Giant bandgap tuning of InN nanowires by *post-growth* Hydrogen irradiation for creation of tunable quantum dots

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Nanowires (NWs) are filamentary crystals whose diameter range from a few nm to a few hundreds of nm. III-V semiconductor NWs offer a great deal of flexibility in the engineering of their electronic properties and more importantly they can host quantum-confined structures like quantum dots (QDs), that can be building blocks of photonic and optoelectronic devices. By alternating regions with various bandgaps, which is normally accomplished by varying the NW composition or its crystal phase, these quantum structures are frequently generated in NWs throughout the growth process. However, this conventional approach can result in a limited capability in controlling the dots' size and emission energy. Therefore, we are working on a new, *post-growth* approach for forming QDs whose size and energy can be controlled. Remarkably, our approach is focused on InN NWs monolithically grown on technologically relevant Si substrates.

In InN, hydrogen incorporated post-growth is expected to increase the bandgap energy [1], thus potentially allowing to modulate the NW bandgap within a same NW when incorporation is controlled at the nano-scale, and lead to the formation of QDs. To achieve this goal, we have optimized low-energy hydrogen irradiation of InN NWs grown on Si that leads to *on demand* bandgap engineering. By µ-photoluminescence spectroscopy on single NWs we demonstrated a giant bandgap tuning of the NWs: pristine NWs have a bandgap of 0.65 eV [2] while hydrogenated NWs can reach 1.45 eV, with a shift of almost 1 eV, thus a giant and unprecedented bandgap tuning. We are currently working on placing a hydrogen opaque mask on top of the NW so that the area below the mask will retain a low bandgap while the rest of the NW will increase its bandgap due to hydrogen. With this method, our aim is to produce site-controlled QDs on Si whose energy is tunable across a wide range (1100-1500 nm, thus including telecom wavelengths) by tuning the mask size. We also investigated possible strain effects and defects-induced effects on hydrogenated InN NWs by spatially resolved µ-Raman.

Hydrogen incorporated in the NWs can be partially removed through thermal annealing so we used this technique to further fine-tune the bandgap of hydrogenated InN NWs and to reverse the emission energy of hydrogenated to pristine NWs. We have studied the effects of different annealing temperatures and time and achieved the desired bandgap fine-tunability.

Besides for the quantum optics applications, we stress that the giant bandgap tunability of InN NWs across the solar spectrum is ideal for optoelectronics, sensing and photo-voltaic applications.

[1] G. Pettinari, F. Filippone, A. Polimeni, G. Mattioli, A. Patané, V. Lebedev, M. Capizzi and A. Amore Bonapasta, Adv. Funct. Mater. **2015**, 25, 5353–5359
[2] S. Zhao, H.P.T. Nguyen, Md.G. Kibria, and Z. Mi, Progress in Quant. Elect., **2015,** 44, 14-68