Workshop on MBE for Emerging Emitter Technologies
Room Tamaya ABC - Session WME2-SuM

Quantum-Dot based Single Photon Emitters II

Moderator: Richard Mirin, National Institute of Standards and Technology

10:15am **WME2-SuM-10 Quantum Dots Obtained by Droplet Etching Epitaxy for Quantum Science and Technology***, **Armando Rastelli,*** Institute of Semiconductor and Solid State Physics, Johannes Kepler University (JKU) Linz, Austria **INVITED**

Entanglement is one of the most peculiar phenomena in quantum science and a key resource for quantum technologies. More than two decades after the initial proposal [1], semiconductor quantum dots (QDs) are now beginning to outperform other light sources for the generation of entangled photon pairs.

Among different material systems, QDs in the (Al)GaAs material platform have demonstrated the highest degree of polarization entanglement to date together with other appealing features for quantum science and technology [2–4]. These QDs are obtained by GaAs overgrowth of an AlGaAs surface with nanoholes and are characterized by small inhomogeneous broadening, high oscillator strengths, shape with high in-plane symmetry, and high optical quality, especially when embedded in charge-tunable diode structures. In this talk, we will discuss the properties of GaAs QDs obtained by the droplet etching method [5] and present recent results relevant to their application in quantum communication, such as entanglement-based quantum key distribution [6], as well as open challenges [7].

[1] O. Benson, C. Santori, M. Pelton and Y. Yamamoto, Phys. Rev. Lett. 84, 2513–2516 (2000).

[2] S. F. C. da Silva, G. Undeutsch, B. Lehner, S. Manna, T. M. Krieger, M. Reindl, C. Schimpf, R. Trotta and A. Rastelli, Appl. Phys. Lett. 119, 120502 (2021).

[3] L. Zhai, G. N. Nguyen, C. Spinnler, J. Ritzmann, M. C. Löbl, A. D. Wieck, A. Ludwig, A. Javadi and R. J. Warburton, Nat. Nanotechnol. 17, 829–833 (2022).

[4] L. Zaporski, N. Shofer, J. H. Bodey, S. Manna, G. Gillard, M. H. Appel, C. Schimpf, S. F. Covre da Silva, J. Jarman, G. Delamare, G. Park, U. Haeusler, E. A. Chekhovich, A. Rastelli, D. A. Gangloff, M. Atatüre and C. Le Gall, Nat. Nanotechnol. 18, 257–263 (2023).

[5] C. Heyn, A. Stemmann, T. Köppen, C. Strelow, T. Kipp, M. Grave, S. Mendach and W. Hansen, Appl. Phys. Lett. 94, 183113 (2009).

[6] C. Schimpf, M. Reindl, D. Huber, B. Lehner, S. F. Covre Da Silva, S. Manna, M. Vyvlecka, P. Walther and A. Rastelli, Sci. Adv. 7, eabe8905 (2021).

[7] B. U. Lehner, T. Seidelmann, G. Undeutsch, C. Schimpf, S. Manna, M. Gawełczyk, S. F. Covre da Silva, X. Yuan, S. Stroj, D. E. Reiter, V. M. Axt and A. Rastelli, Nano Lett. 23, 1409–1415 (2023).

10:45am **WME2-SuM-12 Toward a Scalable Single Photon Platform***, **Chen Shang,*** University of California Santa Barbara*; Sahil Patel, Zihang Wang, Sean Doan, Dirk Bouwmeester, Galan Moody, John Bowers,* University California Santa Barbara **INVITED**

The lack of scalable photon sources has been a major roadblock for quantum photonics to realize their full potential. Self-assembled InAs QDs currently hold the best all-around single photon emitter performance as a solid-state source, offering advantages of CMOS-compatible fabrication, highly tunable optical properties, and deterministic emission. The key challenge for deploying the InAs QD single photon source at large scale is the spatial and spectral randomness of each dot due to the self-assembling process on planar substrates. The prevalent method to combat this involves manipulating substrates to create preferential nucleation sites, either grooves or mesas. However, these “site-controlled” QDs typically exhibit inferior optical qualities and less repeatable charge tunability compared to their randomly situated counterparts on planar substrates. Such substrate alternations also limit the integrability with other devices. In this work, we utilize the intrinsic material properties, especially the coefficient of thermal expansion (CTE) mismatch between the GaAs substrate and the oxide layers and the asymmetric surface diffusion of indium adatoms, to develop site-controlled InAs QD single photon emitters nucleated on compartmentalized finite surfaces that will solve both issues simultaneously at wafer scale.

The growth template was fabricated first by oxide deposition on (001) GaAs. To ensure the “epi-ready” surface quality, the hexagonal pockets in two different orientations with respect to the III-V crystal were finished HF wet etching to remove the remaining post-dry etching oxide. The InAs QD material was then deposited in a Veeco Gen II molecular beam epitaxy chamber at elevated temperatures. Due to the CTE mismatch between the GaAs substate and the oxide layers, the substrate was under a global biaxial compression at the QD deposition temperature of 500 °C. The oxide patterns introduce local non-uniform profile with higher strain at the vertices of the hexagon and the strain level lowers toward the center of the pocket. The slow diffusion axis in the [1 1 0] orientation shows as “ridges” on the calculated potential energy profile. As the vertices are being filled, the energy penalty for adding more atoms increases and would generate new local and central potential energy minimums on either side of the slow diffusion axis. Thus, additional indium atoms are funneled toward the newly defined energy minimums. Hyperspectral images were taken under cryogenic temperatures of the as-grown InAs QDs embedded in GaAs.Emission from a single QD within one of the central minimums was observed in the pocket in the preferred orientation.

11:15am **WME2-SuM-14 Invited Paper***, **Matthew Doty,*** University of Delaware **INVITED**

11:45am **WME2-SuM-16 Panel Discussion***,*

12:15pm **WME2-SuM-18 Closing Remarks***,*

Author Index

Bold page numbers indicate presenter