Coupling nano-electronics and photonics through precise alignment with silicon color centers

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Realizing an efficient link between silicon spin qubits and telecommunication photons using silicon color centers (CCs) requires precise overlay between photoluminescence maps of the CCs and lithographic design patterns of quantum dot structures. Precise alignment of silicon CCs to quantum dots is critical for enabling classical and potentially quantum coupling between electronic and photonic systems.

Our alignment precision depends on accurately locating the position of silicon CCs relative to metallized fiducial marks, as we initially seek sub-100 nm alignment of post-fabricated electronic and photonic devices. Sub-50 nm alignment between CCs and electronic/photonic components is estimated to enable strong quantum coupling in these devices.

This talk will present progress on mapping single silicon color centers synthesized through implant masks on SOI (silicon-on-insulator) relative to a lithographically defined system of etched coordinate marks and CC implant masks. The vectors of individual color centers will then be used to place additional metal gates using electron beam lithography, e.g., CC-in-circle, and re-mapped to evaluate the precision of the alignment scheme.

Using photoluminescence (PL) mapping, we observe the concentration of CCs, shown in Figure 1, across the silicon wafer. The etched alignment marks used to navigate across the sample surface seen in Figure 2 are not seen in Figure 1, requiring the use of optical microscopy, which cannot identify the presence of CCs. The precise overlay of these two maps is required for the electrical wiring of the CC.

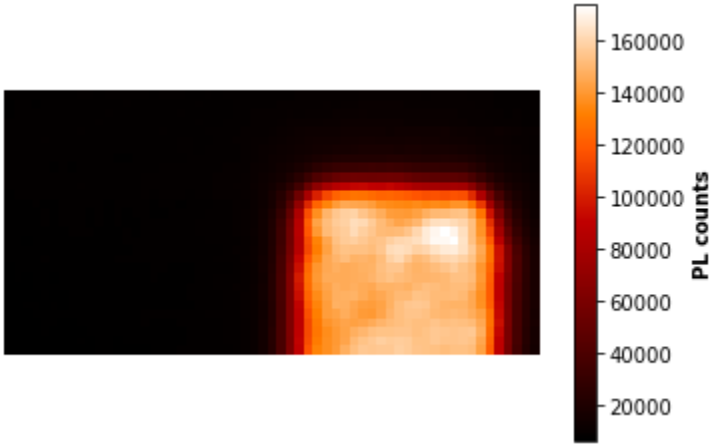

Figure 1: A photoluminescence map showing the active region where carbon was implanted through a photo-resist mask.

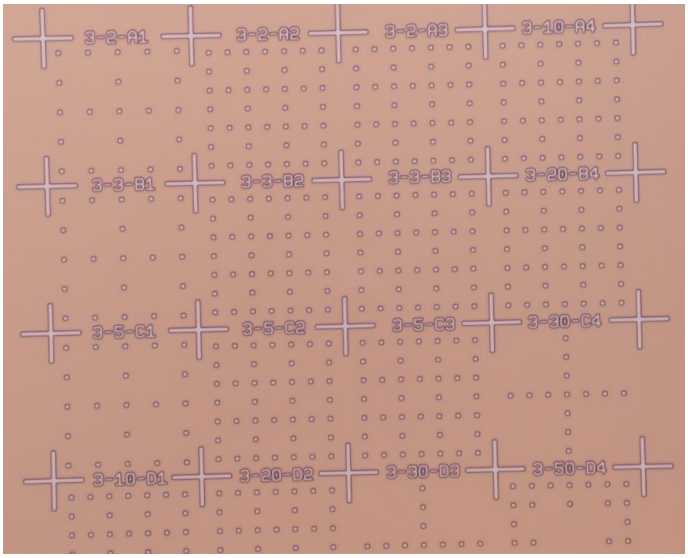

Figure 2: An optical microscopy image of a portion of the wafer showing etched regions of the surface. Dies with etch patterns provide a coarse alignment for finding color center positions with PL, which can then provide precise vectors by locating individual color centers relative to etched fiducials.