ELSEVIER

Journal of Crystal Growth 230 (2001) 305–313

JOURNAL OF CRYSTAL GROWTH

www.elsevier.com/locate/jcrysgro

Stress-induced dislocation generation in large FZ- and CZ-silicon single crystals—numerical model and qualitative considerations

A. Muižnieks[a,b], G. Raming[a,*], A. Mühlbauer[a], J. Virbulis[c], B. Hanna[c], W.v. Ammon[c]

[a] *Institute for Electroheat, University of Hanover, Wilhelm-Busch-Str. 4, D-30167 Hanover, Germany*
[b] *Department of Physics, University of Latvia, Zellu Str. 8, LV-1002 Riga, Latvia*
[c] *Wacker Siltronic AG, D-84479 Burghausen, Germany*

Abstract

When growing silicon crystals with higher diameter (presently up to 300 mm) the thermal stresses and possible dislocation generation in single crystals become a serious problem for both FZ- and CZ-methods. A two-dimensional problem oriented code for the FEM-package ANSYS has been developed to calculate the temperature field in the growing crystal considering radiation exchange with reflectors and environment and thermal stresses. Comparing calculated stresses with critical stresses, the dislocated zone is determined. A qualitative concept for the occurrence of dislocations using the metastable state is developed. In a parametric study for different thermal boundary conditions and crystal geometries, the thermal stresses are calculated and are discussed. From this, some hints on how to reduce stress and avoid dislocation generation are deduced.

Keywords: A1. Computer simulation; A1. Stresses; A2. Czochralski method; A2. Floating zone technique; B2. Semiconducting silicon

1. Introduction

The industrial growth of large diameter silicon crystals by FZ (up to 150 mm) or CZ (up to 300 mm) methods can lead to severe problems with thermal stresses in crystals and dislocation generation. If dislocations are generated because of a relatively high level of thermal stresses, a distinct region in the crystal with intensive multiplication of dislocations can occur. In such a case, the FZ growth process must be interrupted and the dislocation-free crystal length, i.e. the usable part, is shortened by the depth of the dislocated zone. During the CZ growth process it is possible to melt back the dislocated zone, but this disturbs the production process.

The stress field is induced by inhomogeneous thermal expansion of the silicon due to an inhomogeneous temperature field. During FZ and CZ silicon crystal growth, the heat is mainly carried off by radiation and additional reflectors may be applied to control the temperature field. At the Institute for Electroheat, a system of

*Corresponding author. Tel.: +49-762-2872; fax: +49-762-2872.
E-mail address: raming@ewh.uni-hannover.de (G. Raming).

0022-0248/01/$ - see front matter
PII: S0022-0248(01)01322-7