# Strain-Tunable Quantum Dot Devices

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***Abstract* – We introduce a new class of quantum dot-based devices, in which the semiconductor structures are integrated on top of piezoelectric actuators. This combination allows on one hand to study in detail the effects produced by variable strains (up to about 0.2%) on the excitonic emission of single quantum dots and on the other to manipulate their electronic- and optical properties to achieve specific requirements. In fact, by combining strain with electric fields we are able to obtain (i) independent control of emission energy and charge-state of a QD, (ii) wavelength-tunable single-QD light-emitting diodes and (iii) frequency-stabilized sources of single photons at predefined wavelengths. Possible future extensions and applications of this technology will be discussed.**

***Index Terms* – Epitaxial Quantum Dots, Single photon sources, Strained semiconductors, Tunable sources of single photons.**

## I. INTRODUCTION

Optically active semiconductor quantum dots (QDs) can be made as nanoinclusions of a low energy bandgap material in a matrix with larger energy bandgap. One of the simplest ways to obtain QDs with excellent structural, electronic, and optical properties is represented by self-assembly of 3D nanoislands during lattice-mismatched heteroepitaxial growth. In this, so-called Stranski-Krastanow (SK) growth mode, elastic stress is one of the main driving forces leading to the formation and evolution of QDs. The most prominent example is represented by InGaAs QDs in GaAs matrix. A large number of experiments have demonstrated that these QDs are excellent quantum emitters which can be used as sources of triggered single photons, indistinguishable photons and polarization entangled photon pairs. On the other hand virtually strain-free GaAs/AlGaAs QDs can be made by using templates of self-assembled nanoholes on an AlGaAs surface.

Whatever approach is used, QDs are affected by dot-to-dot fluctuations. This makes it difficult to obtain QDs with electronic and optical properties which meet (sometimes very stringent) requirements for their use in advanced quantum optics experiments, especially involving independent sources. Post-growth techniques are therefore required to fine-tune the optical properties of QDs. Vertical electric fields (applied along the growth direction) represent the most powerful “tuning knob” to date. By using the so called “giant Stark effect” (GSE) both the emission energy and the excitonic fine-structure splitting can be widely tuned [1, 2]. The latter is important for generation of entangled photon pairs. Electric fields can also be used to electrically pump single QDs. This feature, which takes profit of mature semiconductor technology, is one of the major advantages of epitaxial QDs compared to other solid state emitters. On the other hand the structure designs for electrical pumping and for exploiting the GSE are not compatible, making additional “tuning knobs” indispensible.

## II. RESULTS

In this contribution we introduce a new class of QD-based devices, in which the semiconductor structures are integrated on top of piezoelectric actuators. This combination allows us on one hand to study in detail the effects produced by variable strains (up to about 0.2%) on the excitonic emission of single QDs and on the other to add a powerful “tuning knob” to QDs.

We first discuss the effects of biaxial strain on the emission of single QDs embedded in optical microcavities [3]. Afterwards we show that strain does not only affect the emission energy of QDs but also the relative binding energies of excitonic species confined in QDs [4] and the fine structure splitting of neutral excitons[5].

We then discuss a technological approach to combine strain with electric fields on the same device.

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