W smutnym kolorze blue

Jacek Szczytko, Wydział Fizyki UW

Juliette Binoche

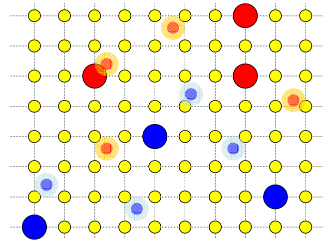
Półprzewodniki

II	III	IV	V	VI
Be	B	C	N	O
Mg	Al	Si	P	S
Zn	Ga	Ge	As	Se
Cd	In	Sn	Sb	Te

Grupa IV: diament, Si, Ge
Grupy III-V: GaAs, AlAs, InSb, InAs...
Grupy II-VI: ZnSe, CdTe, ZnO, SdS...

Nośniki:
dziury +
elektrony -

Domieszki:
Akceptory (typ p)
Donory (typ n)



Przerwa energetyczna

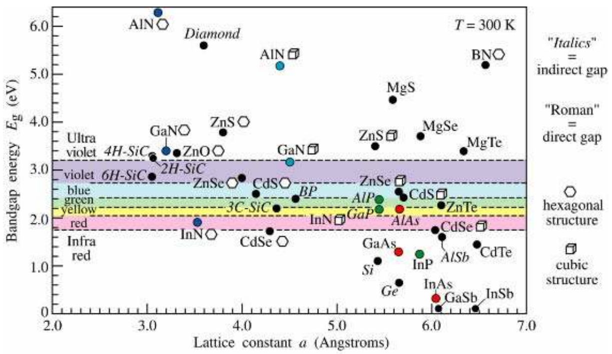
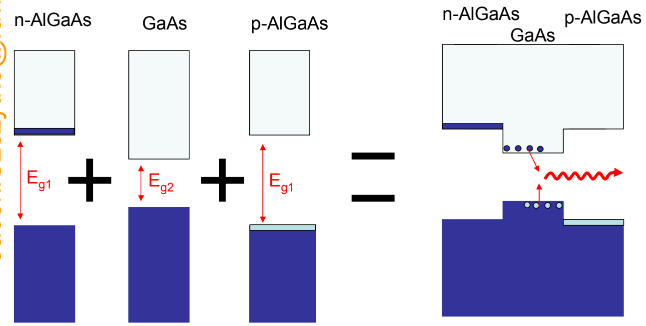
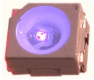


Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

Studnia Kwantowa





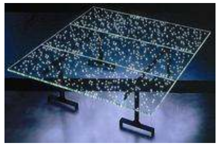
Niebieskość 405 nm

Biel, Biel i jeszcze raz biel!

Żarówka 15-20 lumenów/watt (standardowa 100W – 17 lumenów/watt)
Halogen 20 lumenów/watt
Świetlówka 60-110 lumenów/watt
Świetlówki kompaktowe 45-60 lumenów/watt

Biała dioda: typowo 20-50 lumenów/watt, rekord z 2005r. 130 lumenów/watt!

http://www.otherpower.com/otherpower_lighting.html
http://www.theinquirer.net/?article=27731



Trochę historii

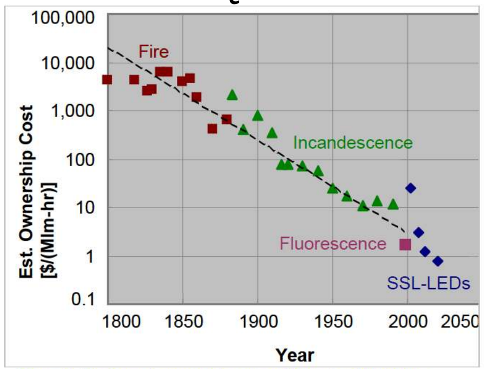


Figure 6. Estimated ownership costs of light, in 1992 dollars. Data for Fire and Incandescence for operating cost are from the work of W. Nordhaus,[15] to which estimates of capital cost have been added. Data for Fluorescence are from our estimates. Data for SSL-LEDs are the targets of this Roadmap.

http://lighting.sandia.gov/lightingdocs/OIDA_SSL_Roadmap_Tutorial.pdf

Trochę historii

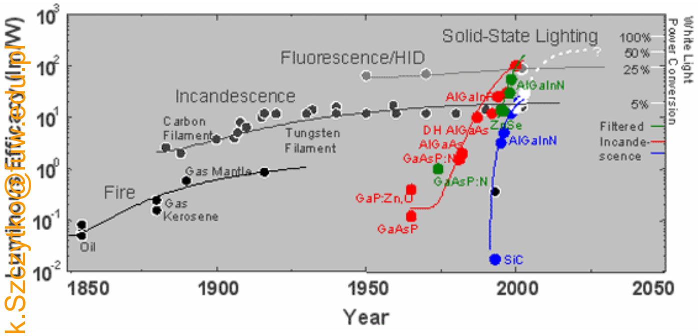


Figure courtesy of Jeff Tsao; a version of this figure was published in IEEE Circuits and Devices Vol 20, No 3, pp 28-37, May/June, 2004

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Trochę historii

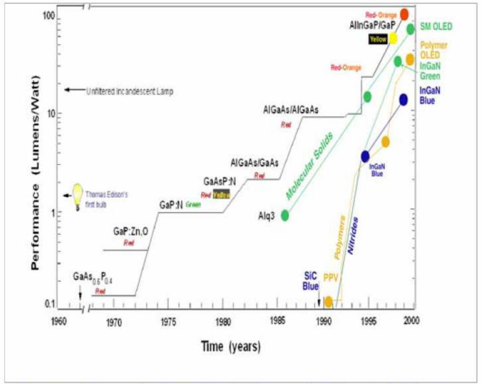

Figure 3. The evolution of total efficacy of solid-state lighting technologies. Also shown are typical efficacies for traditional incandescent and fluorescent technologies. [Courtesy of George Craford, LumiLeds Lighting.]

http://lighting.sandia.gov/lightingdocs/OIDA_SSL_Roadmap_Tutorial.pdf

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„Białe” diody

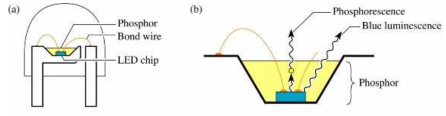

Fig. 11.5. (a) Structure of white LED consisting of a GaInN blue LED chip and a phosphor-containing epoxy encapsulating the semiconductor die. (b) Wavelength-converting phosphorescence and blue luminescence (after Nakamura and Fasol, 1997).

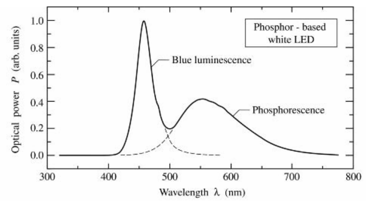

Fig. 11.6. Emission spectrum of a commercial phophor-based white LED manufactured by the Nichia Chemical Industries Corporation (Anan, Tokushima, Japan).

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

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Photon Recycling

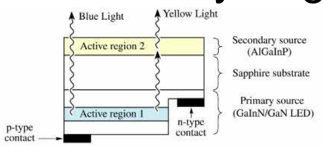

Fig. 11.8. Schematic structure of a photon-recycling semiconductor LED with one current-injected active region (Active region 1) and one optically excited active region (Active region 2) (after Guo *et al.*, 1999).

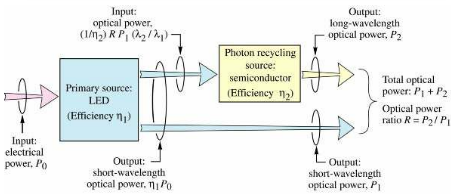

Fig. 11.9. Photon-recycling semiconductor LED power budget with electrical input power P_0 and optical output power P_1 and P_2.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

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Biel, Biel i jeszcze raz biel!

http://www.treehugger.com/files/lighting/

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Biel, Biel i jeszcze raz biel!

http://www.treehugger.com/files/lighting/

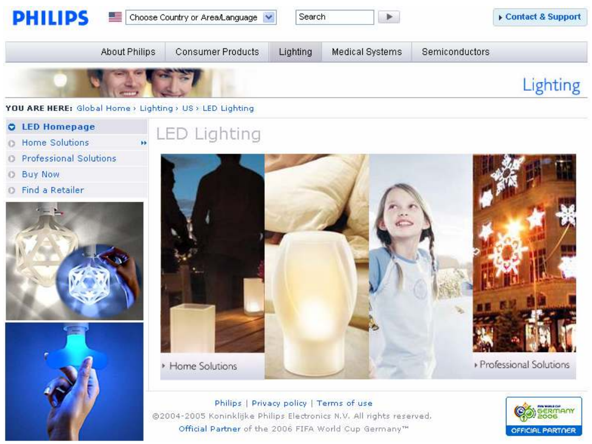
Biel, Biel i jeszcze raz biel!

Forever Flashlights.

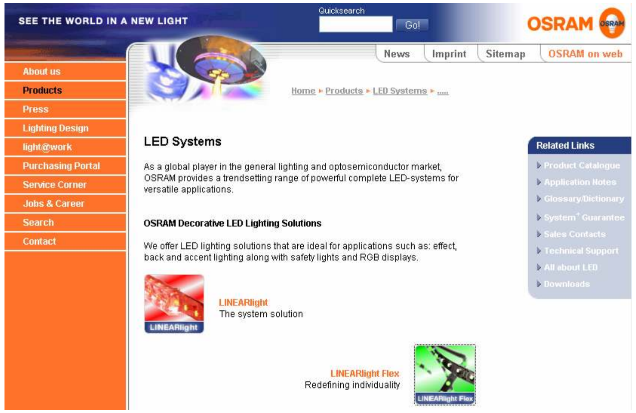
http://www.treehugger.com/files/lighting/

Biel, Biel i jeszcze raz biel!

Biel, Biel i jeszcze raz biel!



Biel, Biel i jeszcze raz biel!



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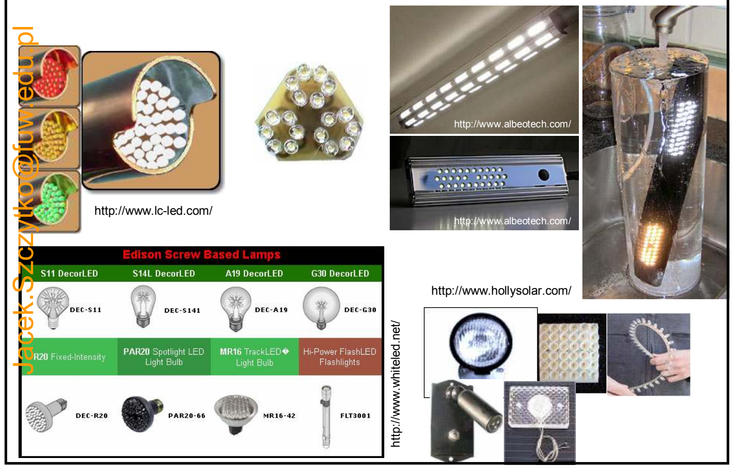
Biel, Biel i jeszcze raz biel!



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Lasery w akcji

http://www.laseronics.com/

http://www.spacelaser.com/laser/

Figure 16: Symbol Laser Projection Display Demo

http://www.symbol.com/

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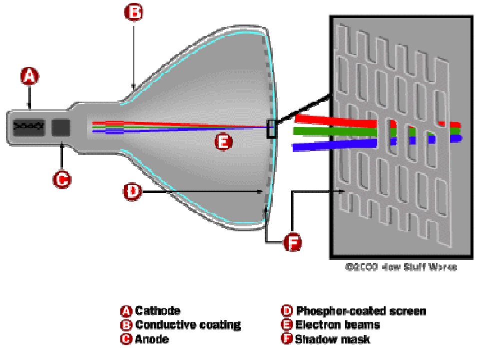
Projektory



http://electronics.howstuffworks.com/projection-tv1.htm

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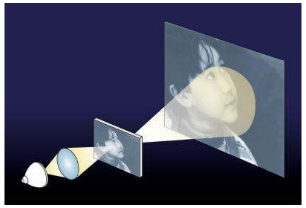
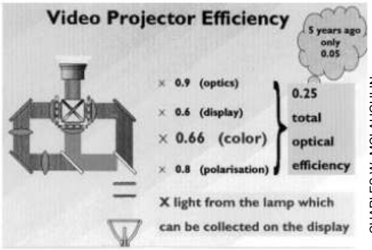
Projektory

• LCD





CHARLES W. MCLAUGHLIN

http://electronics.howstuffworks.com/projection-tv1.htm

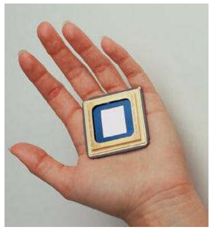
Projektory

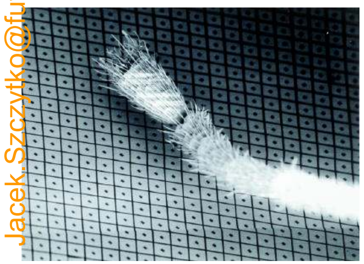
• LCD
• Liquid Crystal on Silicon

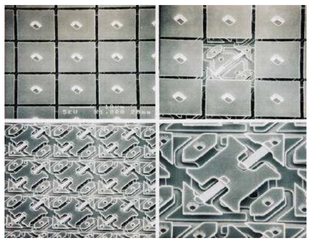
http://electronics.howstuffworks.com/projection-tv1.htm

Projektory

• LCD
• Liquid Crystal on Silicon
• Microelectromechanical Systems (MEMS)
  • Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (1000:1, BENQ 10000:1)







http://electronics.howstuffworks.com/projection-tv1.htm

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• Liquid Crystal on Silicon
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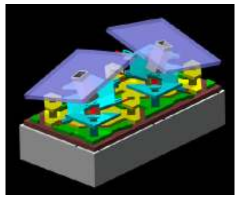
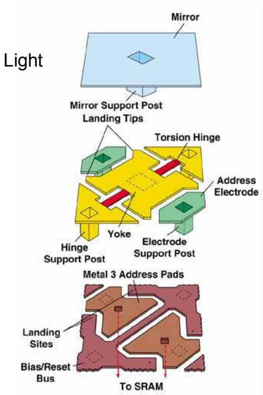
  • Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (1000:1, BENQ 10000:1)





http://electronics.howstuffworks.com/projection-tv1.htm

Projektory

- LCD
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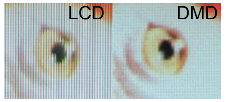
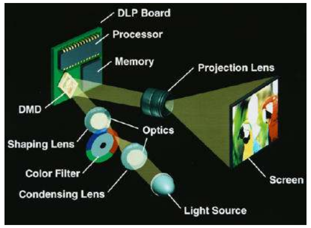
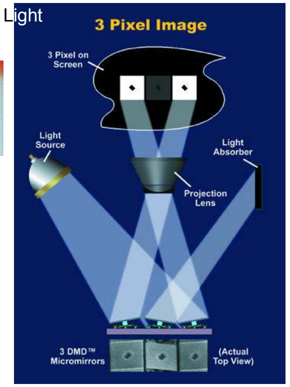
  - Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (1000:1, BENQ 10000:1)







http://electronics.howstuffworks.com/projection-tv1.htm

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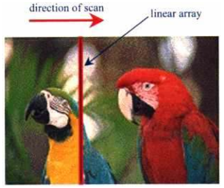
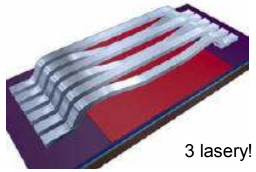
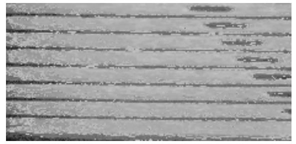
Projektory

- LCD (1000:1)
- Liquid Crystal on Silicon
- Microelectromechanical Systems (MEMS)
  - Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (3000:1, BenQ 10000:1)
- Grating Light Valves (GLV) (Sony 4000:1)





3 lasery!



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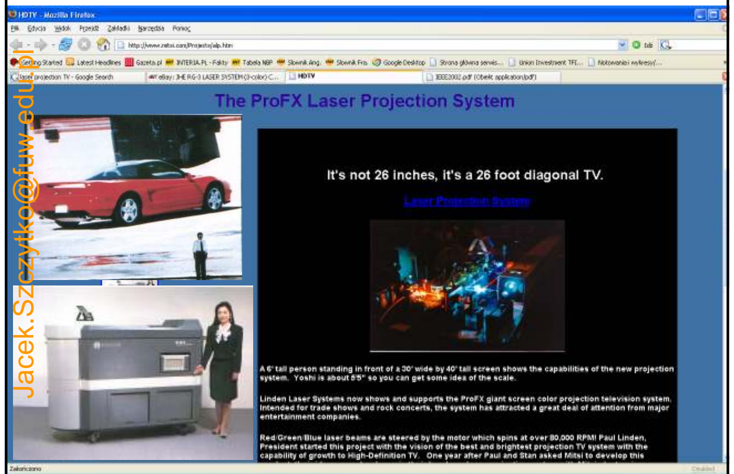
HDTV



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Niebieskość 405 nm

Lasery czerwone nie dają możliwości zapisu filmu w standardzie wysokiej rozdzielczości HDTV

Płyta DVD nagrana przy pomocy lasera 640 nm może pomieścić 4.7 GB

To za mało aby pomieścić film zapisany w standardzie wysokiej rozdzielczości – potrzeba około 15 GB

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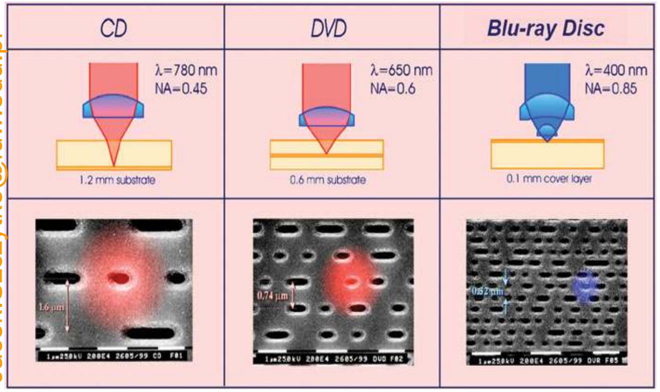
Zapis o dużej gęstości: CD, DVD, Blu-ray



0.8 GB **4.7 - 9 GB** **24 - 50 GB**

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Niebieskość 405 nm

- Blue DVD 23 GB (Sony Pro-Data $2500-3000) **Samsung ~$1000**
- Blue-ray 27 GB (50 GB dwustronnie) (Dell, **Sony**, Koninklijke **Philips** Electronics, Hitachi, Hewlett-Packard Co, LG Electronics, Matsushita Electric Industrial, (Panasonic), Pioneer, Samsung, Sharp, Thomson Multimedia, Walt Disney Company, Buena Vista Entertainment)
- HD-DVD 15-20 GB (Hewlett-Packard Co, Hitachi, **IBM**, Industrial Technology Research Institute (Taiwan), Intel, LG Electronics, Matsushita Electric Industrial (Panasonic), **Microsoft**, Mitsubishi Electric, NEC, Pioneer, Koninklijke Philips Electronics, Samsung Electronics, Sanyo Electric, Sharp, Sony, Thomson, Time Warner, **Toshiba**, Victor of Japan (JVC), Walt Disney Pictures and Television, Paramount, Universal Studios and Warner Bros)

Toshiba ~$400

Źródło: DVD forum

Niebieskość 405 nm

- Blue-ray 27 GB (50 GB dwustronnie) (Sony, Philips Electronics, Sony, Hitachi, Hewlett-Packard Co, LG Electronics, Matsushita Electric Industrial, (Panasonic), Pioneer, Samsung, Sharp, Thomson Multimedia)
- „The licensing agreements, which are 10-year renewable contracts, will include the right to use the Blu-ray format and logo as well as the content protection specifications. Licenses for the format and logo will range from $20,000 to $60,000 depending on which products--discs, players or components--manufacturers want to develop. The same is true for the protection specifications, which range in price annually from $4,000 to $12,000".

Niebieskość 405 nm

Potrzebny laser: 5-100 mW, 405 nm, jednomodowy, dobra wiązka, wysoka niezawodność niska cena

50 GB ☺

3300 $ ☹

14 kg ☹

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Niebieskość 405 nm

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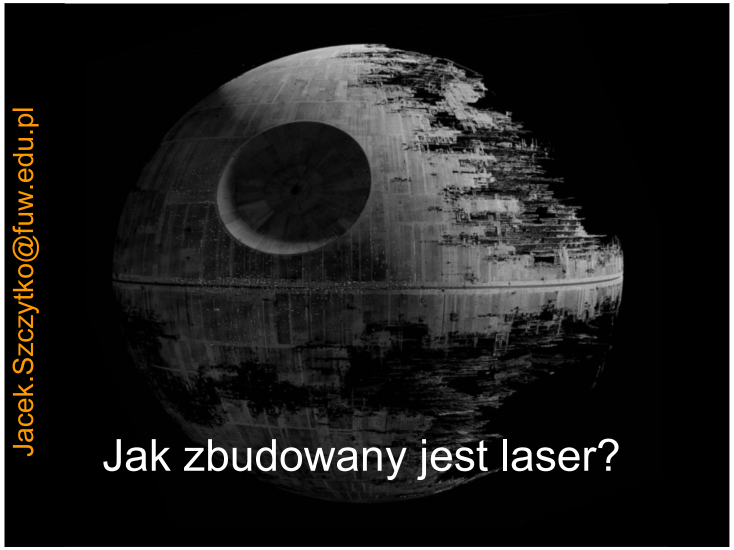
- **Drukowanie**: drukarka laserowa 600 dpi drukująca 60 stron na minute (60 ppm) korzysta obecnie z lasera 760 nm i systemu optycznego o aperturze 6mm by uzyskać 35 µm FWHM. Dla wydruku 1200 dpi (17 µm FWHM) czerwony laser potrzebuje droższego i większego systemu optycznego o aperturze 12 mm i głębi ostrości jedynie 0.5mm (z taką precyzją względem papieru laser musi być ogniskowany). Laser GaN 390 nm może dać wydruk 1200 dpi za pomocą systemu optyki 6mm i głębi ostrości 1mm.
- Do wydruku 60 ppm potrzeba laserów GaN 6 mW CW (większa moc umożliwia większe prędkości wydruku).
- Długośc fali powinna być >430 nm, żeby nie dopuścić do uszkodzenia (rozkładu) materiałów organicznych (plastików) używanych w budowe .



Jak zbudowany jest laser?

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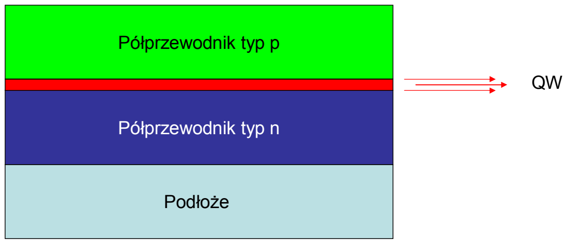

Trochę historii

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- 1907 – żółta elektroluminescencja SiC (Henry Joseph Round)
- 1936 – elektroluminescencja ZnS, George Destriau
- Lata '50 pierwsze diody świecące (w podczerwieni) z GaAs – akronim Light Emitting Diode (LED),
- **MASER** (Microwave Amplification by the Stimulated Emission of Radiation) Charles H. Townes in 1954.
- 1960 **LASER** (rubin, Theodore Maiman) 1961 He-Ne (Ali Javan, William Bennet, and Donald Herriot)

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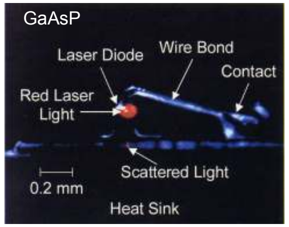
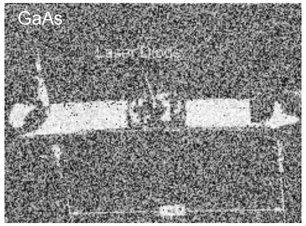
- 1962 Pierwsze diody laserowe GaAsP (Holonyak & Bevacqua) i GaAs (Robert Hall, Lincoln Laboratories) (pulsed,LN)
- Lata '60 pierwsze diody świecące na czerwono z GaAsP/GaAs, a później GaAsP/GaP





http://www.rpi.edu/~schubert/

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- Lata '60 pierwsze diody świecące na czerwono z
- 1970 pierwszy laser cw RT (Zhores Alferov ZSRR
Hayashi and Panish, Bell Labs)

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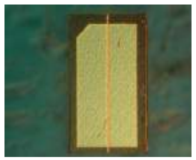
- Lata '60 pierwsze diody świecące na czerwono z GaAsP/GaAs, a później GaAsP/GaP
- 1970 pierwszy laser cw RT (Zhores Alferov ZSRR, Hayashi and Panish, Bell Labs)
- Połowa lat '70 diody z GaP (zielone). **Czerwone** + **Zielone** = **Żółte**
- Połowa lat '80 diody z GaAlAsP (bardzo wydajne).
- Połowa lat '90 diody z InGaAlP (jeszcze bardziej wydajne) czerwone, pomarańczowe, zielone i żółte.

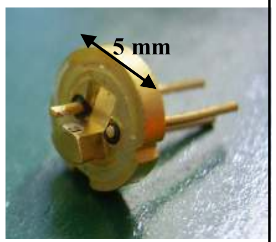
Rozwój laserów

i potrzeb technologii elektronicznych:

1977 – pierwsza rozmowa telefoniczna transmitowana światłowodem
1982 – Phillips and Sony rozpoczynają produkcje odtwarzaczy CD
1996-97 – technologia DVD

Obecnie ponad 60% rynku laserów półprzewodnikowych to :
Lasery telekomunikacyjne: 1.55 μm
Lasery CD, DVD 790, 640 nm





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Przerwa energetyczna

Jacek.Szczytko@fuw.edu.pl

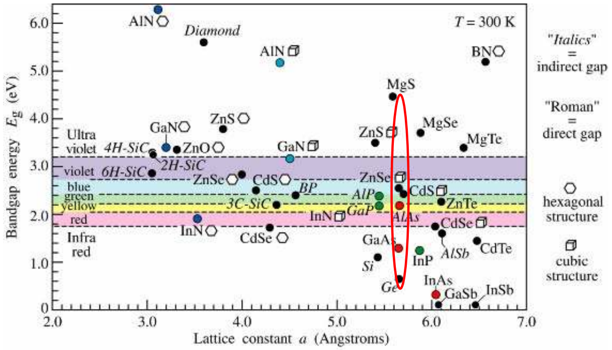


Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

Obiecujący materiał

Jacek.Szczytko@fuw.edu.pl

1272 Appl. Phys. Lett. 59 (11), 9 September 1991 0003-6951/91/361272-03$02.00 © 1991 American Institute of Physics 1272

Blue-green laser diodes

M. A. Haase, J. Qiu, J. M. DePuydt, and H. Cheng
3M Company, 201-1N-35 3M Center, St. Paul, Minnesota 55144

Lifetime 100h

(Received 17 May 1991; accepted for publication 13 June 1991)

The first laser diodes fabricated from wide-band-gap II-VI semiconductors are demonstrated. These devices emit coherent light at a wavelength of 490 nm from a ZnSe-based single-quantum-well structure under pulsed current injection at 77 K. This is the shortest wavelength ever generated by a semiconductor laser diode.

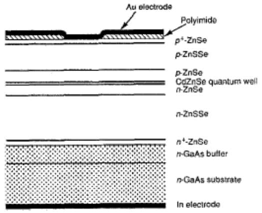


FIG. 1. A cross section of a blue-green laser diode.

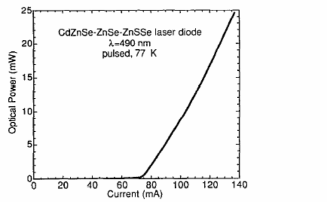


FIG. 2. The L-I characteristic of a blue-green laser diode. This gain-guided device is 20 μm wide and 1160 μm long.

Obiecujący materiał?

Jacek.Szczytko@fuw.edu.pl

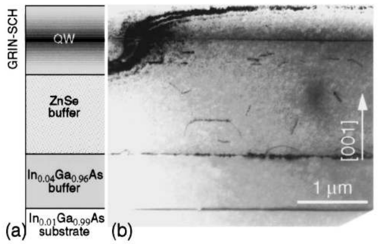


FIG. 1. (a) Schema of the structure; (b) bright field TEM image in the cross section of No. 372 near the [110] zone axis.

JOURNAL OF APPLIED PHYSICS VOLUME 83, NUMBER 4 15 FEBRUARY 1998

Transmission electron microscopy and cathodoluminescence studies of extended defects in electron-beam-pumped $Zn_{1-x}Cd_xSe$/ZnSe blue-green lasers

Jean-Marc Bonard[a),b)] and Jean-Daniel Ganière
Département de Physique, Institut de Micro-et Optoélectronique, Ecole Polytechnique Fédérale, CH-1015 Lausanne, Switzerland

Lia Vanzetti,[c)] Jens J. Paggel,[d)] Lucia Sorba,[e)] and Alfonso Franciosi[f)]
Laboratorio Nazionale TASC-INFM, Area di Ricerca, Padriciano 99, I-34012 Trieste, Italy

Denis Hervé[g)] and Engin Molva
Département Optronique, LETI (CEA-Technologies Avancées) 17 rue des Martyrs, F-38054 Grenoble Cédex 9, France

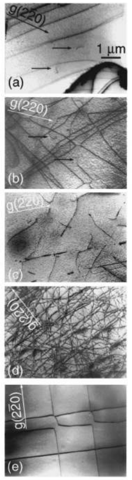


FIG. 3. Bright field TEM images of No. 372 in plan view taken with g =(220) two beam diffraction conditions near the [001] zone axis: (a) top GRIN layer (thickness of the foil: ~400 nm); (b) whole GRINSCH (~800 nm); (c) ZnSe buffer (GRINSCH removed); (d) ZnSe buffer with III-V/II-VI interface (GRINSCH removed); (e) InGaAs buffer and substrate-buffer interface (GRINSCH and ZnSe buffer removed).

Obiecujący materiał?

Jacek.Szczytko@fuw.edu.pl

JOURNAL OF APPLIED PHYSICS VOLUME 91, NUMBER 6 15 MARCH 2002

Patterned heteroepitaxial processing applied to ZnSe and $ZnS_{0.02}Se_{0.98}$ on GaAs (001)

X. G. Zhang, A. Rodriguez, P. Li, F. C. Jain, and J. E. Ayers[a)]
Electrical and Computer Engineering Department, University of Connecticut, 260 Glenbrook Road, Storrs, Connecticut 06269-2157

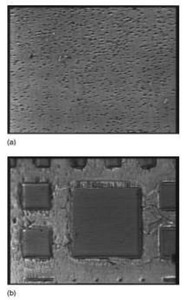


FIG. 1. The etch pit morphology of: (a) a 6000 Å thick as-grown ZnSe layer on GaAs and (b) a PHP prepared layer consisting of 6000 Å thick ZnSe mesas on GaAs. Both pieces were from the same ZnSe/GaAs wafer.

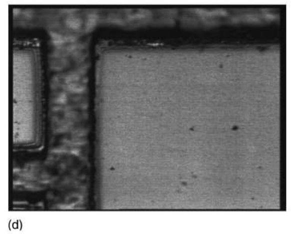


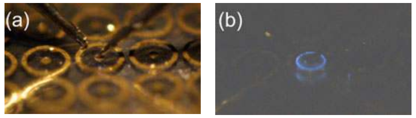
FIG. 5. The etch pit morphology of $ZnS_{0.02}Se_{0.98}$ on GaAs: (a) a 2900 Å thick as-grown and (b) a 2900 Å thick PHP prepared (both pieces were from the same wafer); (c) a 6000 Å thick as-grown and (d) a 6000 Å thick PHP prepared layer [both (c) and (d) were from the same wafer].

Obiecujący materiał

May 19, 2005

World's First Blue LED Made with Zinc Oxide

A Japanese team led by Professor Masashi Kawasaki of the Tohoku University Institute for Materials Research announced it had successfully developed the world's first blue light-emitting diode (LED) made with low-cost zinc oxide in December 2004.



http://www.jetro.go.jp/en/market/trend/topic/2005_05_led.html

Przerwa energetyczna

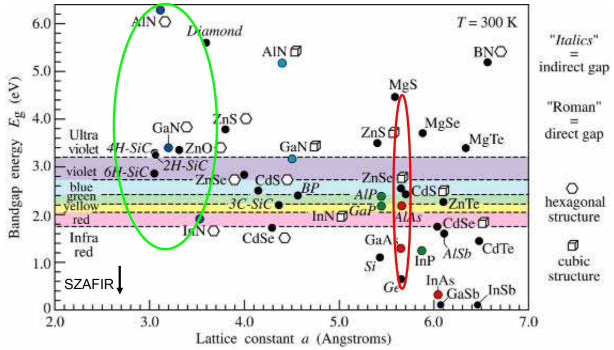


Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

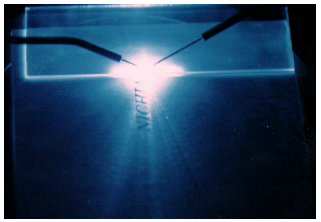
Trochę historii


- 1970 - J. Pankove (RCA labs) odkrył, że GaN może eimitować niebieskie światło.
- 1989 - I. Akasaki & H. Amano (Matsushita, Nagoya University)
  - domieszkowanie na typ p GaN (z Mg),
  - nieskotemperaturowa warstwa buforowa

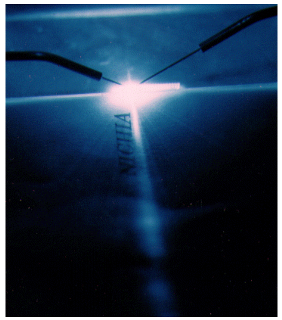

- 1992-1996 - S. Nakamura (Nichia) LEDs oraz LD z MOVPE
  - „two-flow MOVPE process” do wzrostu warstw GaN
  - wygrzewanie termiczne GaN:Mg

Trochę historii

- Połowa lat '90 diody z InGaAlP (jeszcze bardziej wydajne) czerwone, pomarańczowe, zielone i żółte.
- 1993 Niebieskie diody Nichia (Nakamura)
- 1996 Niebieski laser Nichia (Nakamura) RT, pulsed 215 mW



Nichia Chemical Industries



http://nsr.mij.mrs.org/news/flash.html

History'of'Nitrides

SCIENCEWATCH®

Why did you decide to use gallium nitride?

Nakamura: At that time, in 1989, there were two materials for making blue LEDs: zinc selenide (ZnSe) and gallium nitride (GaN). These had the right band gap energy for blue lasers. But everybody was working on zinc selenide because that was supposed to be much better. I thought about my past experience: **if there's a lot of competition, I cannot win.** Only a small number of people at a few universities were working with gallium nitride so I figured I'd better work with that. **Even if I succeeded in a making a blue LED using zinc selenide, I would lose out to the competition when it came to selling it.**

http://www.sciencewatch.com/jan-feb2000/

History'of'Nitrides

SCIENCEWATCH®

You still weren't doing laser research?

Nakamura. Not yet. In 1985, I went to work on a gallium aluminum arsenide epitaxial wafer. This is also used for LEDs. It's called an epitaxial wafer because you use very thin layers to make the LEDs. So I spent the next three years on that and came out with these gallium aluminum wafers for red and infrared LEDs, but the same thing happened: Our sales were not good because the bigger companies were already selling the same product by the time I was. The quality of our LEDs and epitaxial wafers was just as good and the prices were the same, but our company was small and local and couldn't compete. So once again my company was not happy.

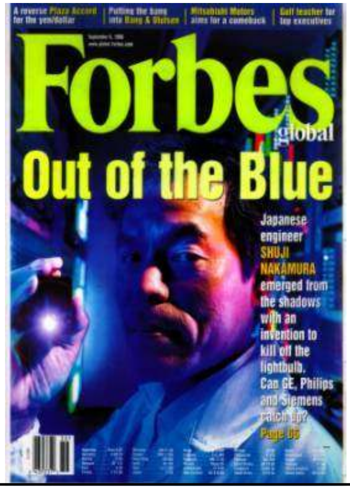
By this time the R&D department was down to just me-the other two people left because the results were so terrrible. I kept at it, but I was dispirited. For ten years I had worked very hard to make these products. I worked twelve hours a day, seven days a week, except holidays. I had a very, very small budget and had to make everything I needed myself. I even made my own reactors- the furnaces needed to do the crystal work. The commercial reactors were too expensive. I made three products all by myself, and still my salary and position were not good at the company. My bosses always complained that my results were terrible, because I spent a lot of money, as far as they were concerned, and nothing sold. But for ten years I had been working to make these LED materials and I knew at the time there were no high-brightness blue LEDs. For LED researchers, this was a dream. But my bosses said it would be impossible to create a blue LED at Nichia, because many big companies and many research teams in big universities were trying to do it and were failing. So I went to went to my company's chairman, Nobuo Ogawa, who was my professor's friend, and the president Eji Ogawa, who was his son-in-law. **I asked them if they would let me do research on blue LEDs and they said "Sure. No problem. Go ahead."** I was very surprised. I asked them to give me a large budget so I could do it. **"Please give me three million U.S. dollars," and they said "Sure. No problem."** They had faith in me because, despite the dismal sales, I had developed three new products for this company and I was the only one at Nichia who had succeeded in making new products.

GaP, GaAs

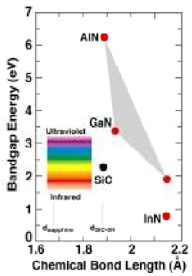
http://www.sciencewatch.com/jan-feb2000/

Trochę historii

Jacek.Szczytko@fuw.edu.pl

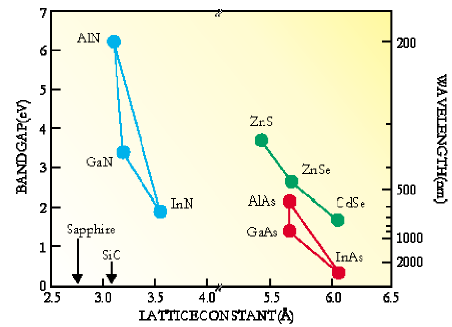


1992-1996

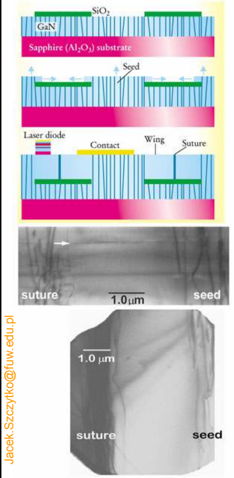


Jak zbudowany jest laser?

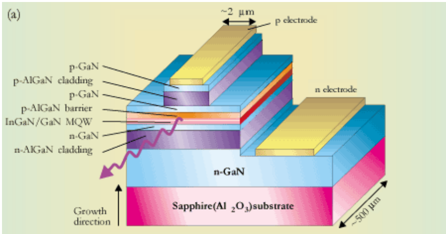
Jacek.Szczytko@fuw.edu.pl

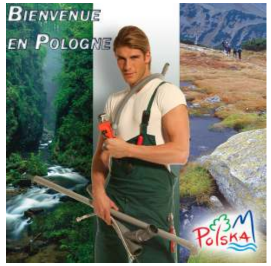


Jak zbudowany jest laser?



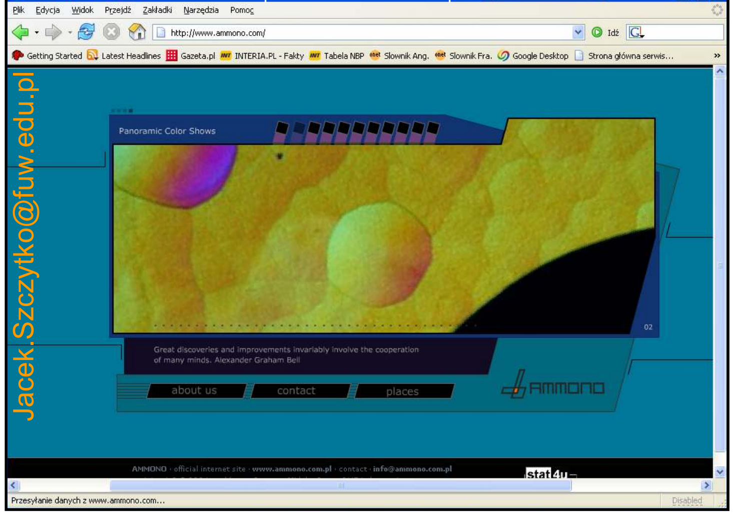
Lateral epitaxial overgrowth (LEO)
ELO

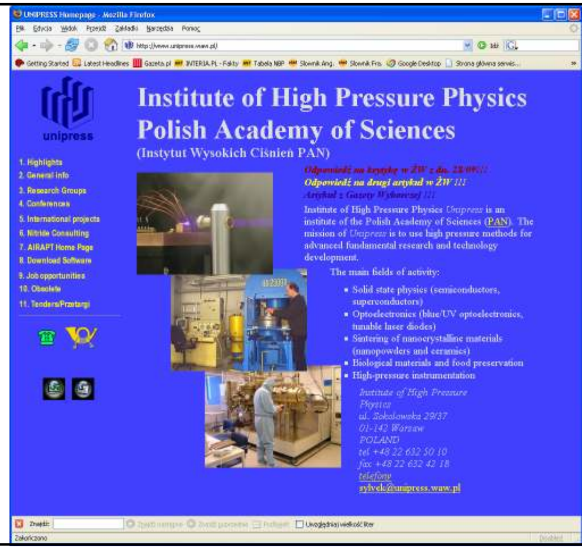




TERAZ POLSKA

http://www.ammono.com.pl/





TopGaN

PRICE LIST JUNE 2005

Module name	Unit price Euro
VLMA1	900
VLMB1	1300

Laser diode type	Unit price Euro
TGL415-50PMG	350
TGL415-200PMG	650

TopGaN Ltd, Sokolowska 29/37, 01-142 Warsaw, Poland

Sales: sales@topgan.fr.pl, or by phone to **+48 22 876 0312, 876 03 25** or by fax to the number **+48 22 876 0314**

LD type	Output power-typical	Output power-maximum	Pulse length - recommended	Wavelength
TGL415-50PMG	50 mW	200 mW	50 ns	415 nm
TGL415-200PMG	200 mW	1000 mW	50 ns	415 nm

Module name	Output power (peak value)	Output power average (100kHz)	Pulse length	Repetition	Beam type	Polarization	Wavelength
VLMA1	50 mW	0.25 mW	50 ns	1,10,100 kHz	elliptical	100% TE, multimode	415 nm
VLMB1	200 mW	1 mW	50 ns	1,10,100 kHz	elliptical	100% TE, multimode	415 nm
VLMC1	500 mW	0.25 mW (at 10 kHz)	50 ns	1,10 kHz	elliptical	100% TE, multimode	415 nm

Niebieskie lasery są ciągle bardzo drogie – 2000 USD/sztukę !

4.1 Manufacturers of Laser Diode Chips

4.1.1 Cree, USA
4.1.2 Matsushita, Japan
4.1.3 NEC, Japan
4.1.4 Nichia, Japan
4.1.5 Osram Opto Semiconductors, Germany
4.1.6 Pioneer, Japan
4.1.7 Rohm, Japan
4.1.8 Samsung, Korea
4.1.9 Sanyo Electric, Japan
4.1.10 Sharp, Japan
4.1.11 Sony, Japan
4.1.12 TopGaN, Poland
4.1.13 Toshiba, Japan
4.1.14 Toyoda Gosei, Japan

Strategy Analytics

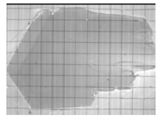
March 2004

http://www.strategyanalytics.com/

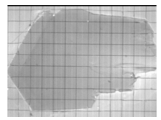
Czesław Skierbiszewski *UNIPRESS*

Etapy wytwarzania lasera niebieskiego

1. Wytwarzanie podłoży GaN
(metoda wysokociśnieniowa – unikalna na skale światową)



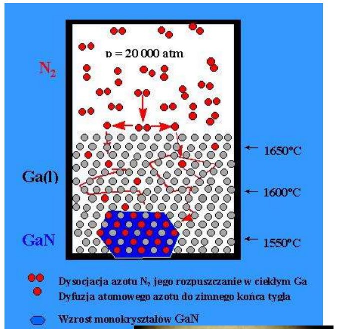
2. Epitaksja warstw laserowych
(metoda MBE lub MOVPE)



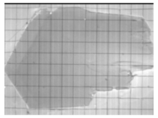
3. Processing linijek laserowych

Czesław Skierbiszewski *UNIPRESS*

Wzrost podłoży w IWC PAN



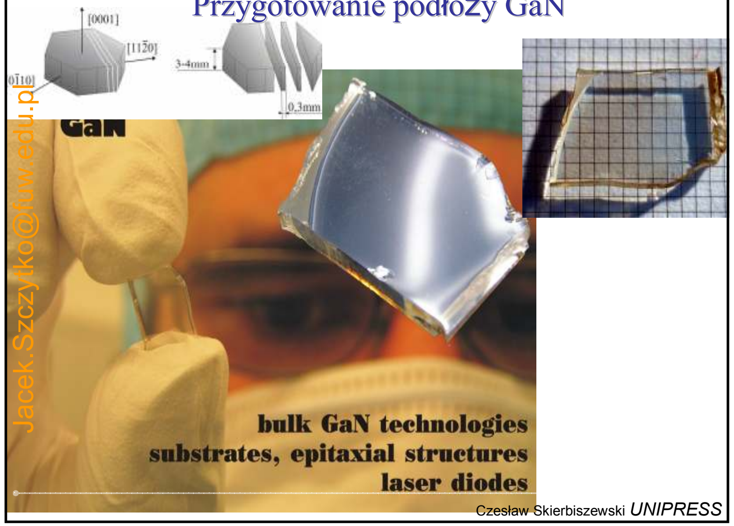
- Objętość robocza 4500 cm^3
- Ciśnienie wzrostu 15 000 atm
- Temperatura 1550^{o}C
- Czas procesu >300h.



10^2 dyslokacji/cm^2

I. Grzegory

Przygotowanie podłoży GaN



Czesław Skierbiszewski *UNIPRESS*

Półprzewodnikowe kryształy objętościowe (prywatne oszacowania)

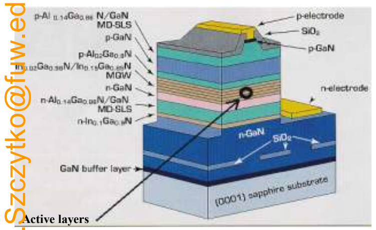
	Cena za cm^2 (Euro)	Produkcja na świecie (mln Euro)	Procent w Polsce (mln Euro) (%)
Krzem	0.2	10-15 000	0.1 (Cemat Silicon)
GaAs	5	1 000	-
GaN	500-1000	5-50	0.1-1 (TopGaN, Ammono)

Czesław Skierbiszewski *UNIPRESS*

Epitaksja struktur laserowych

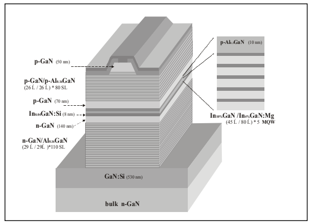
Czyli o układaniu warstw atomów...

Nichia, Japan



Podłoże szafirowe

Unipress, Poland

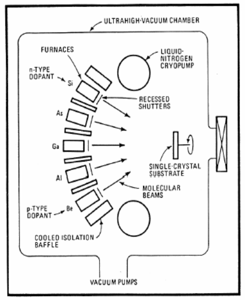


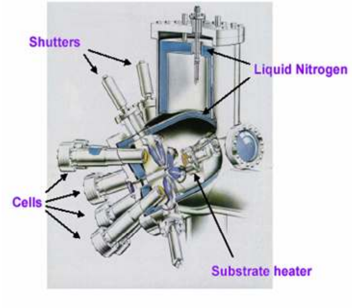
Podłoże GaN

Dioda laserowa zawiera ok. 400 różnych warstw

Czesław Skierbiszewski *UNIPRESS*

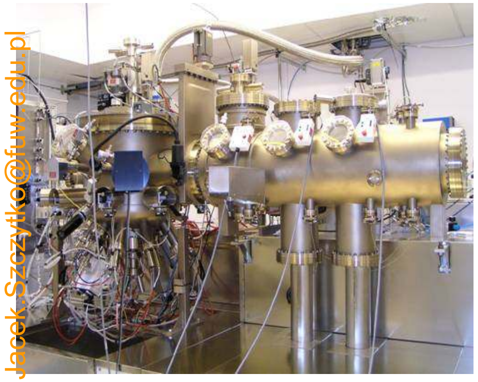
Epitaksja z Wiązek Molekularnych (MBE)





- •Najbardziej wyrafinowana technologia epitaksjalna
- Ultra Wysoka Próżnia UHV ciśnienie rzędu 10^{-11}tor=1, $33*10^{-9}$Pa
- Ultra czyste materiały o czystości 7N=99, 99999%

Urządzenie do epitaksji azotków w Unipressie

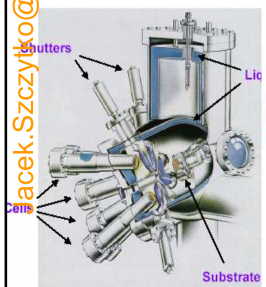


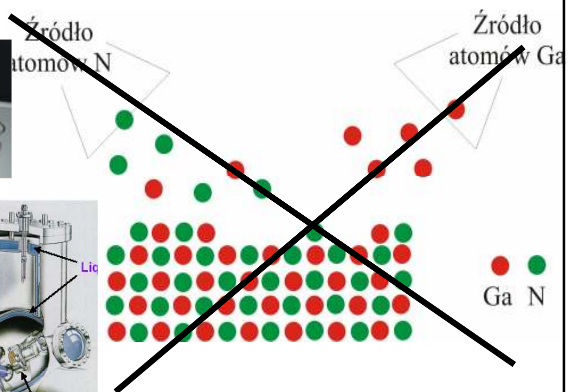
1. Pierwsza w świecie azotkowa dioda laserowa (czerwiec 2004) Nowa technologia (niezależna od Japończyków - 2patenty)

2. Tranzystory polowe GaN/AlGaN

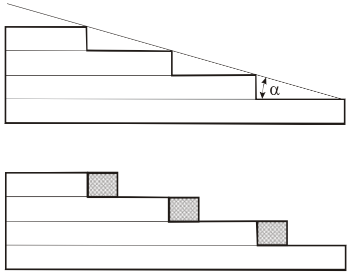
Urządzenie do epitaksji azotków w Unipressie

Nanoszenie warstw metodą MBE



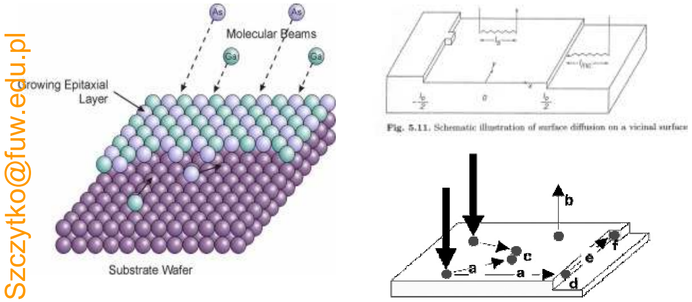


Nanoszenie warstw metodą MBE



Wzrost metodą płynięcia stopni atomowych:
1. Należy przygotować podłoże wypolerowane pod kątem do płaszczyzn krystalograficznych (kąt polerowania ok. 0.5-1°)

Nanoszenie warstw metodą MBE

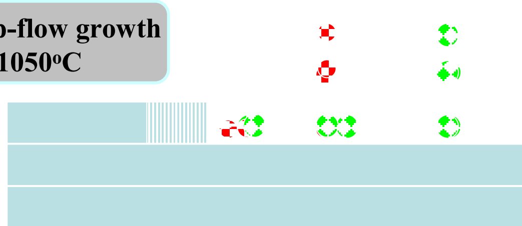


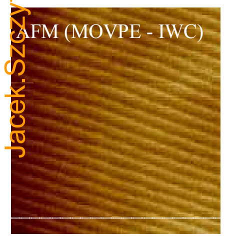
Wzrost metodą płynięcia stopni atomowych:
2. Należy tak dobrać warunki wzrostu (np. temperatura wzrostu) aby padające atomy dyfundowały do stopni atomowych (droga dyfuzji rzędu 20 - 200 nm!)

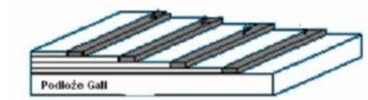
Po dotarciu do stopnia atomowego , atom jest silnie wiązany

N rich conditions and High growth temperature: 1050°

2D step-flow growth 1050°C

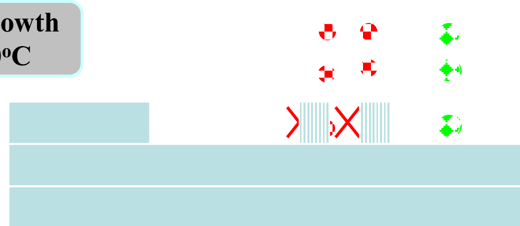


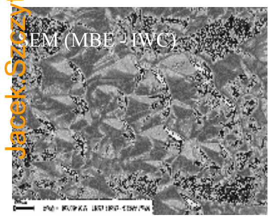




N rich conditions and low growth temperature: 700°C

3D growth 700°C



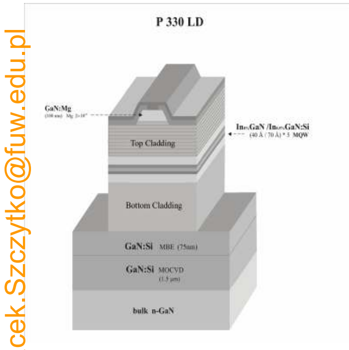


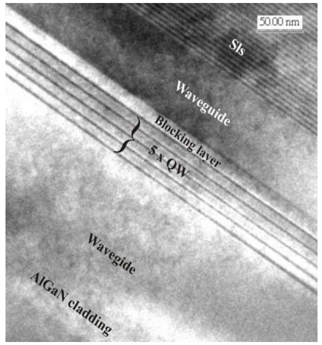
Barrier for adatom diffusion !!!

Jak wygląda przekrój warstw diody laserowej

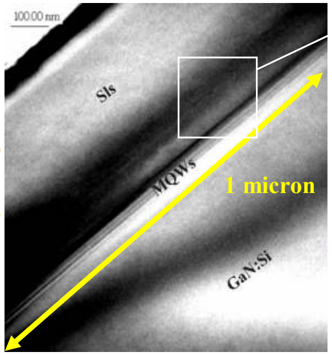
Obrazy z Transmisyjnego Mikroskopu Elektronowego (TEM)

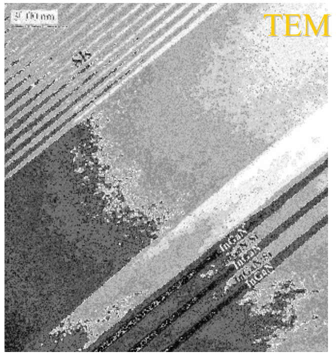
Dioda laserowa wykonana metodą MBE

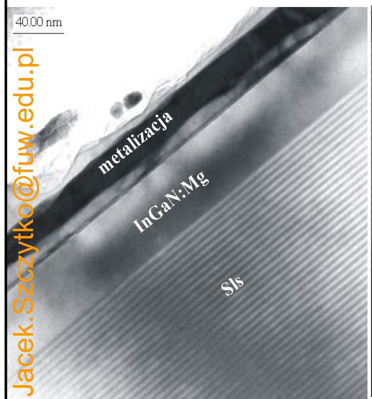


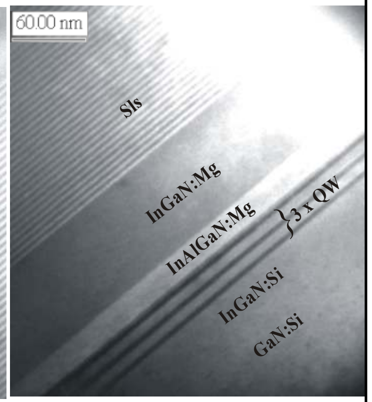


TEM

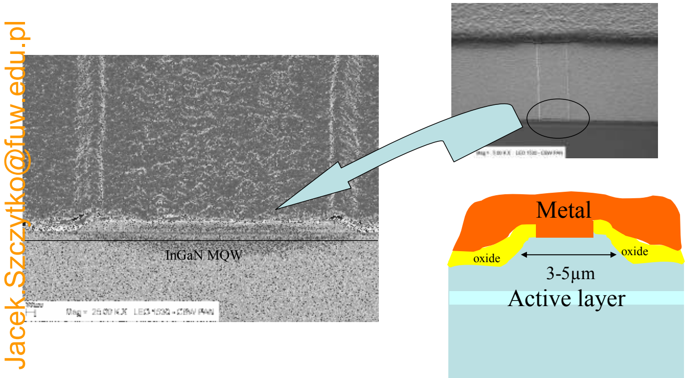








Processing laserów na azotku galu



P. Perlin, P. Wiśniewski

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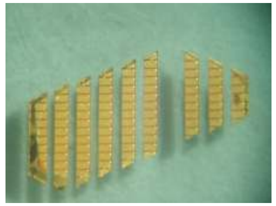
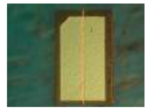
Processing laserów na azotku galu

Struktura laserowa po processingu

Łupanie na linijki laserowe



Pojedynczy przyrząd



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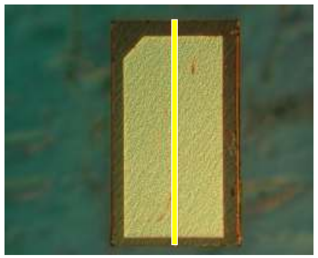
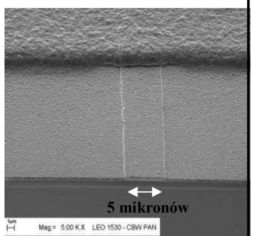
Lasery półprzewodnikowe są bardzo małe

Szerokość kostki = 0.3 mm



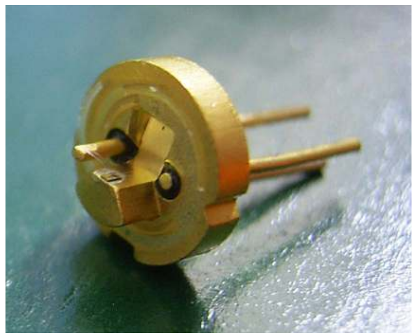
Długość lasera = 0.5 - 1 mm



Szerokość lasera = 0.001 – 0.02 mm !! (1 μm - 20μm)

IWC PAN, UNIPRESS

Montaż laserów – wersja impulsowa



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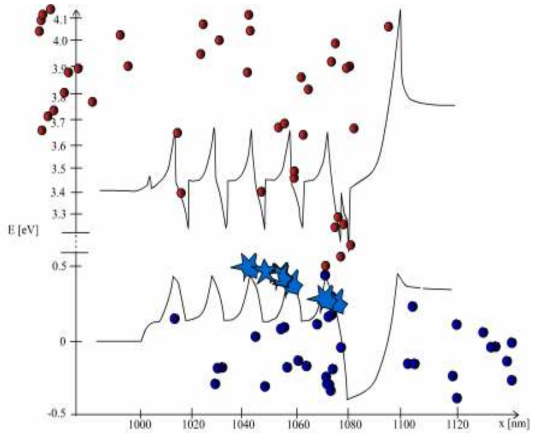
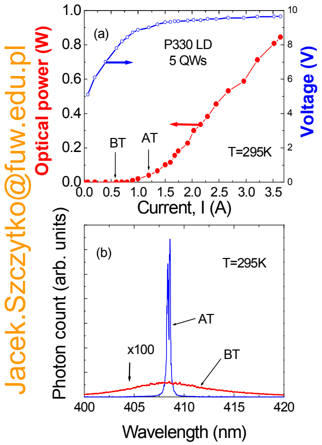
Electron blocking layer



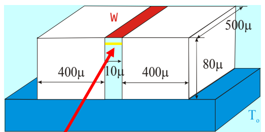
Charakterystyki diody laserowej MBE

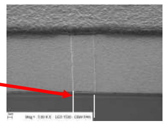


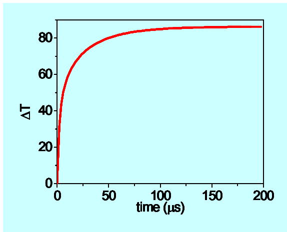
	MBE Lasers
λ	408 - **422** nm
J_{thr}	9 kA/cm^2
V_{thr}	8 V
Max. output power (pulsed)	1.1 W
Slope efficiency	0.47 W/A
T_0	120K
$T_{operation}$	Up to 80C

Ewolucja czasowa temperatury w laserze IWC PAN

Moc cieplna W = 12 W



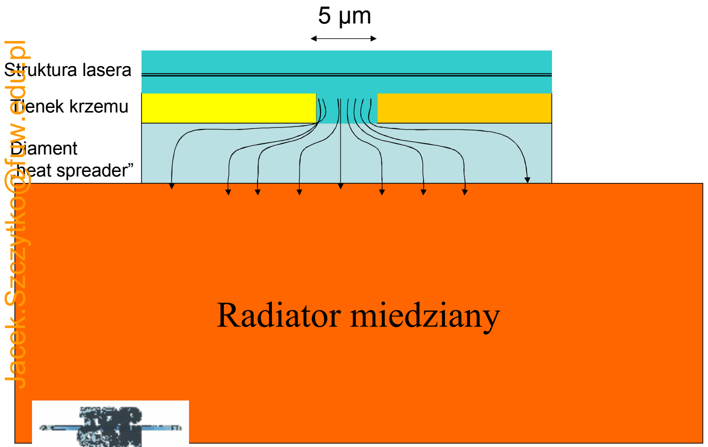




Złącze p-n

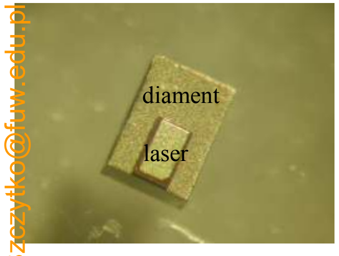
Modelowanie - S. Krukowski

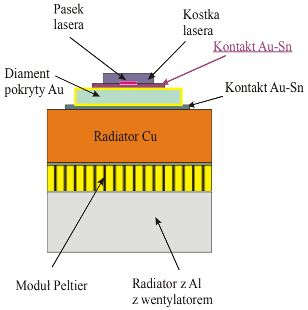
Odprowadzenie ciepła ze struktury laserowej



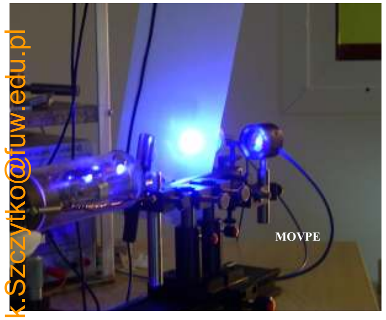
P. Wiśniewski

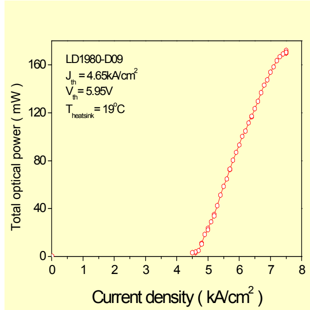
Montaż laserów – praca ciągła





Laser IWC PAN pracy ciągłej dużej mocy

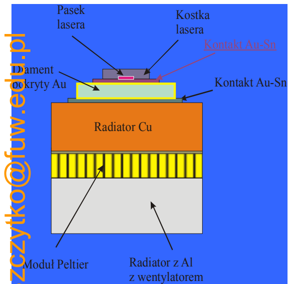




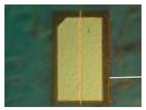
$\underline{P_{max} = 200\text{ mW}}$; J_{thr} = 4.65 kA/cm^2; V_{thr} = 5.95V; λ= 406 nm; d = 20 μm; L = 1000 μm

Zastosowania: PROJEKTORY LASEROWE

Pierwszy laser MBE IWC PAN pracy ciągłej mocy 10 mW



21 grudzień 2005 godz 15.10



Pasek laserowy

Pasek laserowy na diamencie

Kostka lasera (miedź)

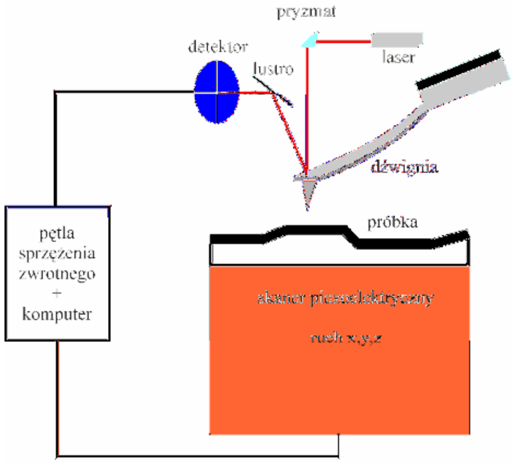
Badania na Hożej

WYDZIAŁ FIZYKI UNIWERSYTET WARSZAWSKI

- Technologia w Labolatorium Wzrostu Kryształów (ul. Pasteura):
  - Ammono GaN z Mn, Gd, Eu (M. Zając, Prof. M. Kamińska)
  - MOCVD (K. Pakuła, R. Bożek)
- Spektroskopia
- Własności transportowe

•Prof. J. Baranowski, Prof. R. Stępniewski,

ZASADA DZIAŁANIA MIKROSKOPU SIŁ ATOMOWYCH



Rafał Bożek

Mikroskop AFM

mikroskop optyczny z kamerą

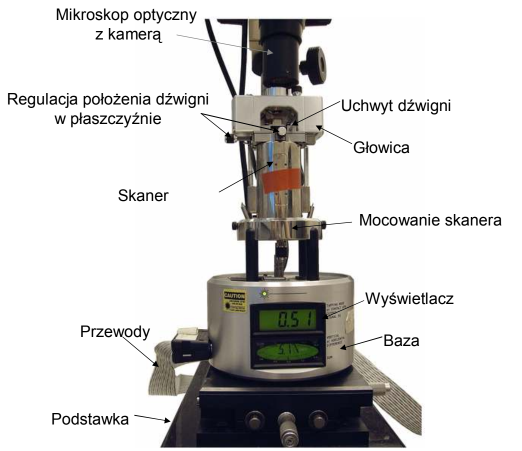
AFM ~25cm

podstawa

MultiMode AFM
+Nanoscope IIIa
Digital Instruments
(obecnie Veeco)

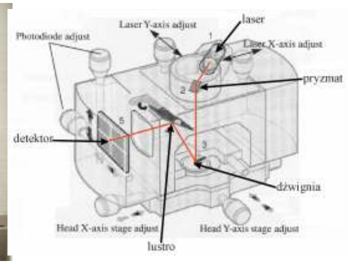
Rafał Bożek

Budowa mikroskopu AFM: ruchoma próbka



Rafał Bożek

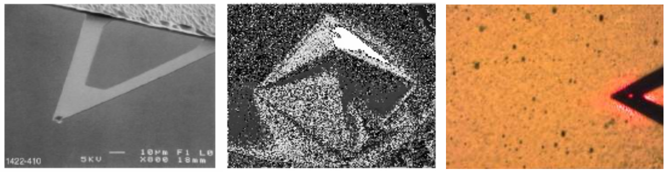
Głowica i mocowanie dźwigni



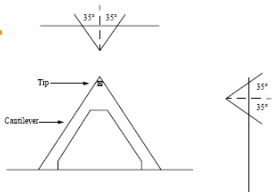
Rafał Bożek

Jacek.Szczytko@fuw.edu.pl

Dźwignia i ostrze - tryb kontaktowy



SEM　　　　Mikroskop optyczny

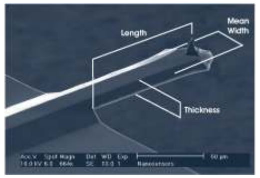


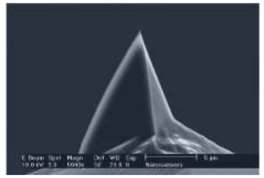
Długość:	**100÷200 μm**
Stała sprężystości:	**0.06÷0.6 N/m**
Promień krzywizny:	**20÷60 nm** **pokrycie utwardzające Si_3N_4**

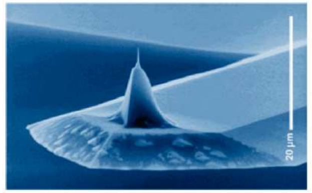
Rafał Bożek

Jacek.Szczytko@fuw.edu.pl

Dźwignia „tapping mode”







Długość	**125 μm**
Szerokość	**30 μm**
Grubość	**3 μm**
Wysokość	**10 μm**
Stała sprężystości	**100 N/m**
Częstość rezonansowa	**~300 kHz**
Promień krzywizny	**10 nm**
Kąt rozwarcia stożka	**30°**

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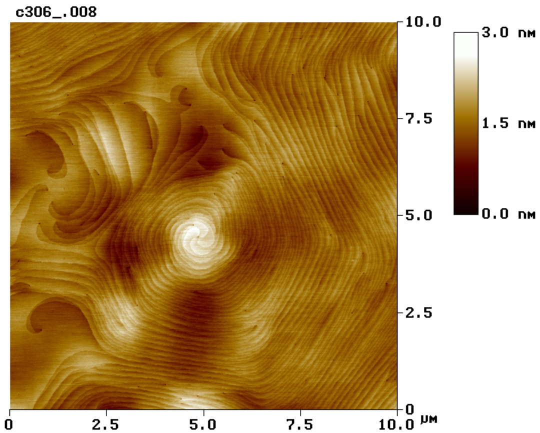
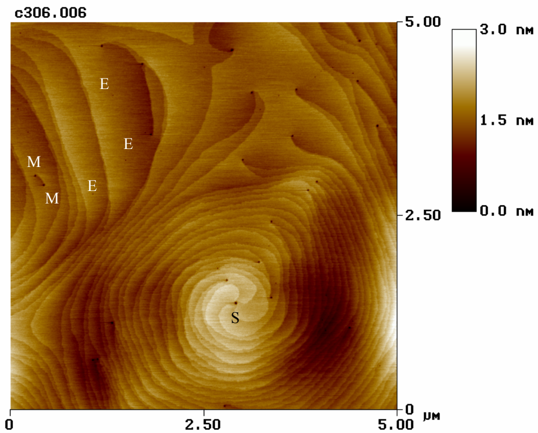


GaN na szafirze (0001) - widoczna symetria heksagonalna

Rafał Bożek

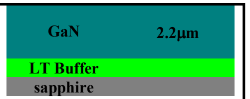
Jacek.Szczytko@fuw.edu.pl

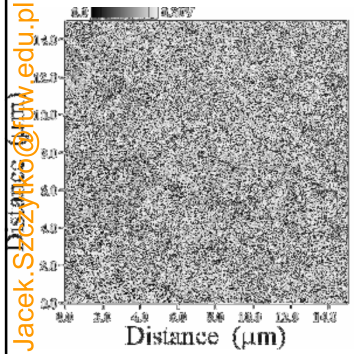


GaN na szafirze (0001) - dyslokacje: śrubowa (S), krawędziowa (E) i mieszana (M) - przykłady

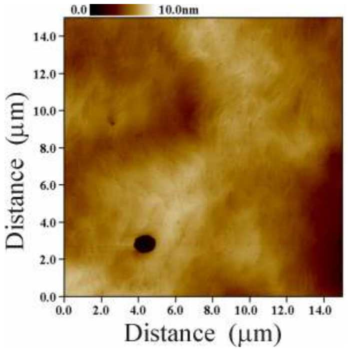
Rafał Bożek

GaN





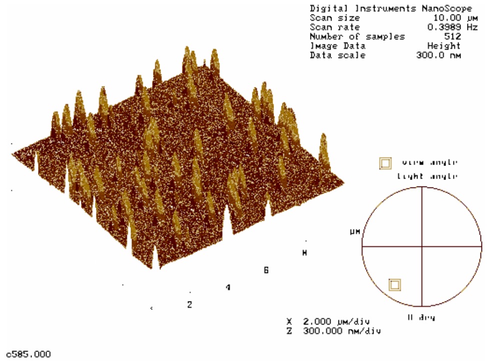
potencjał (KPFM)



topografia (AFM)

Rafał Bożek

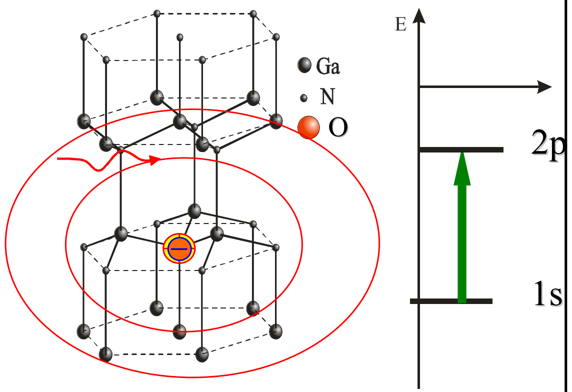
GaN/AlGaN QD's



Wzrost – K. Pakuła, AFM - Rafał Bożek

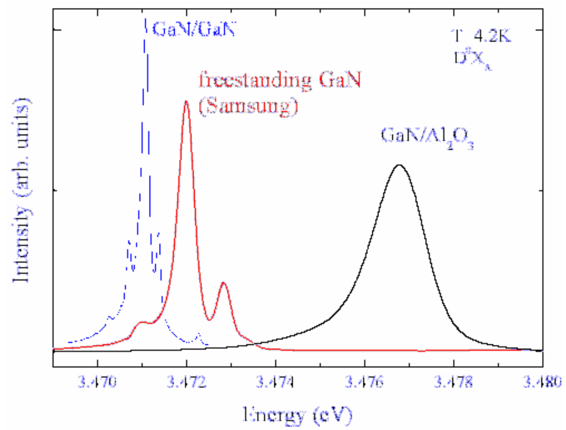
Neutralny donor

m*

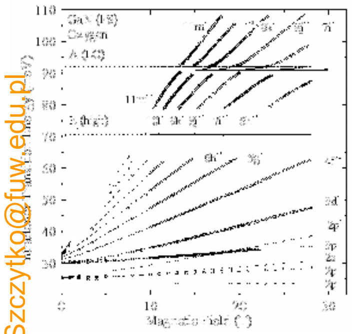


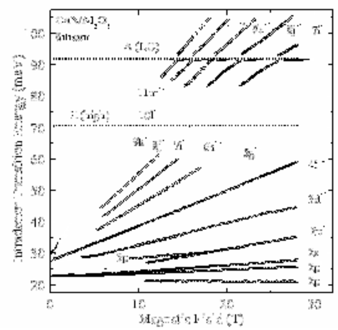
Andrzej Wysmołek

Próbki GaN



Andrzej Wysmołek

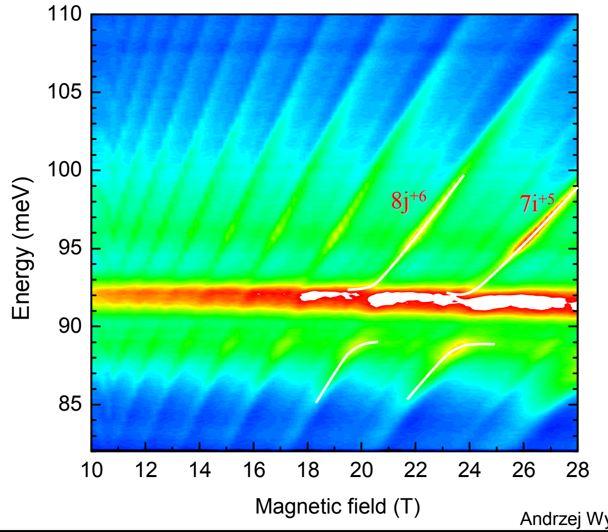




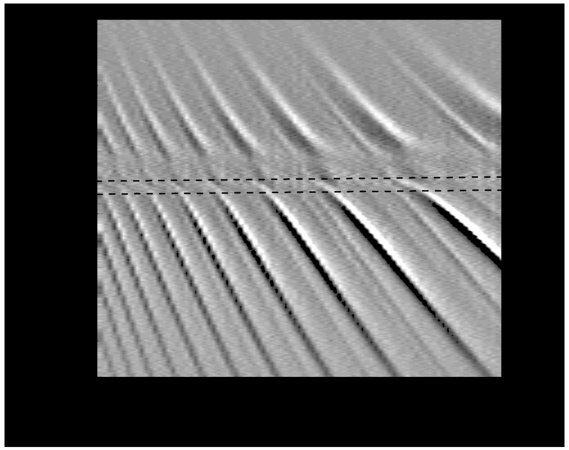
Oxygen
R_y=30.28(5) meV
Δ_{1s}=2 .9meV
E_B=33.18meV
ΔE_p=1.3(1) meV,
Δg=0.4(1)
p=2.2(1)

Silicon
R_y=30.28(5) meV
Δ_{1s}=0
E_B=30.28meV
ΔE_p=1.3(1) meV
Δg=0.3(1)
p=2.3(1)

Andrzej Wysmołek



Andrzej Wysmołek



Andrzej Wysmołek

Podziękowania

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Dr Robert Dwiliński AMMONO

Prof. Roman Stępniewski, Prof. Jacek Barabnowski, mgr Rafał Bożek, Dr Andrzej Wysmołek, IFD UW

Jacek.Szczytko@fuw.edu.pl

W przyszłym tygodniu

Optoelektronika

Źródło: www.gazeta.pl 17-11-2005