

Defect engineering of CaF_2 - the master key to achieve the requirements for the 45nm node and beyond

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Abstract

Homogeneity residuals of the refractive index have a strong influence on the performance of next generation lithography tools for 45 nm and 32nm nodes [1],[2]. Smallest local variations of the refractive index generate straylight in the projection optics and lead to flare in the imaging - one of the most critical parameter in optical lithography.

By systematic investigations of various defects in the real structure of CaF_2 crystals, the origin of homogeneity residuals can be shown. Different types of real structure defects will be discussed in their correlation to optical inhomogeneity. Furthermore the influence of the process- as well as the equipment-parameters on real structure will be presented. This special approach we characterize as so-called defect engineering.

In conclusion new champion data for refraction index variations for both orientations (111) and (100) show the potential to meet the requirements expected for the 45nm node. Compared to the last years the value are significant reduced down to 70%.

Introduction

The trend towards ever smaller structures in semiconductor devices are still driven by Moores Law. A major part in the production process for semiconductor devices is optical lithography. The optics used in these lithography tools require materials of exceptional high quality. Due to increased requirements for the application wavelengths 193nm dry and immersion or 157nm CaF_2 single crystalline lenses are a major part in the optics of these systems.

For the supplier of optical materials it is essential to have a profound understanding of the physical properties underlying material behavior. The key to improve the quality of CaF_2 is the defect engineering which we define as follows:

- Comprehension of the influence of real structure effects on optical performance is necessary
- Knowledge how real structure defects can be influenced

The production process as well as the equipment performance used for processing play a crucial part in achieving the highest qualities.

Figure 1 shows an example for a very good correlation between slip planes and optical inhomogeneities

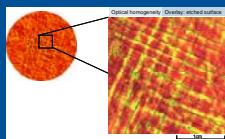


Fig. 1: Slip planes, aligned perpendicular to blank surface lead to disturbing optical inhomogeneities. Local strain related to the planes is the reason for change in refractive index.

Experimental

Influence of annealing temperature on defect structures

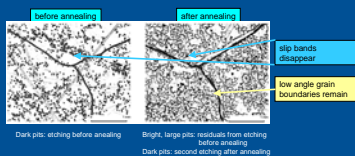


Fig. 2: Defect density for low temperature annealed CaF_2

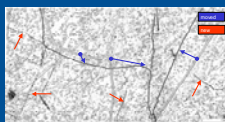


Fig. 3: Defect density for mid temperature annealed CaF_2



Fig. 4: Defect density for high temperature annealed CaF_2

Influence of temperature gradients on grain size

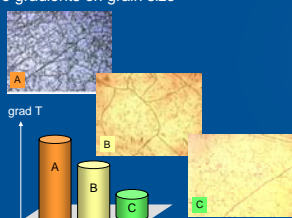


Fig. 5: Defect density and grain size for different temperature gradients

Results

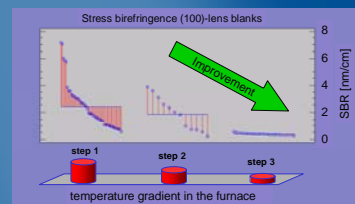


Fig. 6: Influence of equipment on achievable material quality. Best temperature homogeneity in the furnace is necessary to reach the quality of high end products

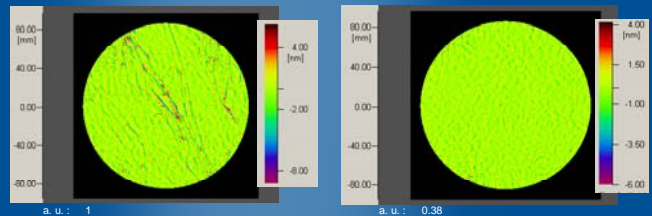


Fig. 7: Short range refractive homogeneity data for champion (100) lens blanks before (left) and after process improvement (right)

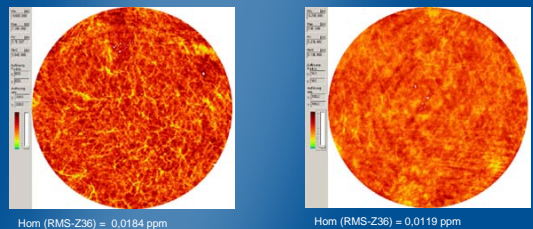


Fig. 8: Refractive index homogeneity data (residuals), Comparison of production (left) and status R & D (right) for (111) oriented blanks. Significantly reduction of real structure defects

Summary

CaF_2 Quality Improvements were demonstrated in all areas

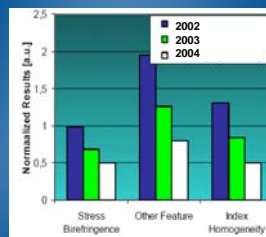


Fig. 9: Quality improvement of CaF_2 lens blanks at Schott Lithotec

- Average results of all produced CaF_2 lens blanks
- Results normalized to the tightest specification for each shown feature
- Ongoing activities will provide for next improvements

References:

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- L. Parthier, G. Grabosch, G. Wehrhan, K Knapp, J. Hahn, T. Morisawa, 39th Research Meeting JPS April 2004, Tokyo, Japan