MBE Growth of III-V Materials and its Applications to 2D/1D/0D Nanostructured Devices

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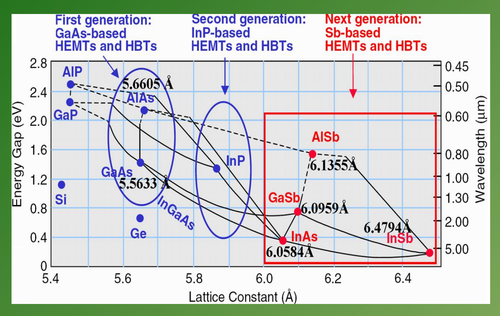
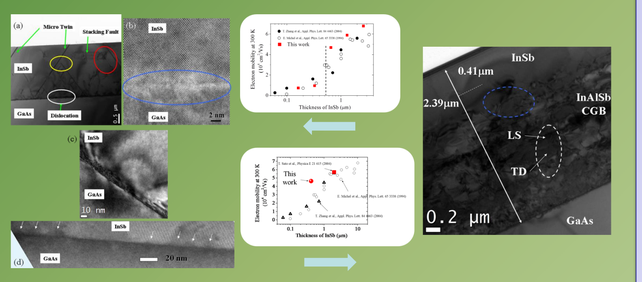
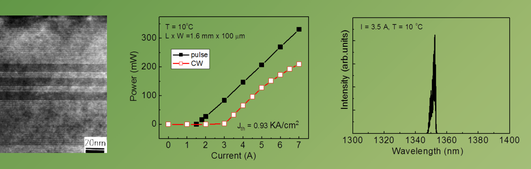
3 Dimensional structures (artificial bulk, new materials)

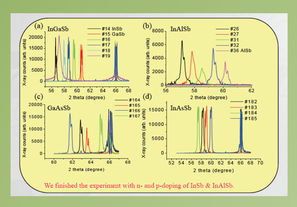




In these MBE systems, all generation of 3-5 materials are grown. ▲

High quality InSb (~ 70,000 cm²/Vs @ 300K, 2.6um) were grown on GaAs or Si wafers using InAs interlayers. High-quality thin InSb (0.4 um) were obtained by grading InAlSb buffers. ▲

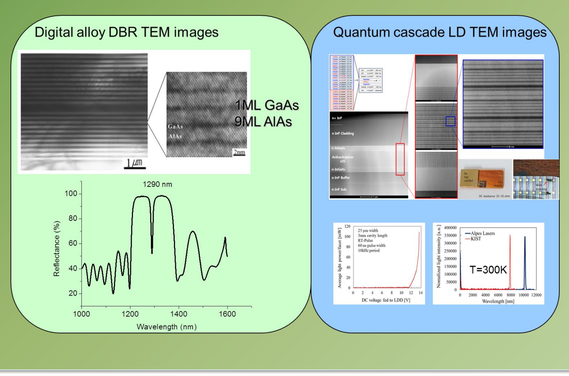


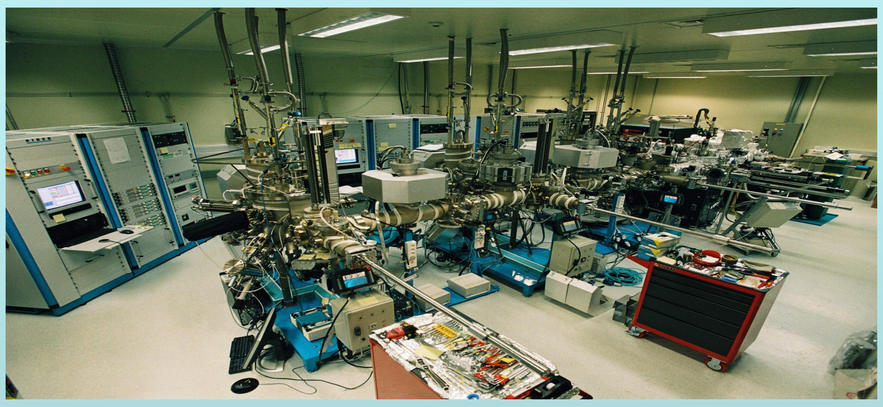


All kind of Sb-As based ternary compound were grown. Sb-P based materials are under research. ◄

Digital alloy InGaAlAs were grown by repetition of short period superlattices of few monolayer thick-InGaAs and InAlAs.▲

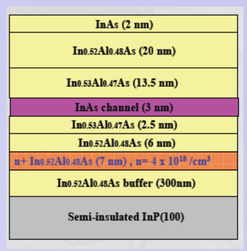
This artificial bulk materials can be used for 1.3um QWs, uniform DBR, QCL lasers. ▼





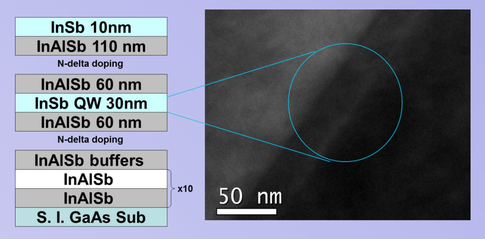
- **Riber compact 21 cluster MBE systems: 3MBEs+1E-beam evaporator + 1 Sputter [In/Ga/Al + As/P/Sb + Be/Si/GaTe]**
- **VG 80 cluster MBE systems: 2 MBEs [In/Ga/Al + As/P + Be/Si]**
- **VEECO 930 MBE [In/Ga/Al + As/P + Be/Si/C]**
- **Home-made MBE (under construction) [In/Ga/Al + N + Be/Mg]**

2 Dimensional structures (type-1,-2 QWs)



InAs/InGaAs/InAlAs HEMT structure achieved the mobility of 14,000 cm²/Vs at 300 K and ~140,000 cm²/Vs at 77K. ◄

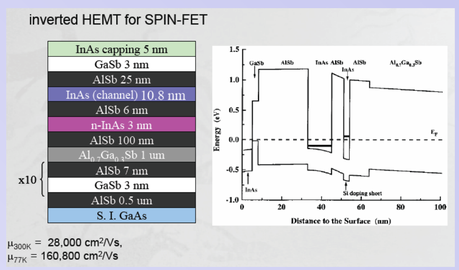
This structure was used for the implementation of Spin-FET.

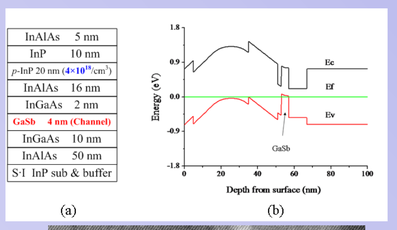


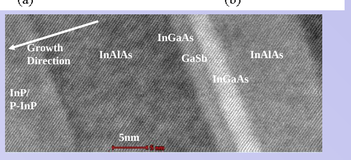
Formation of InSb well is confirmed. More in-depth study is necessary for real application. ◄

(electron mobility @ RT ~ 20,000 cm²/Vs, Ns ~ 1.5E12/cm²)

Cf) Target is > 40,000 cm²/Vs @ RT







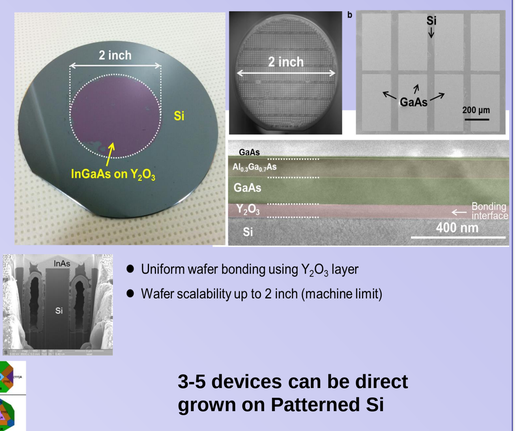
Sb-based type-2 QW shows large mobility of 2DEG/ 2DHG which are critical for low power consumption devices. ◄

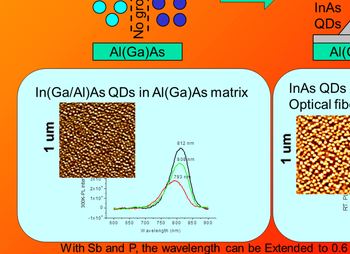
1/1000 of power consumption is expected with implementation of 3-5 CMOS with this structure.

Speed of Charges In Different Materials (cm²/V-s)							
Charges	Si	GaAs	$In_{0.53}Ga_{0.47}As$	InAs	InSb	Ge	GaSb
Electrons*	300	7000	10,000	15,000	30,000	3,900	5,000
Holes*	450	400	200	460	1250	1,900	1,500

*Electron carrier mobilities measured in transistor channels with electron concentration of 1x10¹⁷ cm⁻³. Hole mobilities in bulk.

3-5 devices can be transferred to Si wafer



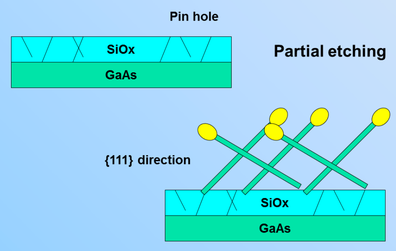


- **Uniform wafer bonding using Y_2O_3 layer**
- **Wafer scalability up to 2 inch (machine limit)**

3-5 devices can be direct grown on Patterned Si

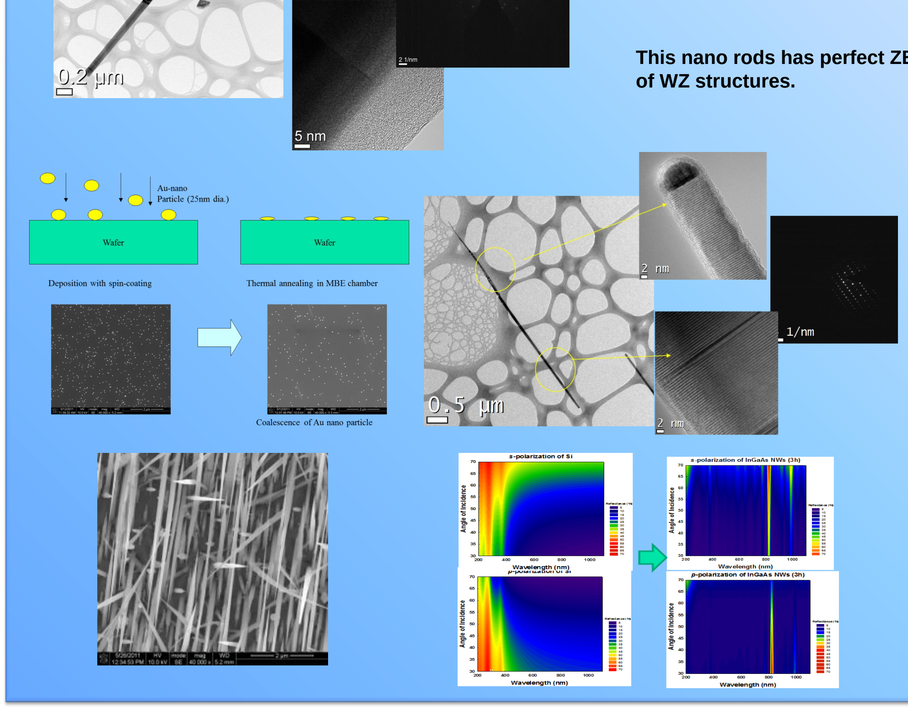
1 Dimensional structures

35nm-thick SiOx deposition



GaAs nano rods grown by Ga-droplets (Catalyst-free Nano wires) were successfully achieved on (100) GaAs.◄

This nano rods has perfect ZB structures without contamination of WZ structures.



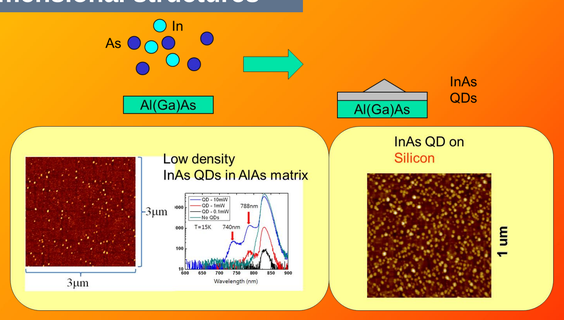
Gold nano-particles were used as a catalyst for 3-5 nano rods. Nano rods were grown on (111) Si substrates with gold nano-particles. ◄

The GaAs Nano rods shows perfect WZ without contamination of ZB structures.

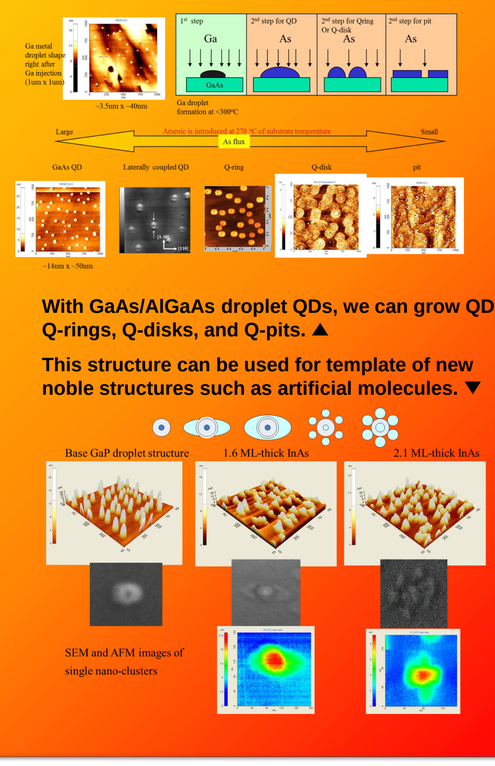
The nano-rods can be used for perfect anti-reflects.

Various nano rods such as In(AsPSb) and Ga(AsPSb) nano rods are prepared or under research for single photon source or 1D electronic devices.

0 Dimensional structures



Conventional SK-mode grown In(Ga)As QDs are grown on GaAs, Si. These were used for solar cell, QDIP (IR sensor) etc. ▲

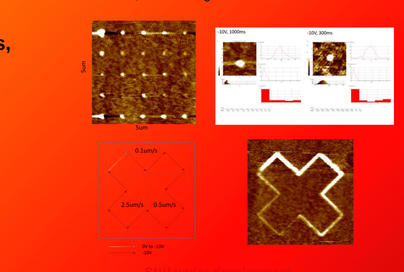


With GaAs/AlGaAs droplet QDs, we can grow QDs, Q-rings, Q-disks, and Q-pits. ▲

This structure can be used for template of new noble structures such as artificial molecules. ▼

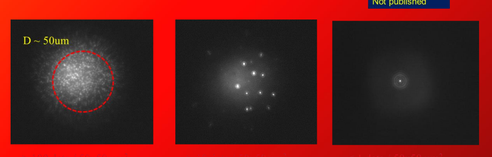
MEE-mode grown InAs, InGaAs QDs were used for 1.3um-LD, PD etc. ◄

InGaAlAs QDs were used for short-wavelength LD.



QD can be

Position controlled



Very low density (few QDs/um²) InAs QDs were grown for quantum physics studies. ◄

Conclusion

•Constraint of carriers by heterostructure affects the physical characteristics of devices.
•With it, researchers have put quantum physics in practice to enhance and modify the properties of devices. Constraint of carriers can be classified by degree of restriction of dimensions. As a result, carriers can move freely in 2 (1 and 0) dimensional space with 1 (2, and 3) dimensional constraint(s), respectively.
•Naturally, not only introduction of new structures but also new materials, such as Sb-based 3-5 materials, can be resource of new idea.
•In this presentation, the authors will show various MBE-grown 2D, 1D and 0D-structures. Low density large droplet quantum dots (QDs), long wavelength type-2 InSb QDs on InAs substrate, and short wavelength InP/InGaAs QDs (Dashes) will be discussed for 0 D-structures, and (In)GaAs nano-wires on (111) Si will be shown for 1D-structure. Finally, electrical properties type-2 quantum wells for p-type will be presented for 2D-structures.

•We are happy to work with co-workers in the world