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РАСПРЕДЕЛЕНИЕ ПРЕЦИПИТАЦИИ КИСЛОРОДА В МОНОКРИСТАЛЛАХ КРЕМНИЯ ПРИ ВЫСОКОТЕМПЕРАТУРНОМ ТЕРМИЧЕСКОМ ОТЖИГЕ

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Аннотация. В данной работе изучено распределение плотности преципитации кислорода в пластинах кремния, подвергнутых быстрому термическому отжигу в среде аргона в температурном диапазоне 850-1250 °C. Было определено, что плотность преципитации увеличивается по всей толщине пластины, и вблизи каждой из поверхностей наблюдаются пики плотности и существенное увеличение преципитации кислорода с увеличением времени термической обработки. Такое увеличение сильно зависит от температуры термической обработки.

Ключевые слова: преципитации кислорода, термическая обработка, плотность кислородных преципитатов, усиления кинетики преципитации

Abstract. This paper examines the distribution of oxygen precipitation density in silicon wafers subjected to rapid thermal annealing in an argon atmosphere at temperatures ranging from 850 to 1250°C. It was found that the precipitation density increases throughout the wafer thickness, with density peaks observed near each surface and a significant increase in oxygen precipitation with increasing heat treatment time. This increase is highly dependent on the heat treatment temperature.

Keywords: oxygen precipitation, heat treatment, density of oxygen precipitates, enhancement of precipitation kinetics

Abstrakt. Ushbu maqolada argon atmosferasida 850 dan 1250°C gacha bo‘lgan haroratlarda termik toblash vositasida kremniy plastinkalarida kislorod cho‘kmalarining taqsimlanishi o‘rganildi. Cho‘kmalarning plastinka qalinligi bo‘ylab ortishi, har bir sirt yaqinida zichlik cho‘qqilari kuzatilishi va issiqlik bilan ishlov berish vaqtining oshishi bilan kislorod cho‘kmalarining sezilarli darajada oshishi aniqlandi. Bu o‘sish issiqlik bilan ishlov berish haroratiga juda bog‘liq.

Kalit so‘zlar: kislorod yog‘inlari, issiqlik bilan ishlov berish, kislorod cho‘kmalarining zichligi, yog‘in kinetikasini kuchaytirish

1. INTRODUCTION.

Single-crystal silicon wafers subjected to high-temperature pre-annealing exhibit a stable increase in oxygen precipitation, which depends on the annealing

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time and temperature [1-3]. Measurements of the density of oxygen precipitates carried out by the authors of [3] show that oxygen precipitation within the silicon wafer is distributed non-uniformly, reaching peaks near the surfaces and a minimum in some boundary regions of the sample. On the other hand, high annealing temperatures lead to the formation of defects, which serve as precursors for the subsequent nucleation and growth of oxygen precipitates. Previous studies [2-4] have shown that the suitable temperature range for the growth of oxygen precipitates is from 870 to 1100 °C, since in this range the formation and dissolution of oxygen precipitate nuclei is minimized.

2. RESEARCH METHODOLOGY.

In this work, we study the process of enhancing the kinetics of oxygen precipitation due to vacancy injection at high temperatures in polished silicon wafers with a resistance in the range of ρ = 10-20 Ω cm . The initial concentration of interstitial oxygen in the sample was measured using a Fourier transform infrared spectrometer and was found to be 7.7×10^{17} at cm^{-3}. The sample was subjected to rapid thermal annealing in an argon atmosphere at temperatures from 850 to 1250 °C for times from 1 to 45 s, depending on the temperature. Cooling rates of about 55 °C/ s were used . Samples treated by rapid thermal annealing were subjected to a two-stage treatment consisting of 5 h at 850 °C and 18 h at 1150 °C in an argon atmosphere. The residual oxygen concentration and the oxygen precipitate density were measured by etching cleaved cross-sections of the wafers with an etching solution. The dependence of the percipitated oxygen concentration on the pre-annealing time at different temperatures was recorded by counting defects under an optical microscope at 800x magnification [3]. Typical oxygen precipitate density depth profiles for three different annealing times at 12, 75 °C, 1200 °C, and 1175 °C are shown in Fig. 1. A significant increase in oxygen precipitation was observed with increasing heat treatment time. This increase also strongly depends on the relative value of the heat treatment temperature. Cross-section etching showed that this increase in oxygen precipitation is not uniform throughout the entire thickness of the sample: the precipitation density increases throughout the entire thickness of the wafer, and density peaks are observed near each of the surfaces.

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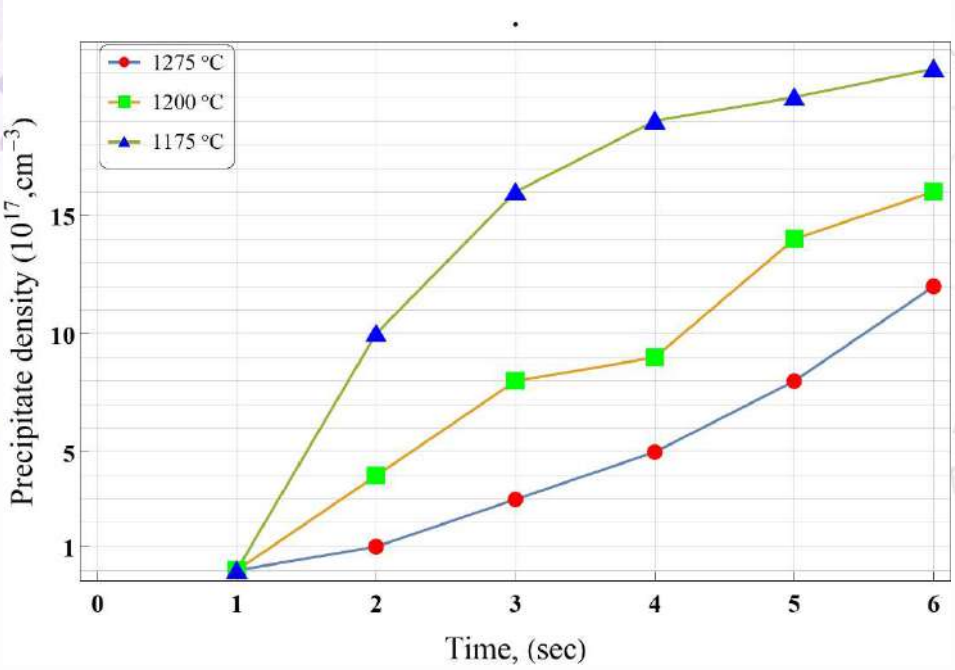


Fig. 1. Dependence of the density of precipitates on the time of heat treatment at 1275 °C, 1200 °C, 1175 °C for 45 s in an argon atmosphere.

The data in Fig. 1 show that short heat treatment times above 1050 °C are extremely effective in increasing oxygen precipitation during subsequent treatment at 850/1150 °C. Subsequent annealing at 900 °C for 4 hours and at 1100 °C for 16 hours prevents additional crystal nucleation and, under normal conditions, has an effect solely on the growth of existing nuclei (Fig. 2). Thus, we can state that high-temperature heat treatment creates a new type of defects that can be, at least partially, stabilized as oxygen precipitate nuclei during treatment at 850/1150 °C. We will refer to these defects as high-temperature nuclei to clearly distinguish them from the nuclei into which they transform, as well as from the nuclei formed at a lower temperature and themselves precipitated [4].

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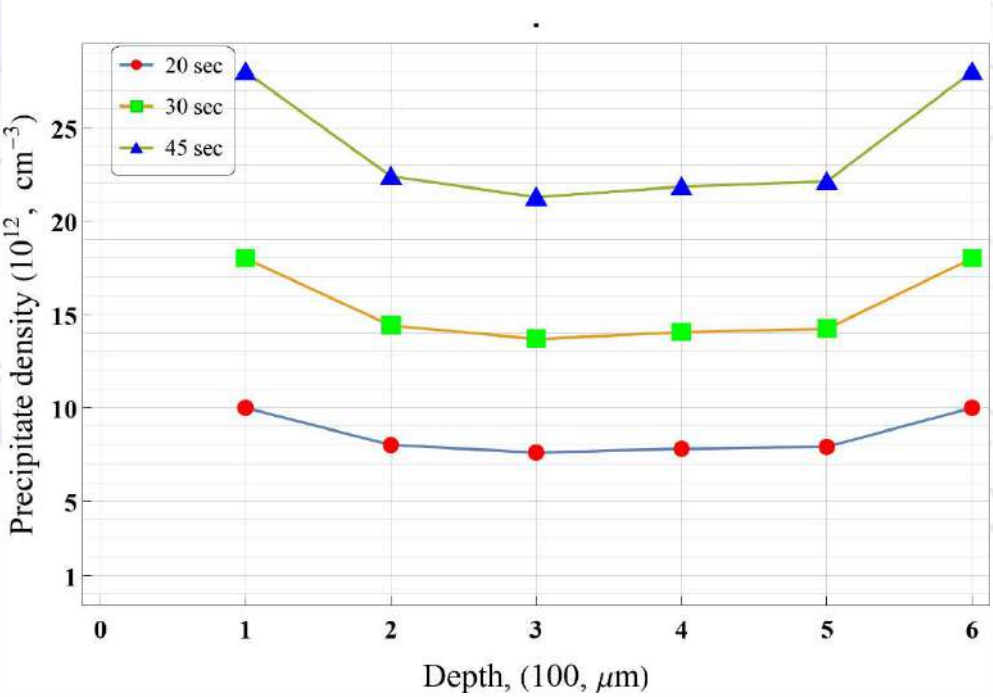


Fig. 2. Precipitate density distribution profile by depth after heat treatment at 1250 °C for 45 s in an argon atmosphere

3. RESULTS OBTAINED AND THEIR DISCUSSION.

Currently, the nature of these defects is not fully understood; there is experimental data indicating a correlation with the argon environment during high-temperature processing. It is known that many of the observed phenomena of oxygen kinetics in silicon can be described within the framework of the classical theory of homogeneous nucleation [1,2] and diffusion-limited growth [3,4]. However, recently, numerous heterogeneous effects on oxygen nucleation have been observed: high concentrations of dopants, as well as the concentration of carbon or a silicon layer on the back side of the wafers, can significantly affect the kinetics of oxygen precipitation. Increased oxygen precipitation has also been observed near surfaces with a high density of oxidation-induced stacking faults. In all these situations, the role of internal point defects appears to be significant.

Conclusion and recommendations

Thus, this study experimentally investigated the distribution of oxygen precipitation density in silicon wafers subjected to rapid thermal annealing in an argon atmosphere at temperatures ranging from 850 to 1250°C. It was determined that the deposition density increases throughout the wafer thickness, with density peaks observed near each surface and a significant increase in oxygen precipitation, unevenly distributed throughout the sample thickness, with increasing heat treatment time.

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