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Characterization and Modeling of Si-Si Bonded Hydrophobic Interfaces for Novel High-Power BIMOS Devices

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In this work, the suitability of silicon-silicon bonding for fabrication of new thyristor-type power electronic devices is investigated. A systematic investigation of the bonding interface, particularly in bipolar semiconductor structures, is performed. A detailed analysis of the grain boundary physics in unipolar and bipolar structures is presented for the thermal equilibrium state as well as non-equilibrium state. Based on grain boundary physics, an analytical model of the bonding interface is developed, which allows the calculation of the voltage-current characteristics in bipolar device structures. Moreover, the grain boundary characteristics predicted by the physical analysis and the model are verified by wafer bonding experiments as well as finite-element simulations.

In addition, new concepts for combined bipolar-MOSFET devices are proposed based on the direct wafer bonding technology. A disc-type MOS-Turn-Off Thyristor (MTO) structure is presented where MOSFETs are integrated into the thyristor structure using Si-Si bonding. Hence, the proposed structure enables outstanding switching performance comparable to monolithically integrated designs. The turn-off process can further be optimized by the Double-Gated MTO structure proposed in this work, which enables switching off both emitters of the thyristor structure. Finally, even bidirectional power devices can be realized using Si-Si bonding as demonstrated with a Double-Gated MCT device structure. Finite-element simulation results of the proposed high-power BIMOS device structures are presented verifying their excellent device characteristics.