Low Thermal Budget Fabrication of III-V Quantum Nanostructures on Si Substrates

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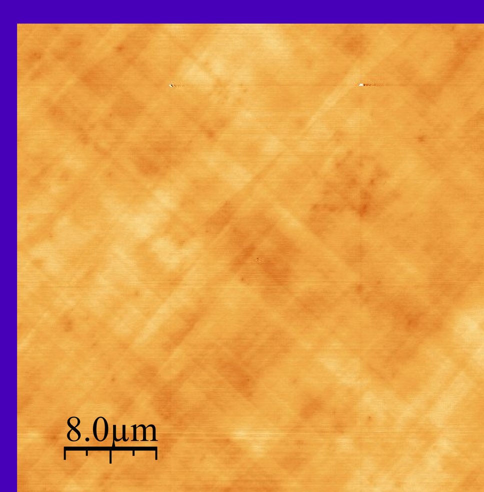
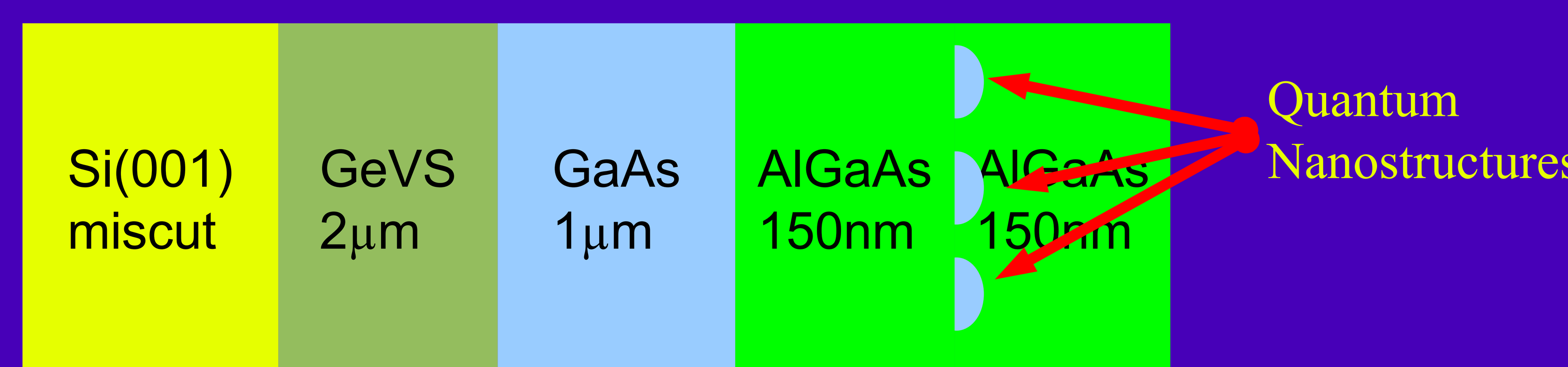
Introduction

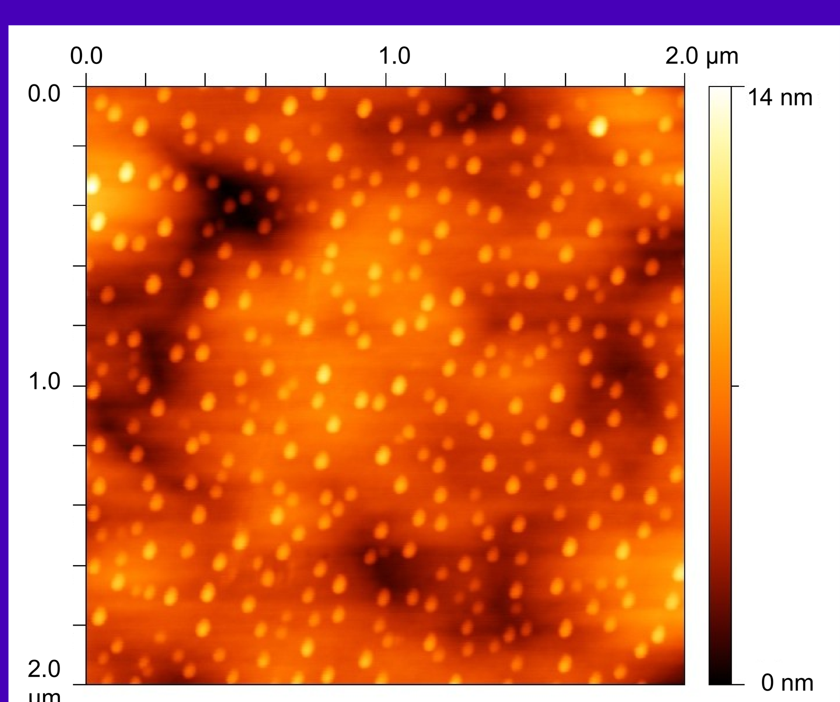
We present a low thermal budget procedure for the integration of high quality AlGaAs/GaAs quantum nanostructures on Si Substrate.

To accomodate large lattice mismatch between GaAs and Si, a 2 µm fully relaxed Ge layer was deposited on silicon (001) substrate, 6° misoriented towards [110] by Low-Energy Plasma-Enhanced Chemical Vapour Deposition (LEPECVD) [1] in order to form a Ge virtual substrate (GeVS). Threading dislocation density is reduced to $2x10^7$ cm^{-2} by *in situ* thermal annealing cycles between 600 and 780°C

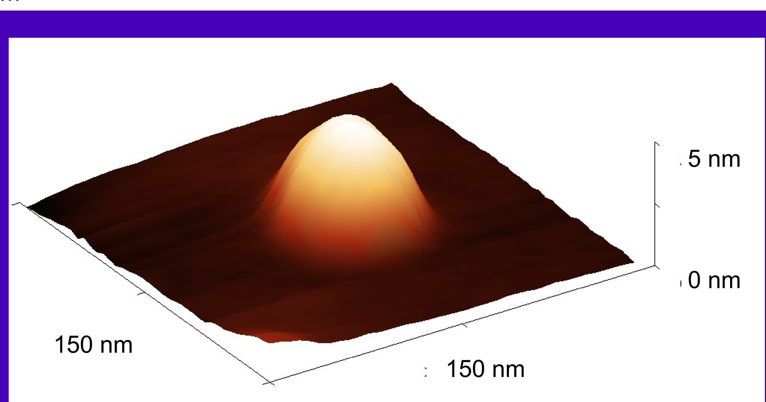


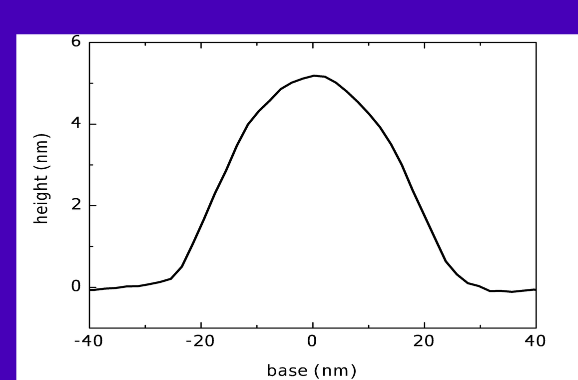
For the nanostructure growth we selected an intrinsecally low thermal budget technique, the droplet epitaxy [2]. Being performed at 200-350° C, droplet epitaxy is perfectly suited for the realization of growth procedures compatible with back-end integration of III-V nanostructures on CMOS.



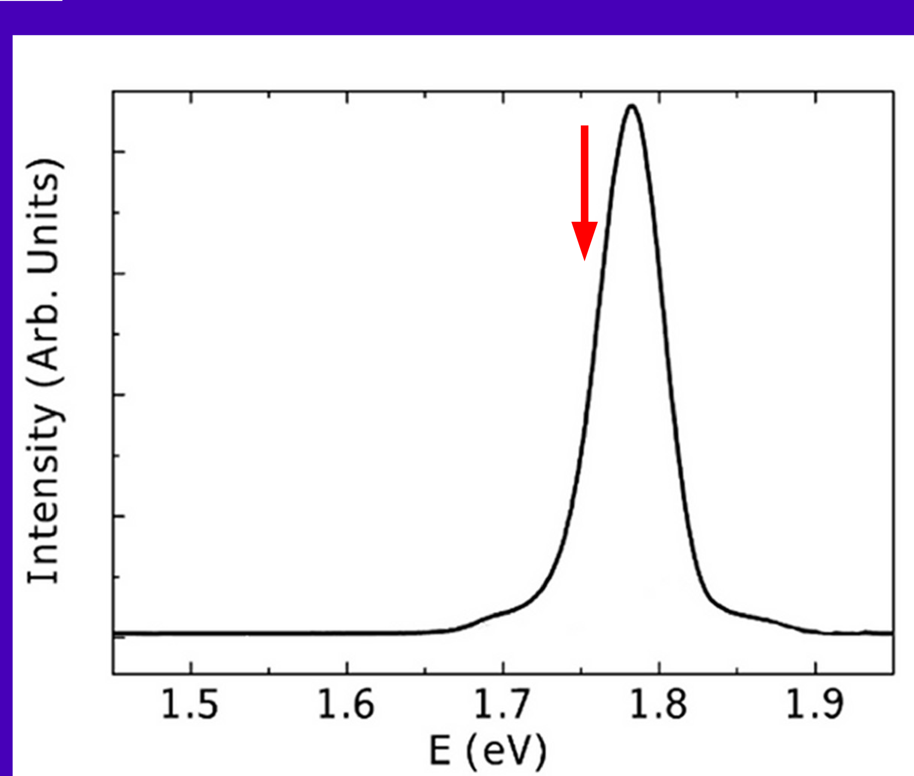


We demonstrated the possibility to obtain self-aggregation of quantum nanostructures by droplet epitaxy on a GaAs/Ge/Si substrate, using standard high temperature deposition for GaAs and AlGaAs buffer layer and post growth annealing [3]. Atomic Force Microscope image confirms the formation of quantum dots on the surface with density of about $1x10^{10}$ cm^{-2} .

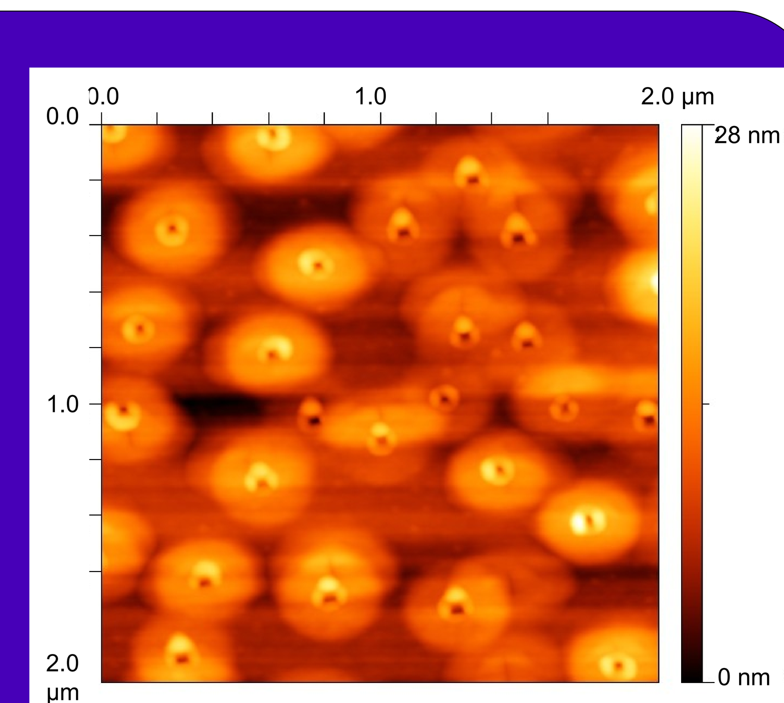


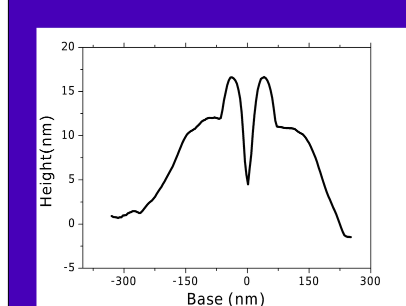


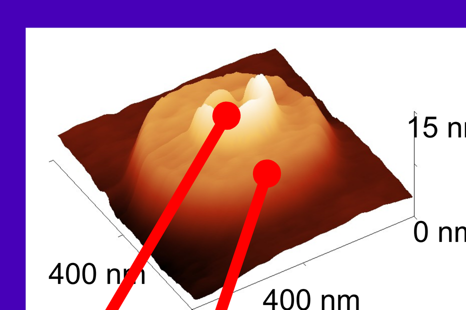
Photoluminescence spectrum at 14 K of the quantum dot capped sample shows an intense emission peak at 1.78 eV, in good agreement with the calculated value of E_{gs} =1.75 eV.



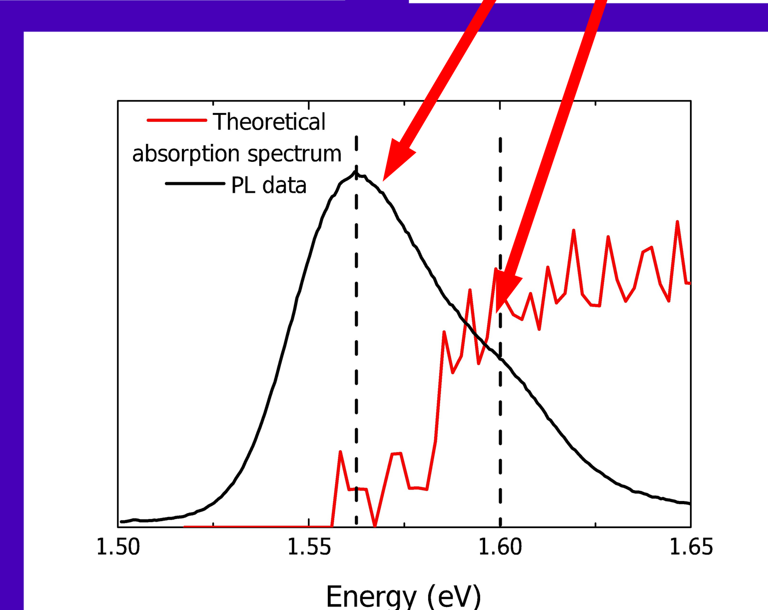
We fabricated quantum nanostructure active layer for infrared detector at 350°C [4]. This temperature is fully compliant with low thermal budget requirements of back-end CMOS technology. AFM image shows the formation of quantum nanostructures we called Coupled Ring-Disks [5] with a density of $6x10^8$ cm^{-2}.



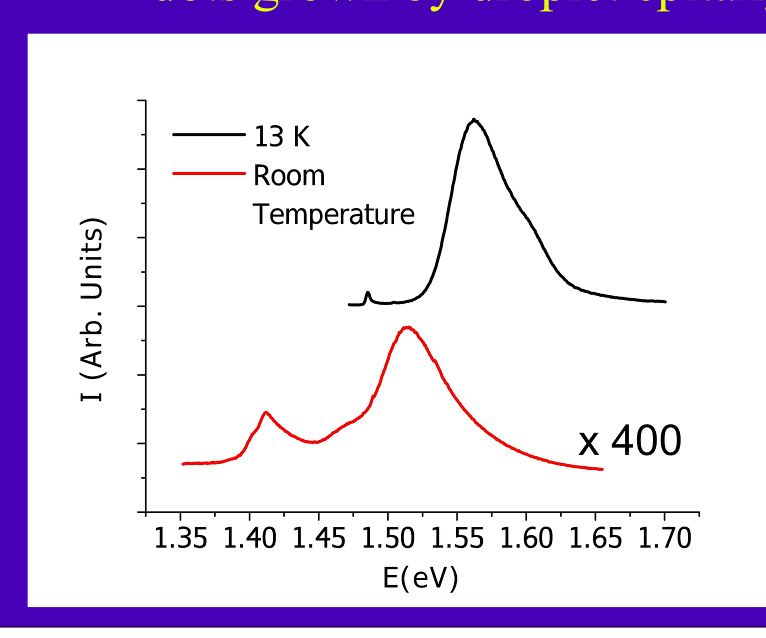




Photoluminescence measurement on coupled ring-disk sample shows an intense emission peak at 1.53 eV, in good agreement with theoretical emission energy of E_{gs} =1.56 eV. Electron and hole are confined in the inner ring, and the excited state is extended along the external disk. The value of quantum efficiency, $\eta\sim3x10^{-3}$, well compares with $\eta\sim1x10^{-2}$ calculated for standard quantum dots grown by droplet epitaxy.



The photoluminescence emission is clearly detectable at room temperature, where photoluminescence intensity is reduced by a factor ~400 respect to the low temperature case.



Thermal Budget and CMOS technology compatibility	Germanium virtual substrate	AlGaAs buffer	Quantum Nanostructures	Annealing
	Deposited at 500°C annealing 600-780°C	MEE at 350°C	Droplet Epitaxy between 200-350°C	Rapid Thermal Annealing 600°C 4 min
	CMOS front-end	CMOS back-end	CMOS back-end	CMOS back-end

Conclusions

We demonstrated the possibility to grow high quality and high efficiency III-V quantum nanostructures on Silicon substrate, using a low thermal budget procedure. In particular, the fabrication procedure for the germanium virtual substrate we propose is compliant with front-end CMOS integration, while the growth procedure for the AlGaAs/GaAs active region is fully compliant with CMOS back-end integration.

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[2] N. Koguchi, S. Takahashi, and T. Chikyow. *J. Cryst. Growth* 111 (1991), 688
[3] S.Bietti, C.Somaschini, S Sanguinetti et al *IOP Conf. Ser.: Mater. Sci.Eng.* 6 (2009) 012009
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