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SILICON CARBIDE ON INSULATOR (SiCOI) MATERIALS FOR MEMS AND QUANTUM APPLICATIONS USING WAFER BONDING METHODS

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Summary:

This paper reports two novel process flows to fabricate SiCOI (Silicon Carbide on Insulator) with very high purity for use in MEMS and quantum applications using anodic bonding. 100mm SiCOI wafers with different over layer thicknesses have been fabricated using semi insulating 4HSiC material from Cree. Samples with color centers (SiV) ensemble have been fabricated and verified using EPR (Electron Paramagnetic Resonance) and ODMR (Optically Detected Magnetic Resonance). EPR-results show the feasibility of this technology and the potential of this material for MEMS and quantum applications. The coherence time in RT is in hundred ms range similar to the one from NV diamond.

Keywords: SiC, SiCOI, Point defects, SiV in SiC, SiC MEMS, quantum sensor

Background

Single photon sources (SPSs) are essential for a wide range of quantum applications, including quantum communication, quantum cryptography, quantum computing, quantum sensing and quantum metrology. In these applications, single photons are used as fundamental building blocks to encode and transmit quantum information (figure 1). Differences in fundamental properties of single photons over attenuated coherent states will lead to quantum applications mostly based on their interference properties for single-photons. Scalability to more complex setups combining multiple indistinguishable photons generated by independent sources will be essential in future.

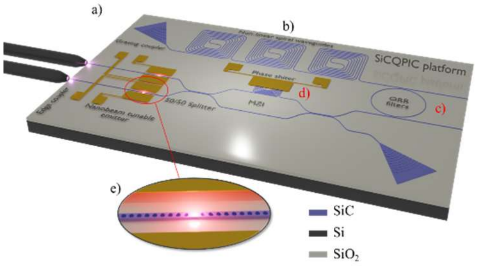

Fig. 1: Schematic of a PIC (Photonic Integrated Circuit) circuit and building blocks in SiCOI material.

SiC is a robust and versatile material that is widely used in the semiconductor industry. It has a wide bandgap and high thermal conductivity, making it suitable for high-temperature and high-power applications. SiC also has a high concentration of defects (figure 2, [2]), including silicon vacancy (VSi), divacancy (VSiVC) and many other defects in the O-band (NCVSi and Vanadium), which can act as single photon emitters.

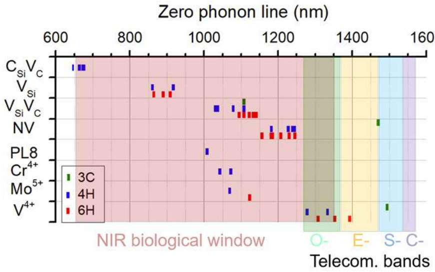

Fig. 2: Summary of the SiC colour centres versus zero-phonon line emission wavelength in different polytypes of SiC. Blue lines, green lines, and red lines represent the 4H, 3C and 6H SiC polytypes respectively. The NIR biological windows and the telecommunication band.

Color centers in SiC exhibit several desirable properties for single photon sources. One example is the VSi defect, which has a strong optical transition at around 917 nm. This transition can be frequency converted to the telecom wavelength range using nonlinear optical techniques, making VSi a promising candidate for on-chip single photon sources that can emit at telecom wavelengths. Additionally, VSi defects can operate at room temperature, which is crucial for practical quantum technologies. Furthermore, the VSi defects in SiC have a long coherence time, allowing them to maintain their quantum state over longer times being essential for matching requirements to future quantum memories. SiC is compatible with existing semiconductor fabrication technologies, which allows for the development of integrated photonic devices that are scalable and compatible with existing optical communication infrastructure. This enables the development of compact, scalable, and reliable quantum devices based on SiC.

Novel Process Flow to Manufacture SiCOI

We used anodic bonding and gluing to bond high purity 100mm 4H SiC wafers [1] onto silicon wafers as carrier. After bonding, the SiC has been thinned and polished to get the final thickness. Both methods have been successfully implemented to fabricate SiCOI substrates with very high purity, as the process temperatures are very low. The developed technology here is compatible to other material systems without any issues. For the anodic bonding material, we have used a bondable glass of about 3-5µm [3] deposited using plasma method on the SiC-surface. For gluing method, a very thin glue (mrl9020) of 200nm has been used. We used electron irradiation with a dose of ($1x10^{18}cm^{-2}$, 2 MeV) and annealed the samples at an appropriate temperature to get desired concentration of color centers. Figure 3 and 4 show the two process flows to fabricate SiCOI materials in thisproject.

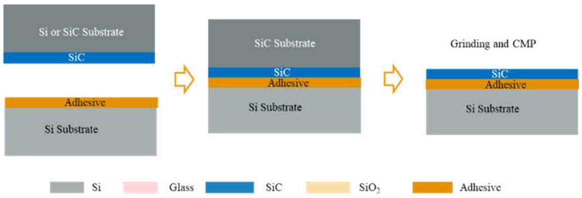

Fig. 3: Process flow for fabrication of SiCOI using gluing, grinding and polishing techniques.

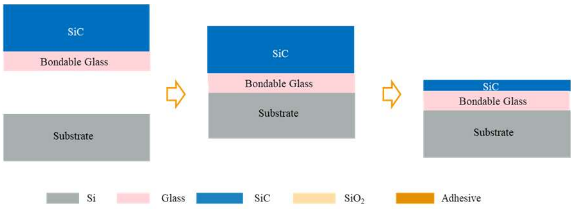

Fig. 4: Process flow for fabrication of SiCOI using anodic bonding, grinding and polishing techniques.

Results

The SiCOI (100mm, different over layers – figure 5) wafers have been fabricated and tested regarding mechanical stability using crack test, regarding surface quality and quantum performance using EPR. ODMR measurement is still ongoing. Crack test shows similar stability as bulk anodic bonding near 40MPa. EPR setup at RT with 9.8 GHz, power 0.1438 mW, modulation amplitude 0.12G, modulation frequency 100kHz and conversion time 20ms and 150 scans. The spins concentration of $1.8x10^{10}cm^{-3}$ has been confirmed and coherence time in ms range.

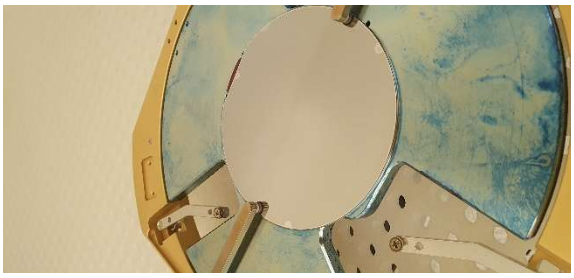

Fig. 5: 100mm SiC-Insulator-Silicon carrier after bonding.

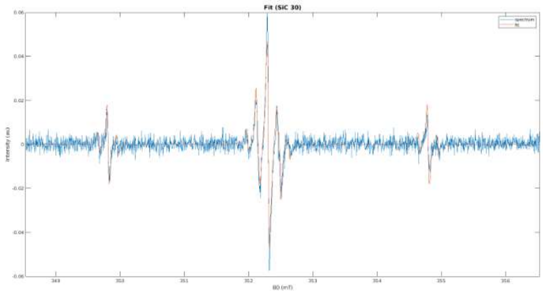

*Fig. 6. EPR spectrum of a SiC sample with 1,8*1010 spins. EPR setup with 9.8 GHz, power 0.1438 mW, modulation amplitude 0.12G, modulation frequency 100kHz and conversion tome 20ms and 150 scans..*

References

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