Local droplet etching holes in vicinal InGaAs/GaAs(111)A

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We extended the standard Local Droplet Etching (LDE) procedure [1] on flat InGaAs Metamorphic Buffer Layers (MMBLs) grown on GaAs(111)A vicinal surfaces [2,3] in order to shift an emission from InAs QDs to the C-Band wavelength region [4]. In addition, the use of (111)-oriented crystallographic growth direction opens a path to use the symmetry of the surface to fabricate highly symmetrical nanostructures to erase the detrimental fine structure splitting of the excitonic emission [5].
Highly symmetrical holes were obtained. The formation of holes was systematically studied as a function of the growth parameters: temperature, deposition rate, and the amount of material deposited. The temperature window when the etching effectively occurs is about 450 – 560°C. A lower temperature limit is caused by the temperature-activated nature of the process and the etching rate tends to be zero. At temperatures above 560°C, indium adatoms start to strongly desorb from the InGaAs MMBL making the surface rough which limits the etching process. Well-defined holes with the shape of a triangular-based pyramid are obtained at 520 – 540°C with an aspect ratio (depth/lateral size of the hole) of 0.1 – 0.2 (see Fig. 1).
The change in Ga flux during the LDE process doesn't affect the sizes of self-assembled holes but can slightly change their density. The density increased by about 2 times increasing Ga flux from 0.3 to 1 ML/s. An increase in the Ga amount leads to an increase in hole sizes and decreases their density due to coarsening effect since the time of the LDE process is increased. The full process is well described by the theoretical model taking into account the different processes active during the hole etching [6]. The LDE process reveals high reproducibility of self-assembled nanoholes. The formation of inverted QDs is shown by the partial filling of self-assembled holes after the deposition of InAs and their sizes can be controlled with high precision.

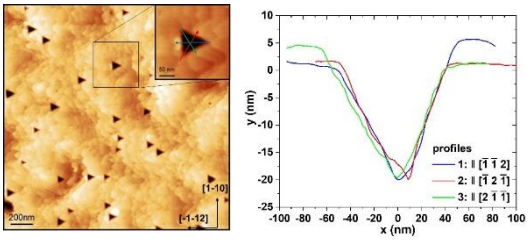

Fig. 1. AFM topography image (2×2 μm^2) of a sample with LDE holes in vicinal InGaAs(111)A. The inset shows a magnified AFM image of a single hole. AFM profiles of the hole in the inset taken along <11-2> directions.

[1] Heyn Ch et al. Highly uniform and strain-free GaAs quantum dots fabricated by filling of self-assembled nanoholes. Appl. Phys. Lett. 2009;94:183113.
[2] Tuktamyshev A et al. Telecom-wavelength InAs QDs with low fine structure splitting grown by droplet epitaxy on GaAs(111)A vicinal substrates. Appl. Phys. Lett. 2021;118:133102.
[3] Tuktamyshev A et al. Flat metamorphic InAlAs buffer layer on GaAs(111)A misoriented substrates by growth kinetics control. J. Cryst. Growth 2022;600:126906.
[4] Paul M et al. Single-photon emission at 1.55 μm from MOVPE-grown InAs quantum dots on InGaAs/GaAs metamorphic buffers. Appl. Phys. Lett. 2017;111:033102.
[5] Basso Basset F et al. High-yield fabrication of entangled photon emitters for hybrid quantum networking using high-temperature droplet epitaxy. Nano Lett. 2018;18:505.
[6] Heyn Ch et al. Dynamics of the mass transport during nanohole drilling by local droplet etching. Nanoscale Res. Lett. 2015;10:67.