冷却過程における温度精密制御法を用いたシリコン単結晶の３次元転位密度解析

Three-dimensional analysis of dislocation multiplication in single-crystal silicon under accurate control of cooling history of temperature

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Introduction

In crystalline silicon, dislocations usually take place in the high-temperature processes of crystal growth, such as crystallization and cooling processes. The crystallization process usually contributes slightly to the increase of dislocations, whereas the cooling process has a large effect on the increase of dislocations. Hence, many studies have concentrated on the cooling process. However, the results are not consistent. Slow cooling was suggested for obtaining low dislocation density in GaP/Si heterostructures and in SiGe layers grown by liquid phase epitaxy. Fast cooling was suggested for obtaining low dislocation density in Pb and Si crystal growth from the melt. To better understand the relationship between the cooling rate and dislocation, it is essential to study the effect of the cooling process on the increase of dislocations from the perspective of accurate control of temperature history inside furnace according to a pre-designed curve.

Results

To determine the influence of the cooling process on dislocation multiplication, three different cooling processes were designed. The heating process was the same for all three cases. The cooling processes of three cases were different at the initial stage, but were the same at the final stage of the cooling process. The distributions of dislocation density for three cases are shown in Fig. 1(a)–(c). The slowest cooling process results in the fewest dislocations (Fig. 1(a)), and the most rapidly cooling process results in the most dislocations (Fig. 1(c)). Because the only difference between three cases is the cooling rate in the high-temperature region, the cooling rate in the high-temperature region has a large effect on dislocation multiplication, and slow cooling is beneficial for reducing dislocations.

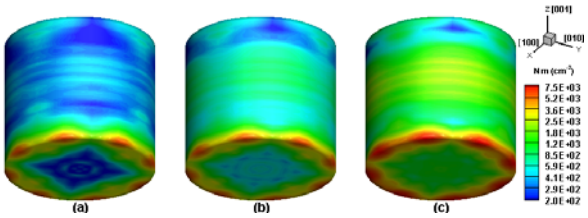

Fig. 1. Distribution of dislocation density after the cooling process for (a) slowest cooling, (b) middle cooling, and (c) fastest cooling rate.

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