ULTRA-RAPID MILLIMETER-WAVE ANNEALING OF SILICON WAFERS

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The use of intense microwave radiation, including the millimeter-wave range, attracts a growing interest of the researchers creating materials with novel properties. One of the most promising research directions is rapid microwave annealing of implanted silicon structures. The development of new generations of integrated circuits requires further scaling of the topological dimensions of the structures into the 90 nm node and below. An important factor that limits the scaling is the diffusion widening of the implanted profile. To solve the diffusion widening problem, alternative annealing methods are widely investigated, such as rapid thermal processing (RTP) using incoherent infrared radiation, and pulse laser annealing. A serious problem of RTP is insufficient cooling rates due to large thermal inertia of the flashlamps. Pulse laser annealing successfully uses natural thermal conduction to remove the heat from the near-surface layer into the bulk of the material; however, its principal problem is achieving uniform heating of large-diameter wafers.

Microwave annealing can combine the advantages of both RTP and laser annealing. The use of microwave energy to anneal semiconductor structures has been discussed in the literature since 1982 [1–3]. In particular, promising first results have been obtained using millimeter-wave radiation [4–6]. However, ultra-rapid annealing processes are only feasible when hundred-kilowatt millimeter-wave sources are used. In this presentation the results of modeling the ultra-rapid (“flash”) annealing of silicon using a 140 GHz / 200 kW pulse gyrotron source are discussed. It is shown that the temperature at the surface of a silicon wafer rises above 1200 ºC in a few milliseconds. Since the heating is transient and the heat is removed into the wafer bulk by thermal conduction, the steady-state temperature of the wafer is lower than the maximum temperature at the surface by about 200 ºC. In other words, the high temperature needed for annealing is reached for a limited time only in the near-surface region, and the rest of the wafer is never exposed to it. This ensures minimum diffusion widening of the implantation profile. The specific temperature profiles over the depth of the wafer are determined by many factors, including the millimeter-wave absorptivity and thermal conductivity of doped silicon. To increase the efficiency of heating, it is desirable to use matching structures that minimize reflection of the millimeter waves from silicon. Experimental implementation of ultra-rapid millimeter-wave annealing will be also discussed.

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