New Laboratory Experiments on thermal Annealing of forsterite in proto-planetary disks. B. Oehm[1], D. Lattard[1], M. Burchard[1], R. Dohmen[2], H.-P. Gail[4], M. Trieloff[1], M. Klevenz[3], A. Pucci[3], [1] Institut für Geowissenschaften, Universität Heidelberg, Im Neuenheimer Feld 234-236, 69120 Heidelberg, oehm@min.uni-heidelberg.de [2]Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, [3]Kirchhoff Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, [4]Institut für Theoretische Astrophysik, Universität Heidelberg, Albert-Überle-Str. 2, 69120 Heidelberg

Introduction: Crystalline silicate dust observed in accretion disks of young stellar objects has been interpreted as resulting from high-temperature annealing of amorphous cosmic dust particles during the preplanetary stage. Laboratory studies have provided insights on the kinetics of thermally induced crystallisation of Mg-silicates from various amorphous precursors (e.g. [1], [2]). However, the results of these studies are contradictory. They stem from completely different experiments, with different starting materials, which were, in some cases, neither completely amorphous nor on the desired chemical composition.

The present project aims at supplying reliable laboratory data on the crystallisation kinetics of end member forsterite (Mg_2SiO_4). We have developed a new experimental approach, involving chemically homogeneous amorphous thin films which were annealed at constant temperatures for well-defined durations. The progress of crystallization is followed not only with IR spectroscopy, but also with AFM (Atomic Force Microscopy) and SEM (Scanning Electron Microscopy).

Methods:

(1) *Sample preparation:* Our emphasis is on thin films produced by pulsed laser deposition (PLD) which are deposited on a Si (111) wafer. These thin films are amorphous and chemically homogeneous, with compositions identical to those of the targets (polycrystalline forsterite pellets). The thin films are continuous and display a flat surface [3].

(2) Annealing procedure: Annealing experiments were performed in a vertical quench furnace at constant temperature in air for well-defined run durations (at 800°C; 2.5 – 260 h). The annealing temperature was reached after a maximum of 5 minutes. The samples were drop-quenched on a copper block which ensures a cool down to room temperature well within one minute.

(3) Sample characterization: Before and after annealing, all samples were characterized not only by IR spectroscopy but also by AFM and SEM.

IR spectra were taken in transmittance in the range 350-6000 cm^{-1} (MIR), some of them also in the FIR (down to 100 cm^{-1}). Before annealing, the spectra display only broad absorption bands stemming from the amorphous thin films and a few narrow bands related to the Si substrate. After annealing, characteristic forsterite and quartz bands develop. The latter originate from the crystalline SiO_2 layer that grows on the surface of the Si substrate during annealing. In order to follow the evolution of the absorption bands of crystalline forsterite with increasing annealing time, we have developed a quantitative evaluation procedure which involves a deconvolution of the spectra by fitting the forsterite bands to symmetric Gaussian peaks.

First results: IR spectra already show distinct forsterite bands after 10 h annealing at 800°C. The quantitative evaluation shows that these bands continuously grow during longer annealing runs, up to 64 h. No significant change appears with longer run durations.

AFM imaging of the surface topography reveals incipient crystallization already after 6 h of annealing, with circular features (approx. 1 µm in diameter) with a central elevation. With longer annealing times, radial structures appear and small crystallites become visible. AFM imaging proves to be a powerful method to detect incipient crystallization features.

The present results on annealing of forsterite at 800°C point to slower crystallisation than reported previously. These discrepancies can be related to Fe-bearing compositions and to the presence of crystallites in the starting materials in previous studies [1],[2].

References:

[1] Brucato, J.R. et al. (2002) Planet Space Sci., 50, 829-837. [2] Fabian, D. et al. (2000) Astron. & Astrophys., 364, 282-292. [3] Dohmen, R. et al. (2002). Eur J Mineral, 14, 1155-1168.

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