Laboratory of Physics of Semiconductor Heterostructures

(Head of Laboratory Prof. Zh.I. Alferov, Vice President of the RAS)

TECHNOLOGY OF III-N MATERIALS

Laboratory of Physics of Semiconductor Heterostructures was the first laboratory in Russia, worked on the development of the MOCVD III-nitride system epitaxial technology. R&D activity of the laboratory is concentrated on fundamentals of growth, physical properties and device applications of III-N structures for LEDs, lasers and HEMTs.

Areas of activity:

Development of the III-N MOCVD growth
LED technology
LD technology
VCSEL
Transistors
Photodetectors

Research areas:

(InGaAl)N heterostructures grown on sapphire substrates (ultraviolet and blue-green emission range)

(InGa)AsN heterostructures grown on sapphire substrates (yellow-green emission range)

(InGaAl)N heterostructures grown on alternative substrates

Investigation of structural, optical and galvanomagnetic properties of III-N materials

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HISTORY OF III-N GROUP

1995	MOCVD group was established at Ioffe Physico-Technical Institute
1996	MOCVD growth of n- and p-type GaN and AlGaN on Al_2O_3 by MOCVD utilizing AlGaN low temperature nucleation layer.
1997	Lazing under optical pumping of AlGaN/GaN heterostructures with P_{th} of 35 kW/cm^2 and 85 kW/cm^2 at 77K and 300K.
1997-1998	First UV LED with dominant band-edge GaN emission based on thick conductive AlGaN buffer/contact/window layer.
1998	SQW and MQW InGaN/GaN heterostructures.
1999	Strain-compensated conductive GaN/AlGaN DBRs.
1999	Photopumped RT operated InGaN/AlGaN VCSEL's.
2000	Photodetectors with cutoff wavelengths near of 350 nm
2000-2001	InGaN/(Al)GaN MQW LED's (415-465 nm).
2002	Growth of GaN/AlGaN HEMT structures having mobility of 1300 cm^2/V×sec, and concentration 1.2×10^{13} cm^{-2}. Growth of AlGaN layers and AlGaN/GaN heterostructures in the whole range (0-100%) of Al contents.
2003	Start-up of the first in Russia AIX2000HT planetary reactor and fabrication of LED (410-470 nm) with efficiency more than 10%. Growth of AlGaN with content up to 40% on the AIX2000HT system.

Staff of Group

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Staff of group - 14 reseachers, including 1 Doctor, 3 Candidates of Sciences, 4 students

MOCVD EQUIPMENT

EPIQUIP VP 50-RP – for R&D growth. This setup was adapted for III-N growth specially at Ioffe Institute and has next parameters:

- Horizontal flow quartz reactor
- Inductively heated graphite susceptor
- $T_{max} > 1100^0C$
- P_{cell} = 200-600 mbar

Growth conditions:

- Precursors - NH_3, TMG (two source), TMA, TMI, Cp_2Mg, SiH_4, AsH_3
- Carrier gas - Ar for InGaN growth and H_2 for all other growth steps

In-situ optical reflectance monitoring in the near-normal incident using He-Ne laser and Si photodetector. The growth process are operated by full automatic system.

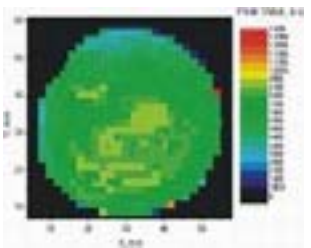
AIXTRON AIX 2000/HT - for R&D and small test series growth. The first in Russia (started in 2003).

- Planetary Reactor® with Gas Foil Rotation®
- Wafer capacity 6 x 2"
- Applications III-Nitrides
- Average throughput up to 27.000 wafers per year

CHARACTERIZATION EQUIPMENT

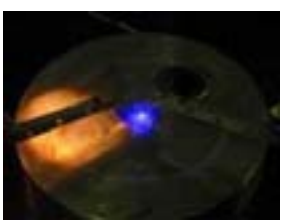
For characterization of the structures following methods are used

- **Photoluminescence** (in the temperature range of 80-300 K)
- **Photoluminescence excitation and absorption**
- **Photoluminescence mapping**



- **Electroluminescence**

Photocurrent



- **Hall measurements**
- **Optical microscopy with differential contrast.**
- **Micro photoluminescence in the temperature range of 80-300 K, spatial resolution of 1 µm**




In cooperation with another Ioffe Labs access to the advanced characterization methods is available

- scanning electron microscopy
- transmission electron microscopy
- X-ray diffractometry
- AFM
- SIMS

PROCESSING

Facilities for the rapid processing of the III-N structures are in the stage of development.

- **Etching system**. In 2004 new ICP system for etching will be start up.



- **Contact evaporation system** under modernization.
- **System of thinning** of samples the stage of construction.
- Laboratory **cutting system** the stage of development.
- Lithography facilities available in the cooperation with other Labs.

  Processing of device structures is carried out with cooperation of Laboratory of Semiconductor Quantum Electronics

Selected papers

- I.L. Krestnikov, et al, Phys. Rev. B 66, 155310 (2002)
- Yu. G. Musikhin, et al, Appl. Phys. Lett. 80, 2099-2101 (2002).
- W.V. Lundin, et al, 4th International Conference on Nitride Semiconductors Denver, USA 2001
- A.F. Tsatsul'nikov et al, International Conference on the Physics of Semiconductors, Osaka, Japan, September 17-22, 2000.
- N.N.Ledentsov et al, Compound Semiconductor 5(9) 61-64 (1999)
- I.L. Krestnikov et al, Appl. Phys. Lett. 75 (9), 1192-1194 (1999)
- A.V. Sakharov et al, Appl. Phys. Lett. 74 (26), 3921-3923 (1999)
- A.V.Sakharov et al, MRS Internet J. Nitride Semicond. Res.V. 3, 28 (1998))
- W.V.Lundin et al, Proc. of 23 International Symposium on Compound Semiconductors 23-27 September 1996, St.- Petersburg, Russia pp. 319-322