KINETICS OF CRYSTALLIZATION OF AMORPHOUS FORSTERITE THIN FILMS WITH RELEVANCE TO THERMAL ANNEALING OF DUST IN PROTO-PLANETARY DISKS

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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 [1].

To obtain necessary kinetic crystallization parameters for numerical modelling of accretion disks we perform time and temperature dependent annealing experiments. Starting materials are Si (111) wafers coated by pulsed laser deposition (PLD) with approx. 140nm thick amorphous silicate films of forsterite composition. The samples are annealed at temperatures in the range of 1023-1173K for 1 to 260 h in a vertical quench furnace and drop-quenched on a copper block. To monitor progress of crystallization, samples are characterized by AFM, SEM and TEM imaging, and IR spectroscopy.

For TEM studies, foils were cut perpendicular to the surface using focused ion beam (FIB) techniques. TEM images of selected samples annealed at 1173K show that there is no contact between newly formed crystals and the silicon substrate, i.e. that epitaxial growth of forsterite on silicon can be excluded. Electron diffraction patterns of the observed crystals show that they are single crystals randomly oriented within the amorphous material. At annealing times > 10 hours the amorphous matrix between the early formed forsterite single crystals reacts to radial aggregates of tabular forsterite crystals.

On the basis of a quantitative evaluation of AFM / SEM images in combination with TEM imaging we are currently determining the nucleation rate, the size distribution of the crystals and their growth velocity and we are trying to retrieve activation energies for the different mechanisms involved in the crystallization process.

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