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The inferior quality of RTA MOSFET interfaces

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Abstract. We have examined the quality of silicon MOSFET interfaces, comparing those obtained by RTA and conventional furnace-annealing processing techniques. Electrical characterisation has shown that the RTA interface quality is inferior.

Today's VLSI silicon processing requires an annealing stage after ion implantation. Conventionally this annealing has been done in a furnace at a temperature of about 950 °C for 30 min. However, this causes an unwanted redistribution of the implanted species. Recently, rapid thermal annealing (RTA) has been used to minimise this diffusion. In RTA the sample is heated and cooled quickly with high peak temperatures of about 1100 °C.

The low-frequency noise, interface-state density, surface mobility and threshold voltages of electron beam RTA MOSFETs have been examined. These measurements all relate to regions close to the gate oxide/silicon interface. The performance of RTA devices was inferior to that of devices obtained with conventional furnace annealing.

The input referred noise $E_n(f)$ of n-channel transistors increased by up to an order of magnitude. This implied an increase in the oxide defect density (close to the interface). The magnitude of the noise increase was a function of the cooling rate at the end of the annealing cycle. Normally the samples cool by radiation loss at a rate of about 200 °C s^{-1}. A slow cool of 10 °C s^{-1} gave an improved noise performance.

Noise versus temperature studies (100 to 350 K) revealed bulk defects in the silicon below the interface for short-duration RTAs. It was thought that these defects were already present in the samples, and that they were only removed if the annealing cycle was long enough. Interface-state densities increased (by up to two orders of magnitude) and surface mobilities fell for RTA samples. As with the noise measurements, this suggests that RTA induces imperfections in the crystal structure. Another degradation of device performance was revealed in threshold measurements, which suggested an increase in the positive oxide charge.

A few other studies have also shown a deterioration of oxide interface quality, including [1]. However, this is the first study to present noise measurements and to demonstrate the benefit of including a slow cool in the RTA cycle.

Post-metallisation annealing (final processing stage) in forming gas (H_2/N_2 mixture) at 450 °C produced a partial recovery towards conventionally processed device performance. Here the hydrogen atoms are thought to combine with the crystal imperfections making the latter electrically inactive.

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In summary, a noise performance comparable with that of furnace-annealed devices can be obtained if the RTA cycle (i) is long enough to anneal bulk defects; (ii) contains a slow cool to reduce the interface noise increase; (iii) is followed by a post-metallisation anneal in forming gas at 450 °C.

Reference

[1] Sun J Y C, Angelucci R, Wong C Y, Scilla G and Landi E 1988 *J. Physique Coll.* C4 401–4