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GaSb quantum dot morphology for different growth temperatures and the dissolution effect of the GaAs capping layer

M Ahmad Kamarudin[1], M Hayne[1], Q D Zhuang[1], O Kolosov[1], T Nuytten[2], V V Moshchalkov[2] and F Dinelli[3]

[1] Department of Physics, Lancaster University, Lancaster LA1 4YB, UK
[2] INPAC-Institute for Nanoscale Physics and Chemistry, Pulsed Fields Group, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
[3] CNR-Istituto per lo Studio dei Materiali Nanostrutturati, Via P. Gobetti 101, I-40129 Bologna, Italy

E-mail: m.ahmadkamarudin@lancaster.ac.uk

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Abstract

We compare the characteristics of GaSb quantum dots (QDs) grown by molecular beam epitaxy on GaAs at temperatures from 400 to 490 °C. The dot morphology, in terms of size, shape and density, as determined by atomic force microscopy (AFM) on uncapped QDs, was found to be highly sensitive to the growth temperature. Photoluminescence (PL) spectra of capped QDs are also strongly dependent on growth temperature, but for samples with the highest dot density, where the QD luminescence would be expected to be the most intense, it is absent. We attribute this to dissolution of the dots by the capping layer. This explanation is confirmed by AFM of a sample that is thinly capped at 490 °C. Deposition of the capping layer at low temperature resolves this problem, resulting in strong QD PL from a sample with a high dot density.

1. Introduction

Self-assembled quantum dots (QDs) [1] are an area of intense interest due to their unusual electrical and optical properties, especially their potential for applications [2]. The vast majority of this research has concentrated on type-I QDs such as InAs/GaAs, but there is increasing interest in type-II dots. In particular, GaSb/GaAs QDs [3–6], which can confine the holes but not the electrons [7], display novel physical phenomena [8, 9] and are of interest for applications in memory devices [10, 11], lasers [12, 13] and solar cells [14]. For all these applications performance is highly dependent on QD density, size, uniformity and composition, so these should be studied as a prerequisite for the realization of any device. In turn, several factors affect QD characteristics such as deposition time of GaSb [15], III–V beam flux ratio [16], growth rate and growth temperature [17]. For example, the capability of QDs to trap carriers is determined by the thermal activation barrier or localization potential which determines the storage time of a QD memory. Very recent research has shown that GaSb/(Al)GaAs is a very promising material combination for such applications. Localization energies were calculated using eight-band k.p theory, leading to the prediction of an extraordinary 10^6 years hole storage time for GaSb/AlAs dots [11]. However, it was also shown that the storage time is highly sensitive to the compositional purity of the dots. $GaAs_{0.4}Sb_{0.6}$/GaAs QDs have a storage time of ∼0.5 μs [11], whereas pure GaSb/GaAs dots have an estimated storage time of 13 min [11], which is approximately 1 billion times greater. The dilution of the QD Sb content is very likely to occur in the capping process immediately after the QD formation. Hence, the capping layer material or growth procedure plays a crucial role in determining the quality of the device. Although we have not probed the purity of the dots, we do demonstrate that the capping layer growth temperature has a remarkably strong influence on QD properties.

