Therminic 2018



Application of silicon micro- and nanofabrication technologies for electronics cooling is under investigation in research level.

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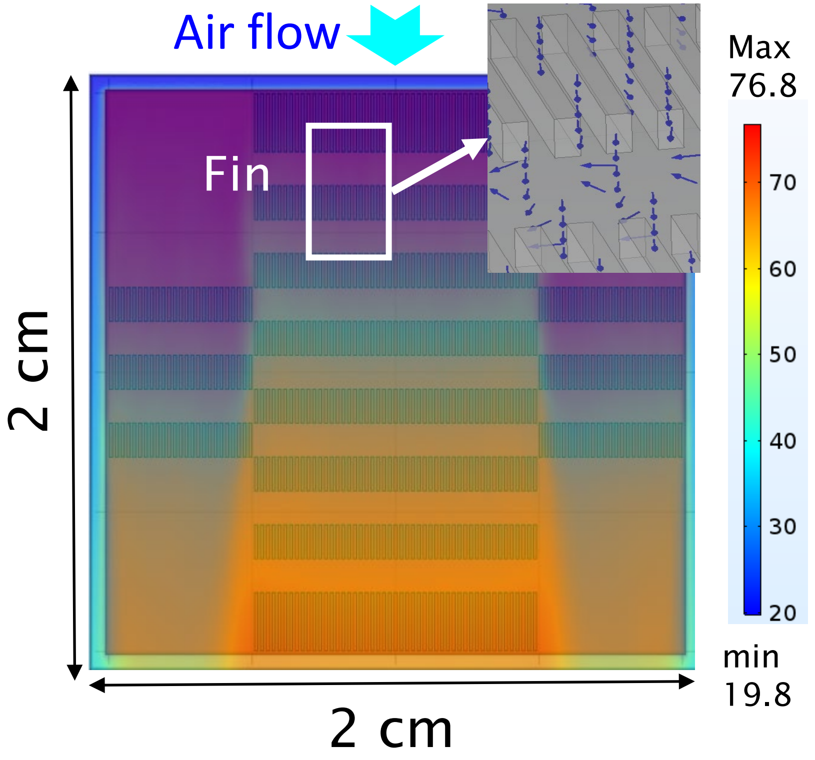
COMSOL simulation results

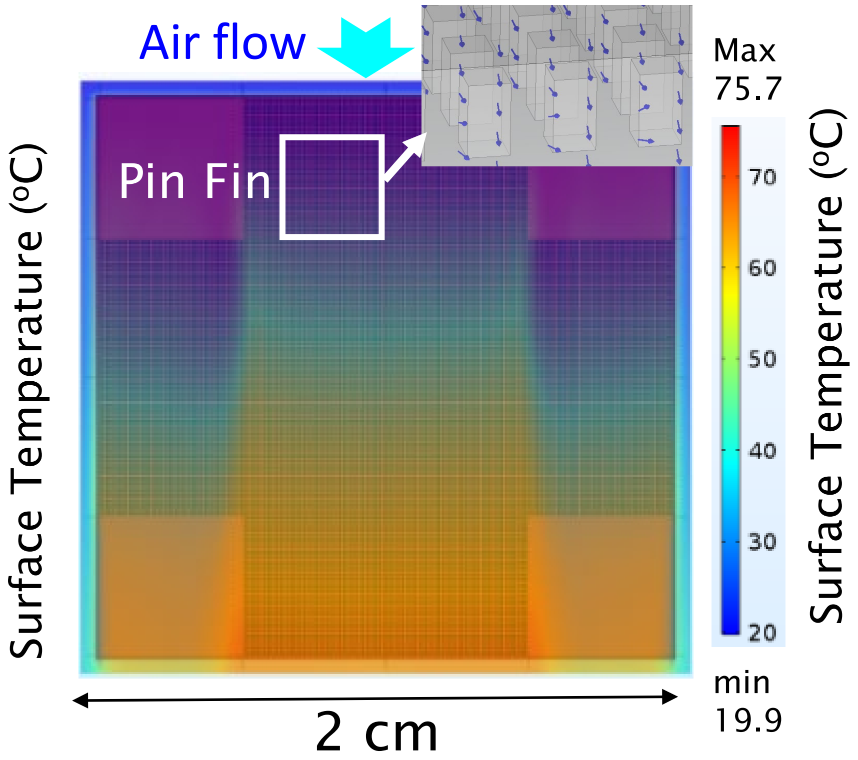
Topic

Y Zhang, PhD thesis

Inlet velocity: 3 m/s, Inlet T: 20 °C, Heater power: 3W



T_{max} = 76.8 °C



T_{max} = 75.7 °C

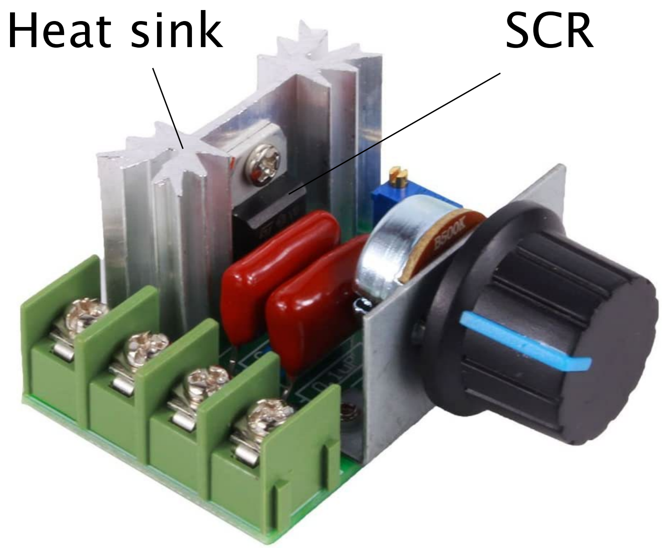
- Micro pin fin with larger surface area shows better.
- Further design optimisation possible (via movable fins, AI, etc)

AC voltage controllers - Products

Topic

https://www.amazon.co.uk/

220 V 4000 W voltage controller



50-220V LED Dimmer

Practical applications

Light dimmer, Fan controller, Motor controller, Temperature controller, etc.

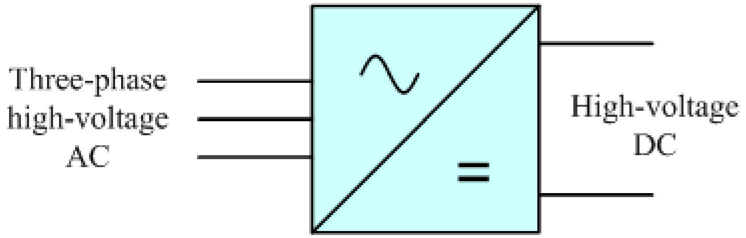
AC/DC converters

Topic

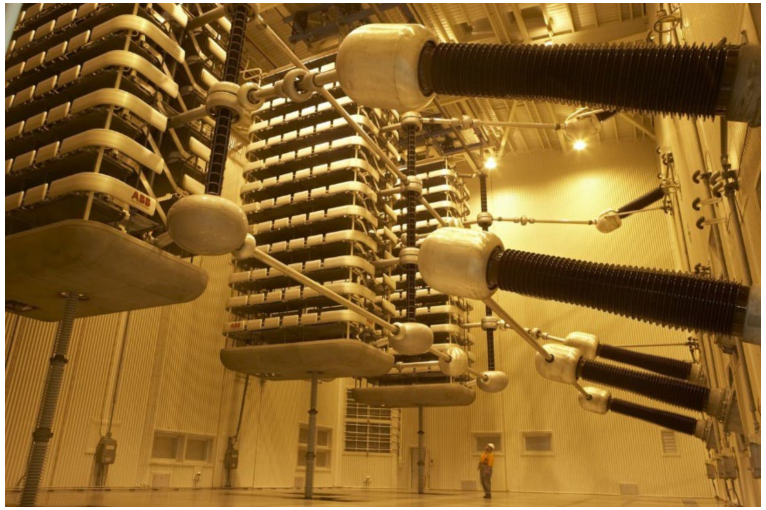
Source: Amazon, Farnell, Wikipedia

AC/DC adapter

AC 100-240V -> DC 12V



Thyristor Bridge Rectifier Module, Three Phase, 1600 V



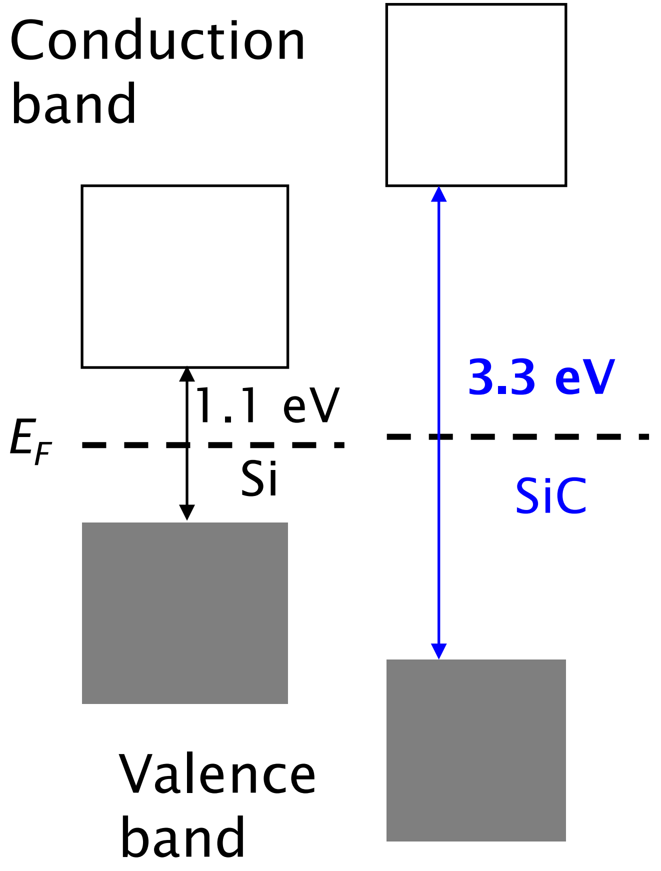
HVDC converter

~ 2000 MW, 900 kV

Wide band-gap Semiconductors

Topic

J. Wang, IOP Conf. Series: Materials Science and Engineering 729 (2020) 012005



	Si	4H-SiC	GaN	β-Ga_2O_3
Band gap, E_g (eV)	1.1	3.3	3.4	4.5
Breakdown field, E_c (MV/cm)	0.25	2.4	3.5	7
Relative permittivity, ε	11.8	9.7	9.0	10-12
Electron mobility, μ_e (cm^2/V.s)	1400	950	1200	200
Thermal conductivity (W/cm.K)	1.5	3.3 – 4.9	2	0.27
Baliga's Figure of Merit ~ $\varepsilon \mu_e E_g^3$	1	340	870	>1,500

Promising materials for future power electronics and devices.

Cycloconverter (CCV)

Topic

https://library.e.abb.com/

ACS 6000c Cycloconverter

Applications

- Ship propulsion
- Ball mills
- Mine hoists

For cases where load changes gradually.

50/60 Hz -> 0 – 24/28 Hz
Speed and torque control of 1-27 MW

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DC-DC converter

Topic

https://www.mouser.co.uk/

MEAN WELL

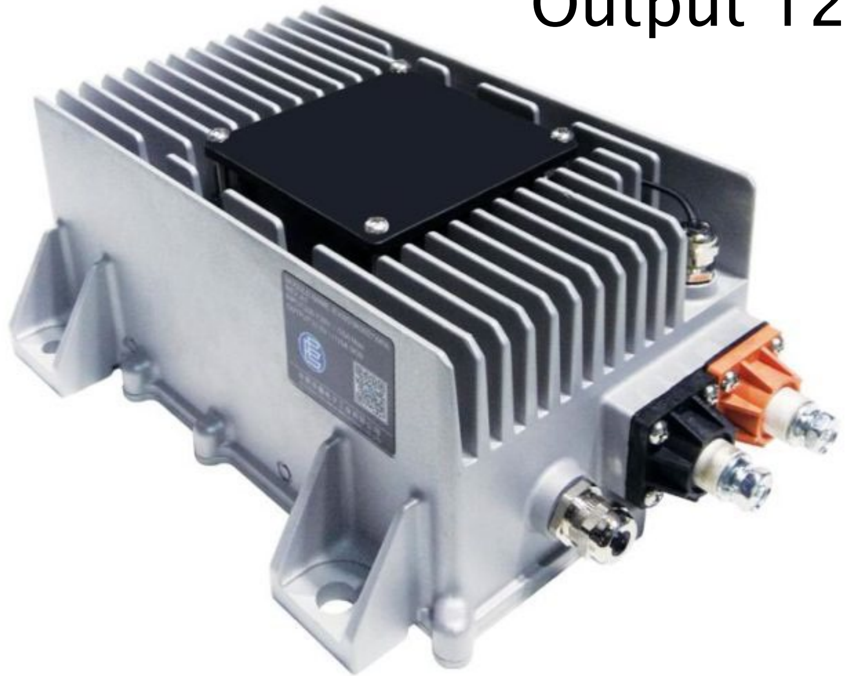
Input 9-36 V
Output 12 V

Power 30W

~ £40

https://www.sunpower-uk.com/

Sunpower Electronics
Input 200 – 750 V
Output 12 or 24 V



1 kW