MILLISECOND MICROWAVE ANNEALING OF ULTRA-SHALLOW BORON DOPED SILICON

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Next generation Si IC transistors, i.e. the 65 nm node, will require ultra-shallow doped regions with depths less than 17 nm and concentrations high enough to get a sheet resistance, Rs, lower than 760 ohms/square [1]. The current state of implant technology, taking into account reasonable throughput and cost considerations, results in as-implanted junction profiles that are slightly shallower than this 17 nm limit. Therefore, to meet the requirements, the subsequent thermal anneal process must result in very little net diffusion while activating the implanted dopants and repairing the implant damage. One potential solution is an ultra-fast spike anneal to 1300^{o}C with the time above 800^{o}C limited to only a few milliseconds. Indeed, reports over the last 2 years indicate that millisecond annealing with advanced flash-lamp technology has resulted in a very effective, zero-diffusion, high temperature anneal process [2].

While lamp-based technology currently dominates the commercial rapid thermal processing (RTP) market, recent advances in high-power microwave equipment make microwave annealing a unique alternative to lamp-based systems. We have constructed a high-power microwave reactor that is capable of heating Si to 1300^{o}C in only a few milliseconds. This system utilizes an advanced gyrotron designed to produce more than 1 MW of continuous wave radiation at a frequency of 110 GHz. The optimal thermal treatment achieved to date with this system involves a 300,000^{o}C/sec ramp rate to 1300^{o}C; only 2 milliseconds above 800^{o}C. Net diffusion of the dopants into the wafer is generally negligible on such a short time scale, and the target temperature is high enough to ensure that a large fraction of the implanted dopants become activated. This millisecond microwave anneal process was applied to several 2.5 cm square Si samples that were pre-amorphized with Ge at 30 keV and implanted with B^{+} at 500 eV. The average Rs after the anneal was 542 ohms/square. Repeating this experiment on Si samples that were implanted with BF_2 at 2200 eV, no pre-amorphization, resulted in an average Rs of 615 ohms/square.

This talk describes the microwave reactor design and the millisecond microwave heating technique necessary to achieve the ultra-fast temperature ramp rates described. The advantages of microwave annealing, as well as the technical challenges to further implementation will be discussed in detail. There will also be a full analysis of the ultra-shallow junctions formed including sheet resistance as measured by 4-pt. probe and junction depth as measured by SIMS.

REFERENCES

[1] International Technology Roadmap for Semiconductors. Obtained via the World Wide Web at http://public.itrs.net.

[2] J. Gelpey, K. Elliott, D. Camm, S. McCoy, J. Ross, D.F. Downey, E.A. Arevalo, "Advanced Annealing for Sub-130nm Junction Formation" in Proc. of the Electrochemical Society: Rapid Thermal and Other Short-Time Processing Technologies III, vol. pp. 2002-11, 2002.