Realization of InAs nanostructures grown on InP substrates with different matrix

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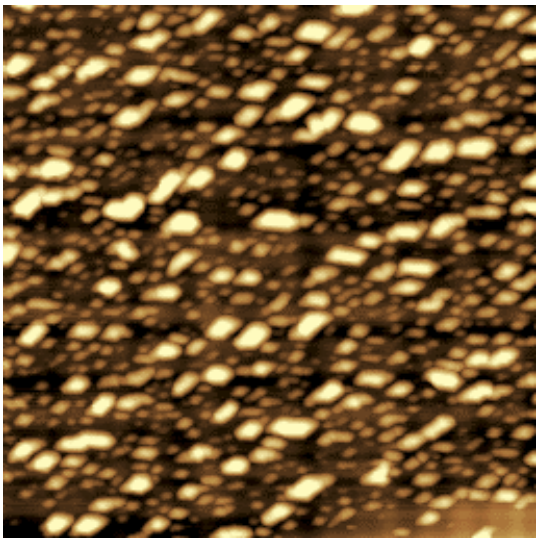
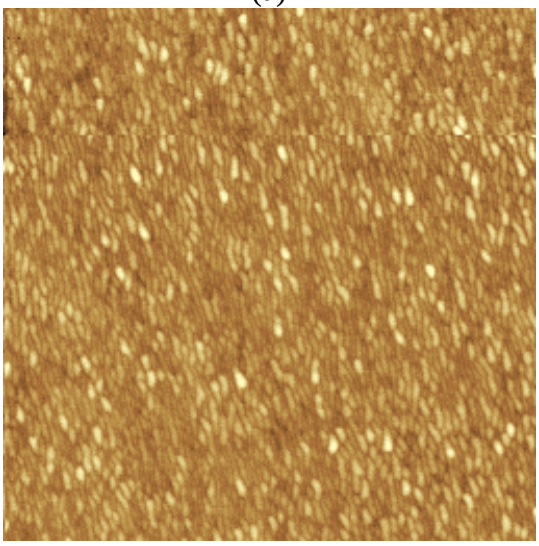
InAs anostructures such as quantum dots (QDs) and quantum wires (QWr) grown on InP(100) are promising candidates for light emitting device in the wavelength range of 1.3~1.55 μm which used in some practically important area, e. g., optical fibre communications and atmosphere pollution control systems. However, due to the low strain systems (lattice mismatch ~3.2%), the self-organisation process was thought to be less effective than for InAs/GaAs. Moreover, the process of QDs formation embedding on InP matrix is rather complicated and differs essentially from the general tendencies characteristic for the InAs/GaAs system due to As/P exchange reaction. The alternative approach is based on using the InAlAs/InGaAs heterostructure system lattice matched to the InP substrate as a matrix for InAs QDs. This gives additional flexibility in designing heterostructures by using various combinations of quantum wells and superlattice with QDs, and have been reported could lead to different properties of nanostructures. In present work, using atomic force microscopy (AFM) measurement, we report the effect of matrix on the InAs nanostructures morphology grown by solid source molecular beam epitaxy (SSMBE).

The samples investigated were grown on (100) semi-insulating InP substrates by SSMBE. After thermal desorption of the native oxide on the InP(100) substrate, a 1000 Å InP buffer layer was grown. The growth temperature was fixed at 500ºC for InAs/InAlAs and InAs/InGaAs, and at 460ºC for InAs/InP to avoid any surface deterioration. All buffer layers of InAlAs, InGaAs, and InP were grown at a growth rate of 1μm/h with a V/III beam equivalent pressure ratio of 20. Then 20 Å InAs were grown at a reduced growth rate of 1 Å/s with respective buffer layer growth temperature. After growth of InAs layer, the temperature of substrates was increased rapidly to 520 ºC, and was held for a time of 60 s for annealing process. Then the samples were quickly cooled down to room temperature with arsenic pressure. AFM measurements were carried out to realize the surface morphology in air with Si tip in a contact mode.

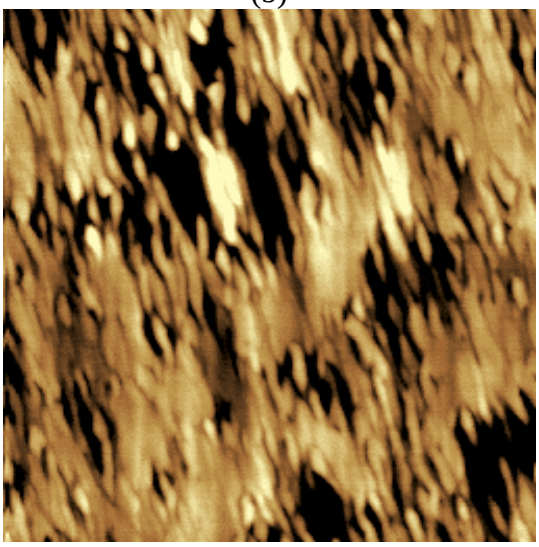
AFM images of typical InAs/InAlAs, InAs/InGaAs, and InAs/InP clearly show the differences of InAs nanostructures properties, such as shape, size, and lateral distribution. (i) For InAs/InAlAs, wire-like nanostructures (QWr) along [1-10] direction formed aggregates, with a linear density of ~18 wires/μm. Most are straight over several thousands Å length. The base width and height of nanowires are ~70 nm, and ~12.5 nm, respectively. (ii) For InAs/InGaAs, 3D nanostructures appear as closely joined wires of around ~100 nm long, ~33 nm base wide and ~20 Å high elongated in the [1-10] direction, with a linear density of ~42 wires/μm. And (iii) For InAs/InP, QDs structures appear with two different size distributions. The large QDs exhibits round shape with average diameter of ~80 nm, height of ~12 nm, and lower areal density of 6.3×10^{9} cm^{-2}. The small QDs perform average diameter of ~50 nm and height of ~3.5 nm with higher areal density of 1.84×10^{10} cm^{-2}, and the InAs QDs appears a little longer in the [1-10] direction. The drastic difference observed of wire-like nanostructure and elongated QDs structure formations are believed to be related the surface anisotropy, chemical reaction, and matrix surface morphology.



(a)



(b)



(c)

2×2 μm AFM images of InAs nanostructures grown on InP substrate with matrix of (a) InP, (b) InGaAs, and (c) InAlAs