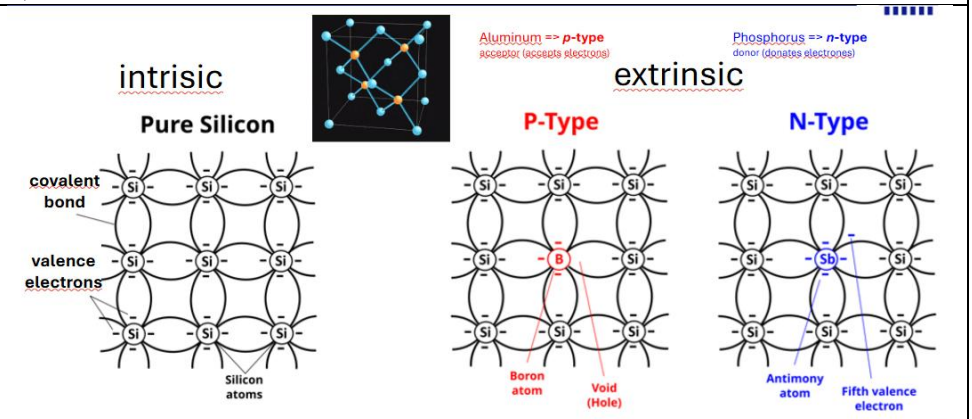
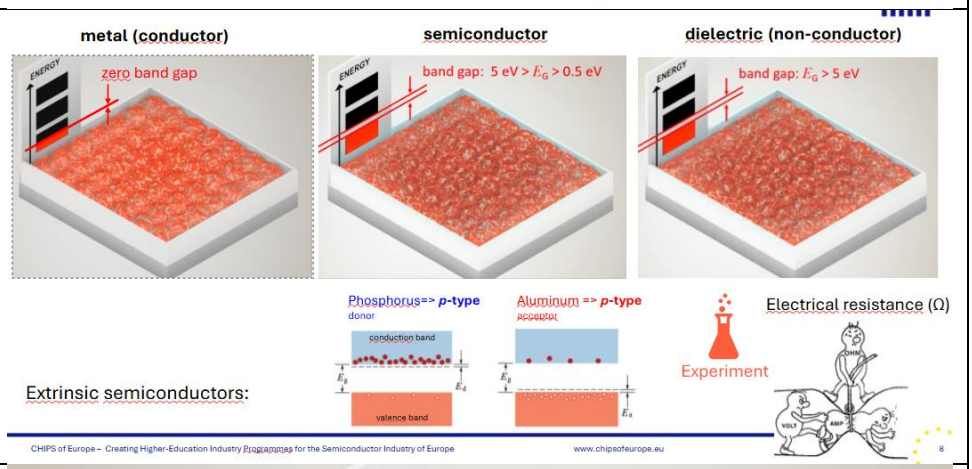
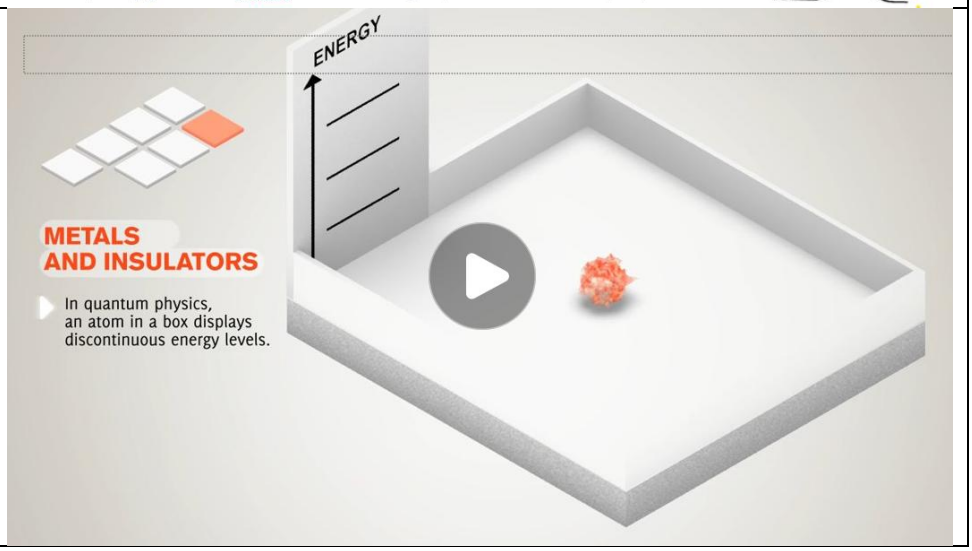
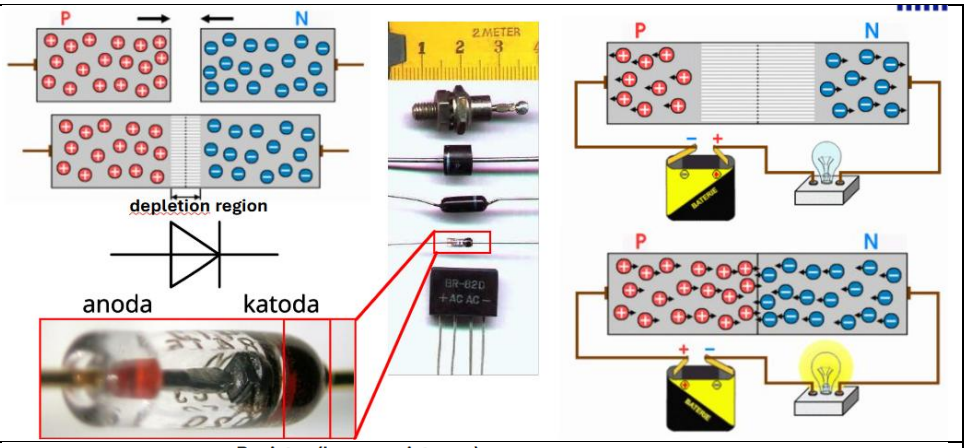
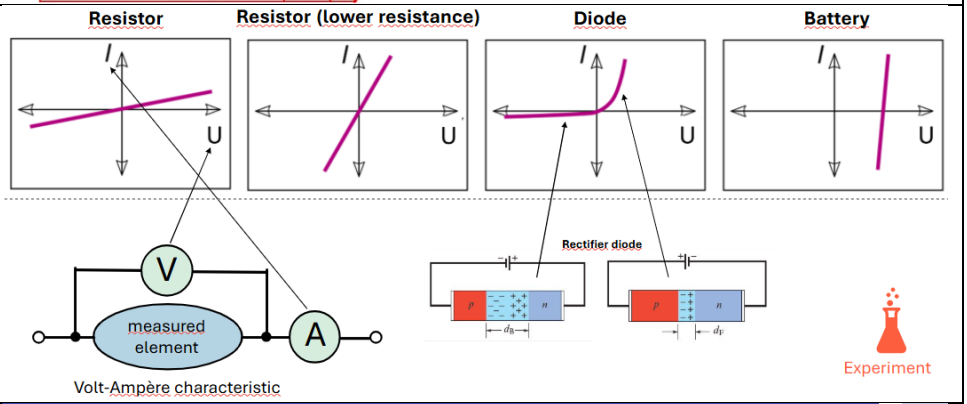
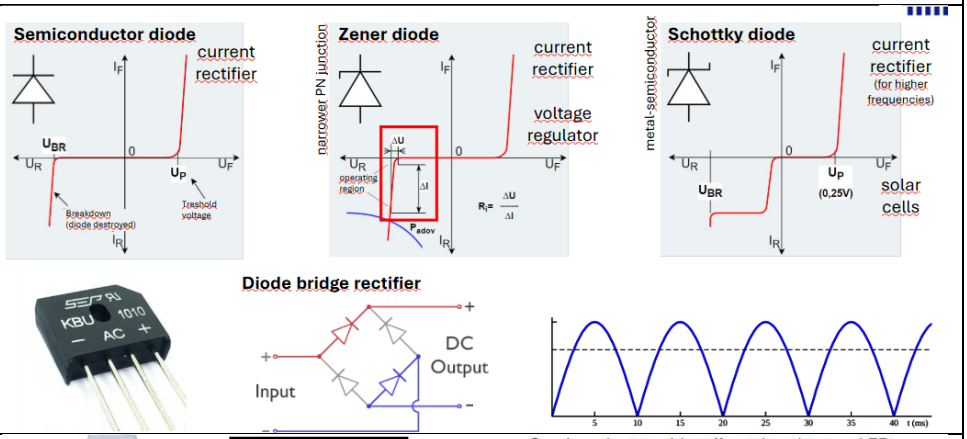
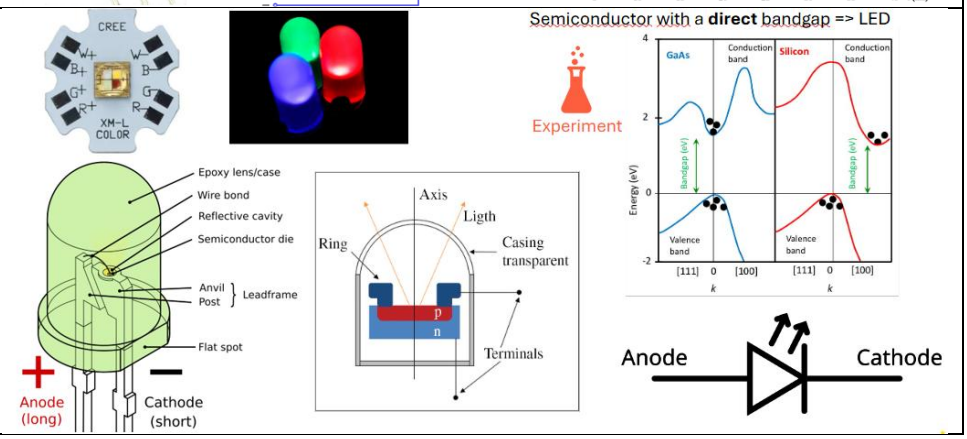
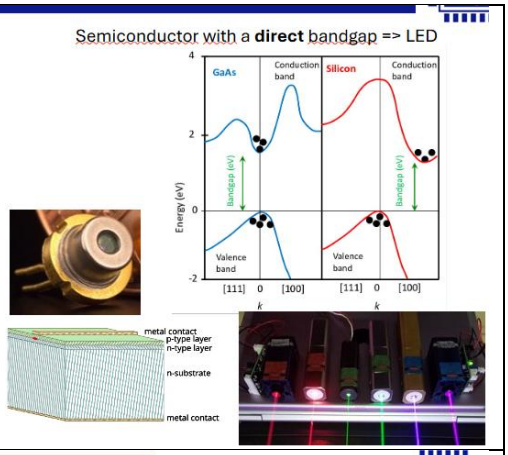
9.	Какво е полупроводник?
Целева група	Ученици, учители
Възраст на учениците	16–18
Продължителност	1,5–2 часа
Какво е полупроводник	
Въведение	
Видео: Проводници и изолатори	

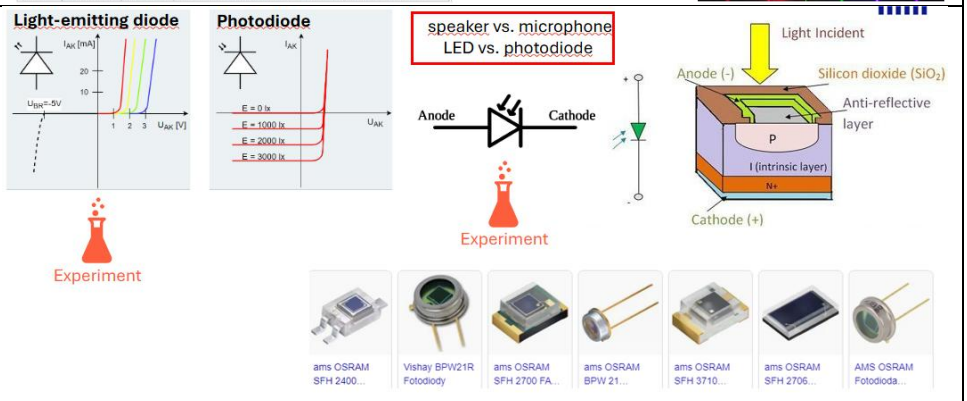
Приложения: PN преход ; Диод	
ВА характеристики (линейни срещу нелинейни елементи)	
ВА характеристики (Продължение)	
Диод → LED (светодиод)	

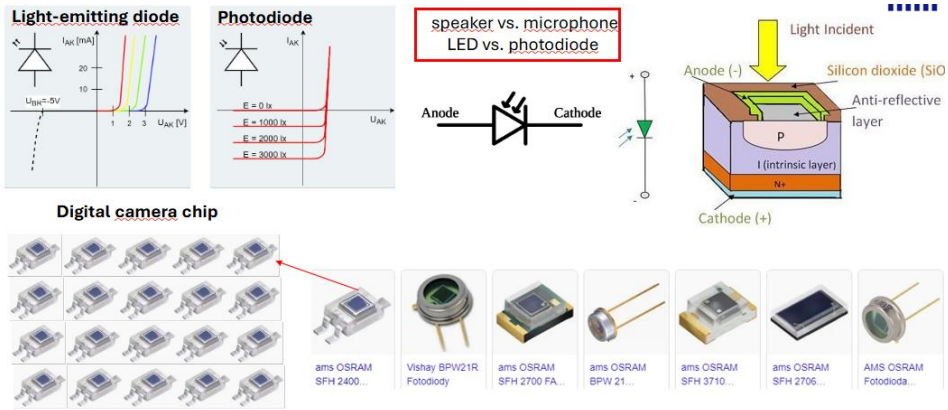
Диод → LED → Лазер

Color	Wavelength (nm)	Voltage (V)	Semiconductor material
Infrared	λ > 760	ΔV < 1.9	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
Red	610 < λ < 760	1.63 < ΔV < 2.03	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Orange	590 < λ < 610	2.03 < ΔV < 2.10	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Yellow	570 < λ < 590	2.10 < ΔV < 2.18	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Green	500 < λ < 570	1.9[171] < ΔV < 4.0	Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN) Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
Blue	450 < λ < 500	2.48 < ΔV < 3.7	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate — (under development)
Violet	400 < λ < 450	2.76 < ΔV < 4.0	Indium gallium nitride (InGaN)
Purple	multiple types	2.48 < ΔV < 3.7	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic
Ultraviolet	λ < 400	3.1 < ΔV < 4.4	Diamond (235 nm)[182] Boron nitride (215 nm)[183][184] Aluminium nitride (AlN) (210 nm)[185] Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN) — (down to 210 nm)[186]
White	Broad spectrum	2.7 < ΔV < 3.5	Blue diode with yellow phosphor or violet/UV diode with multi-color phosphor

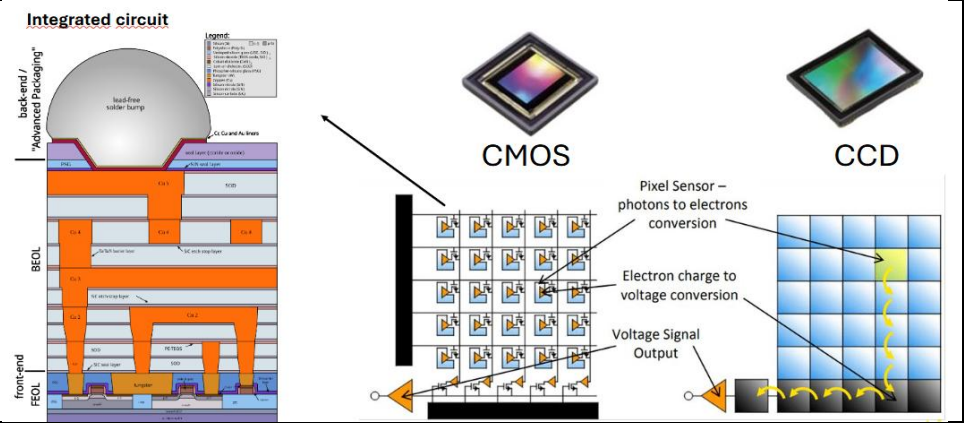


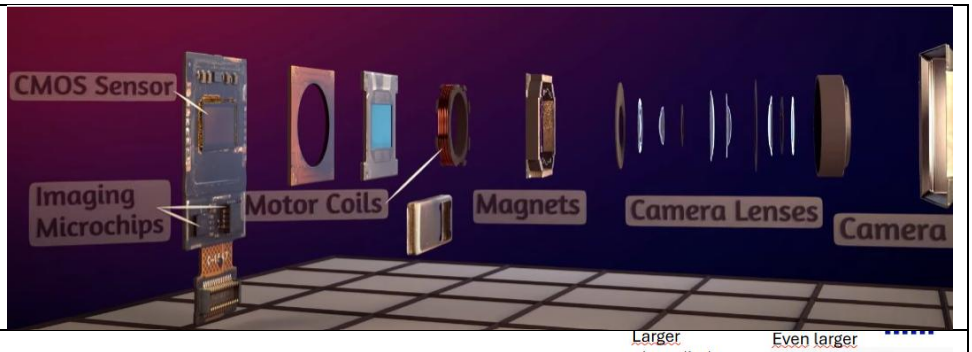
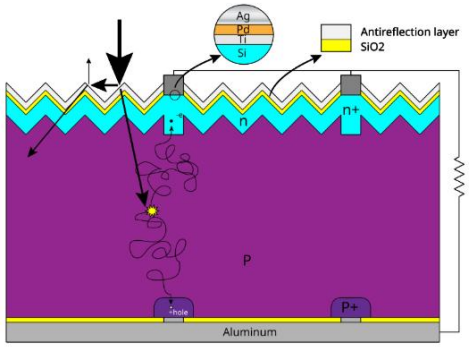
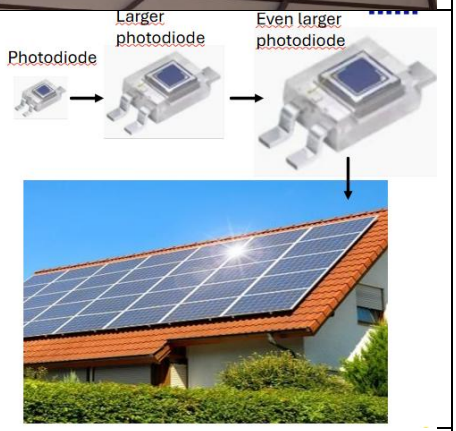
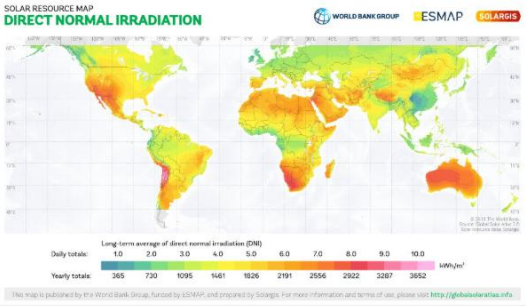
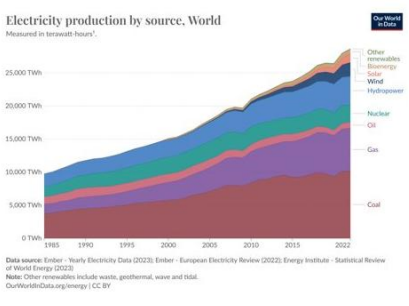
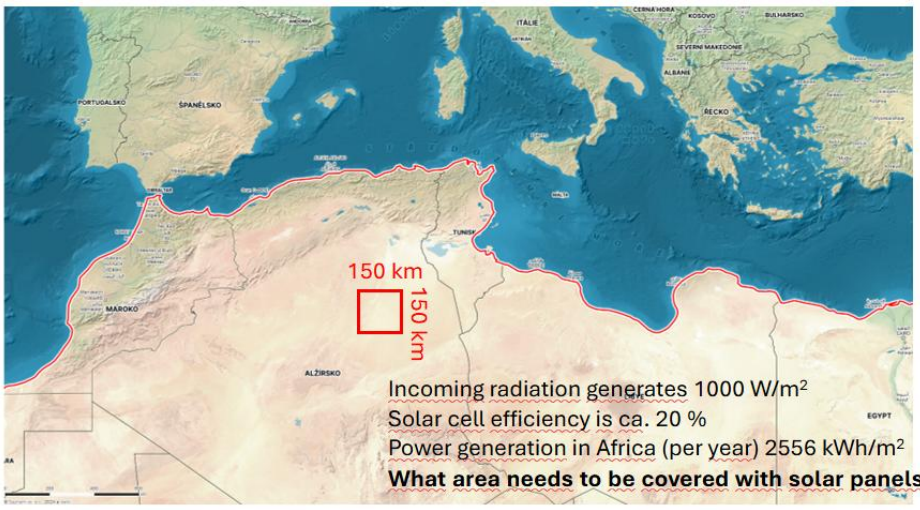
Диод → LED → Фотодиод

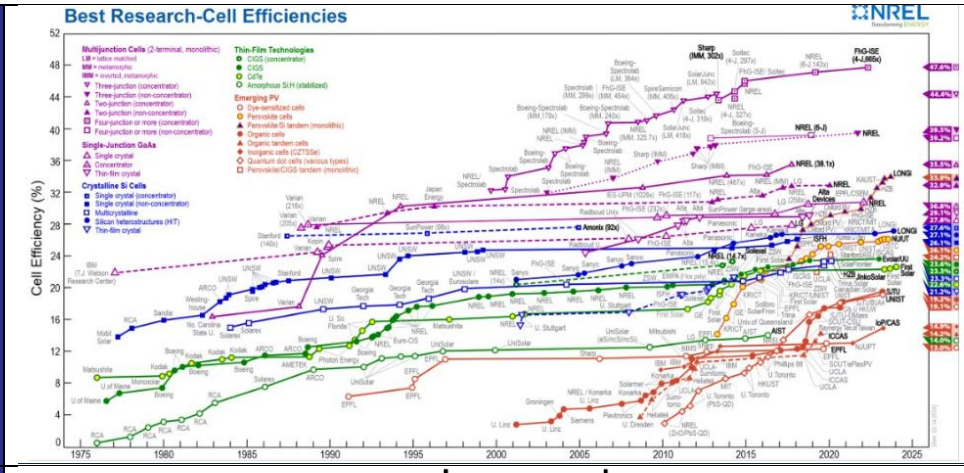
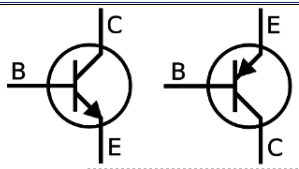
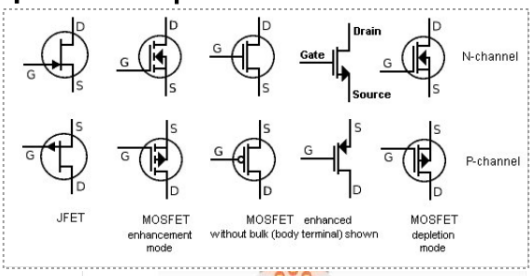
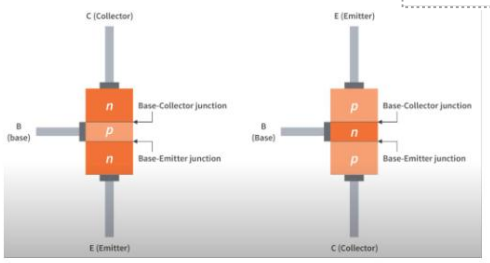
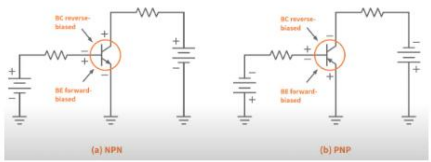
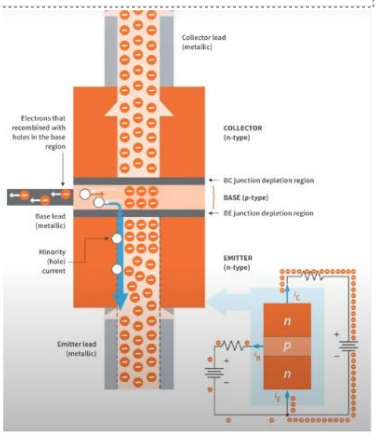
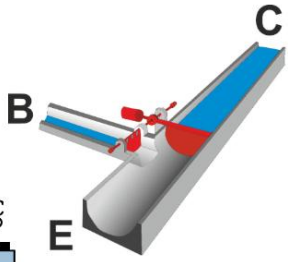
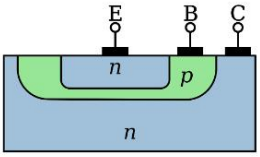
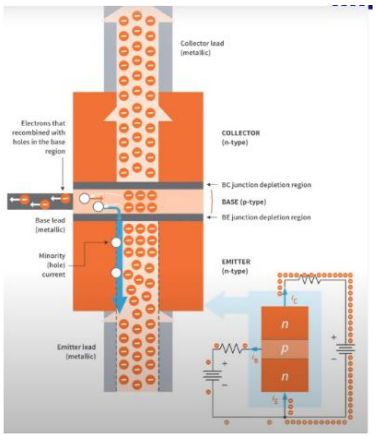


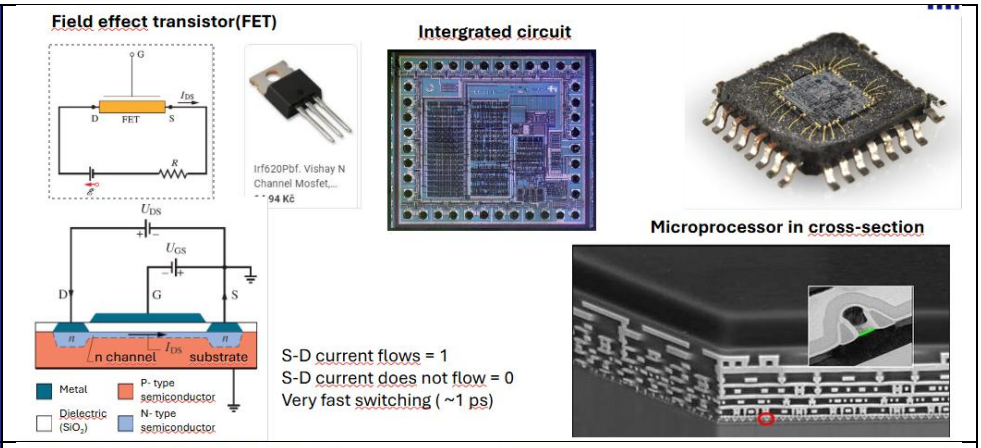
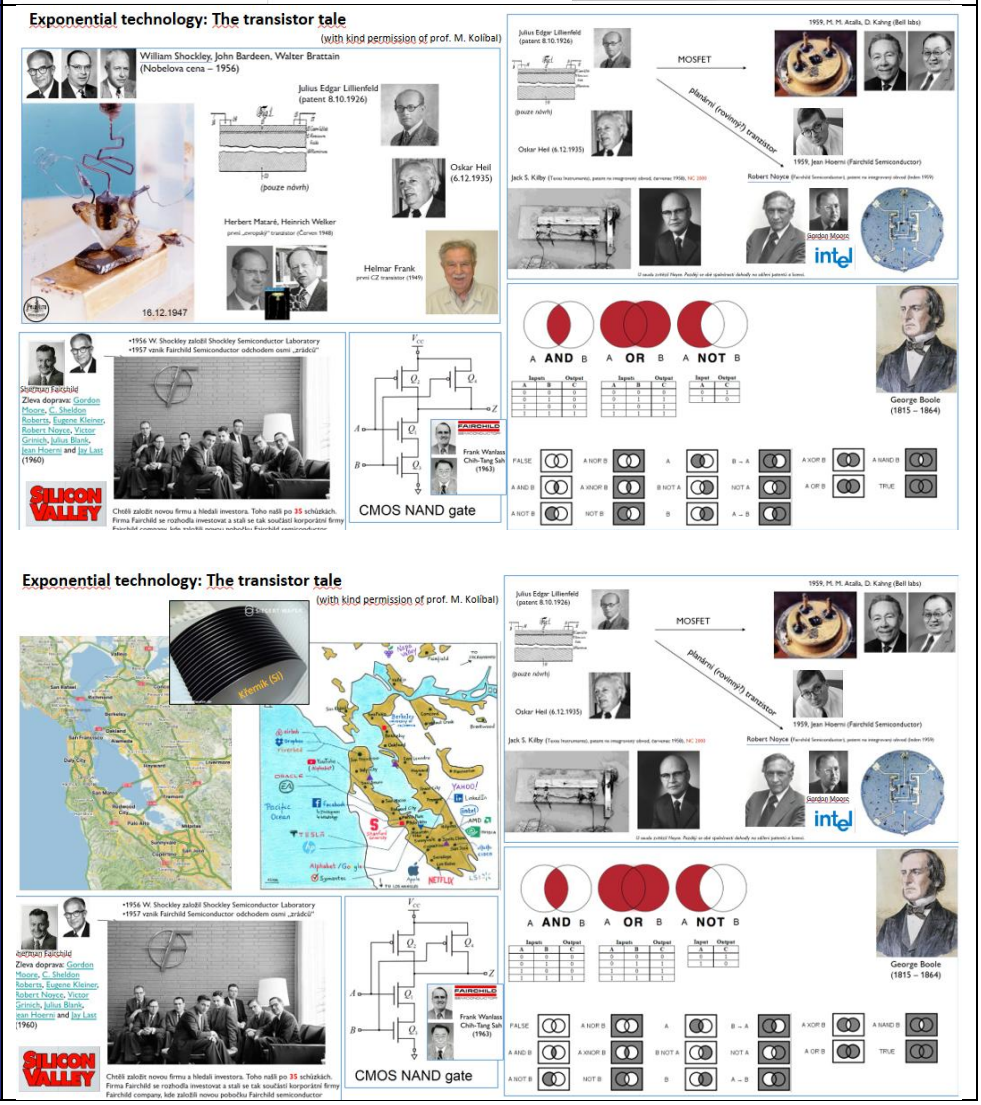


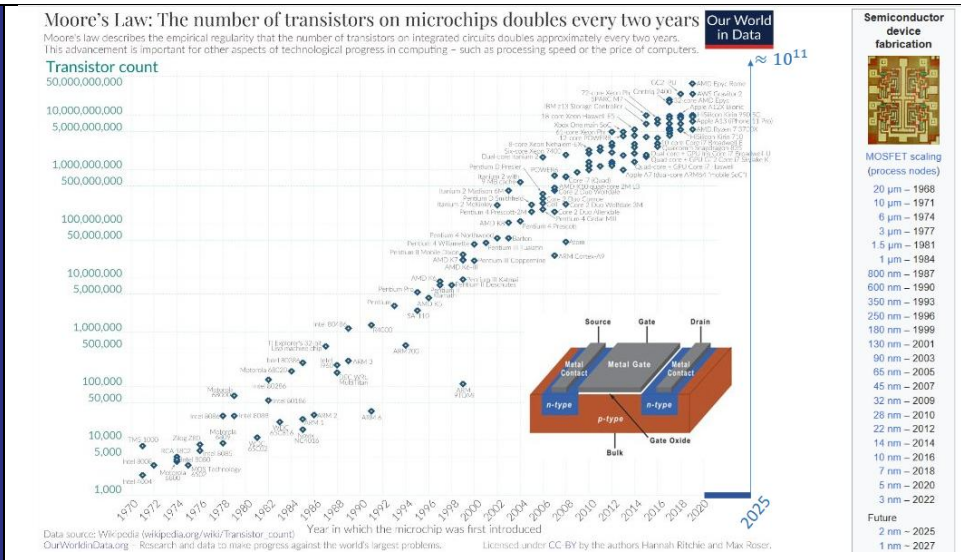
Диод → LED → Фотодиод (CCD, CMOS)



Структура на Камера на телефон	
Диод → LED → Фотодиод → Слънчева клетка	 
Слънчево лъчение спрямо консумация на енергия	 
Слънчеви клетки (защо, колко, как...?)	

Слънчеви клетки: ефективност	
Транзистор	Bipolar junction transistor (BJT)  Unipolar transistor (FET) 
Биполярен транзистор (BJT)	   B low-doped C mid-doped E highly doped   

Полеви транзистор металоксид-полупроводник (MOSFET)	
Експоненциална технология: историята на транзистора	



Semiconductor device fabrication

MOSFET scaling (process nodes)

- 20 µm – 1968
- 10 µm – 1971
- 6 µm – 1974
- 3 µm – 1977
- 1.5 µm – 1981
- 1 µm – 1984
- 800 nm – 1987
- 600 nm – 1990
- 350 nm – 1993
- 250 nm – 1996
- 180 nm – 1999
- 130 nm – 2001
- 90 nm – 2003
- 65 nm – 2005
- 45 nm – 2007
- 32 nm – 2009
- 28 nm – 2010
- 22 nm – 2012
- 14 nm – 2014
- 10 nm – 2016
- 7 nm – 2018
- 5 nm – 2020
- 3 nm – 2022

Future

- 2 nm ~ 2025
- 1 nm ~ 2027

Processor	Transistor count	Year	Designer	Process (nm)	Area (mm²)	Transistor density (tr./mm²)
Apple M3 (octa-core 64-bit ARM64 SoC, SIMD, caches)	25,000,000,000[155]	2023	Apple	3 nm	?	?
Apple M3 Pro (dodeca-core 64-bit ARM64 SoC, SIMD, caches)	37,000,000,000[156]	2023	Apple	3 nm	?	?
Apple M3 Max (hexadeca-core 64-bit ARM64 SoC, SIMD, caches)	92,000,000,000[156]	2023	Apple	3 nm	?	?
Apple A17	19,000,000,000[157]	2023	Apple	3 nm	103.8 mm²	183,044,315
Sapphire Rapids quad-chip module (up to 60 cores and 112.5 MB of cache)[158]	44,000,000,000–48,000,000,000[159]	2023	Intel	10 nm ESF (Intel 7)	1,600 mm²	27,500,000–30,000,000
Apple M2 Pro (12-core 64-bit ARM64 SoC, SIMD, caches)	40,000,000,000[156]	2023	Apple	5 nm	?	?
Apple M2 Max (12-core 64-bit ARM64 SoC, SIMD, caches)	67,000,000,000[156]	2023	Apple	5 nm	?	?
Apple M2 Ultra (two M2 Max dies)	134,000,000,000[7]	2023	Apple	5 nm	?	?
AMD Epyc Bergamo (4th gen/97X4 series) 9-chip module (up to 128 cores and 256 MB (L3) + 128 MB (L2) cache)	82,000,000,000[161]	2023	AMD	5 nm (CCD) 6 nm (IOD)	?	?
AMD Instinct MI300A (multi-chip module, 24 cores, 128 GB GPU memory + 256 MB (LLC/L3) cache)	146,000,000,000[162][163]	2023	AMD	5 nm (CCD, GCD) 6 nm (IOD)	1,017 mm²	144,000,000

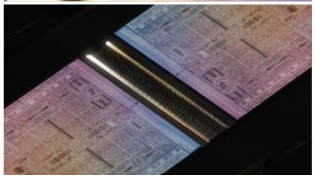












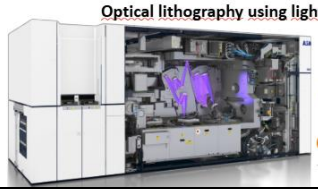
Graphics processing unit (GPU)

Processor	Transistor count	Year	Designer(s)	Fab(s)	MOS process	Area	Transistor density (tr./mm²)
GH100 Hopper	80,000,000,000	2022	Nvidia	TSMC	4 nm	814 mm²	98,280,000
AD102 Ada Lovelace	76,300,000,000	2022	Nvidia	TSMC	4 nm	608.4 mm²	125,411,000
AD103 Ada Lovelace	45,900,000,000	2022	Nvidia	TSMC	4 nm	378.6 mm²	121,240,000
AD104 Ada Lovelace	35,800,000,000	2022	Nvidia	TSMC	4 nm	294.5 mm²	121,560,000
AD106 Ada Lovelace	?	2023	Nvidia	TSMC	4 nm	190 mm²	?
AD107 Ada Lovelace	?	2023	Nvidia	TSMC	4 nm	146 mm²	?
Navi 31 RDNA3	57,700,000,000 (MCM) 45,400,000,000 (GCD) 6×2,050,000,000 (MCD)	2022	AMD	TSMC	5 nm (GCD) 6 nm (MCD)	531 mm² (MCM) 306 mm² (GCD) 6×37.5 mm² (MCD)	109,200,000 (MCM) 132,400,000 (GCD) 54,640,000 (MCD)
Navi 32 RDNA3	28,100,000,000 (MCM)	2023	AMD	TSMC	5 nm (GCD) 6 nm (MCD)	350 mm² (MCM) 200 mm² (GCD) 4×37.5 mm² (MCD)	80,200,000 (MCM)
Navi 33 RDNA3	13,300,000,000	2023	AMD	TSMC	6 nm	204 mm²	65,200,000
Aqua Vanjaram CDNA3	153,000,000,000 (MCM)	2023	AMD	TSMC	5 nm (GCD) 6 nm (MCD)	?	?
GB200 Grace Blackwell	208,000,000,000	2024	Nvidia	TSMC	4 nm	?	?



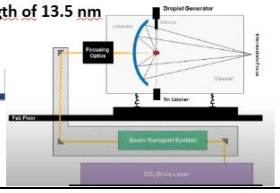
Taiwan Semiconductor Manufacturing Company Limite
(TSMC, sometimes only Taiwan Semiconductor)

Optical lithography using light with wavelength of 13.5 nm



ASML

CYMER



tsmc

Thanks to nanotechnology!

Полеви транзистор металоксид-полупроводник (MOSFET)

