TEMPERATURE OF PROTOPLANETARY DISKS PROBED BY ANNEALING EXPERIMENTS REFLECTING SPITZER OBSERVATIONS

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Pyroxenes and olivines are the dominant crystalline silicates observed in protoplanetary disks. Unexpectedly, recent spectral observations from the *Spitzer Space Telescope* indicate that the abundance of olivine, generally associated with silica polymorphs, relative to pyroxene is higher in the outer cold part of the disk than in the inner warmer part [1-3]. Beside, the crystallinity of the dust around stars contrasts with the mainly amorphous nature of those detected in the interstellar medium [e.g. 4]. Therefore, one dominant astrophysical model invokes a low-temperature and subsolidus transformation of nanometric amorphous dust in the protoplanetary disk. In this framework, starting from an interstellar dust having an Mg/Si ratio close to 1, which is the solar value [e.g. 5] and moderate amount of FeO, one should mainly detect pyroxenes and only traces of olivine in disks, which is clearly not the case.

The interpretation of these unexpected results requires a comprehensive knowledge of the thermal processing of Mg-rich silicate dust. In this respect, amorphous analogs (gels and glass powders) were thermally annealed to identify microscopic crystallization mechanisms.We show that pyroxenes are not produced in significant proportions below the glass transition temperature of the amorphous precursors [6]. The annealing of amorphous enstatite leads to a mineralogical assemblage dominated by forsterite, with only minute amounts of pyroxenes at temperatures as high as the glass transition temperature of enstatite (1050 K). The subsolidus products (forsterite + residual glass enriched in silica) are currently under our scope to derive the conditions requested to react together and form enstatite in astrophysical environments (low pressure, T<1000K, on μm-sized grains). Recent advances in the description of bulk and local dynamics of glasses and melts [7] help to propose a microscopic interpretation of these results, which seems to be independent from the composition of the parent amorphous material [8]. It is shown in this respect that the decoupling of cation mobility in amorphous silicates favors the crystallization of the most Mg-enriched silicates.

Our experimental results are consistent with Spitzer observations of silicate dust and with the documented mineralogy of presolar silicates [9-10], making the low-temperature annealing a possible formation process for these objects. Based on these laboratory experiments and Spitzer observations, it appears that the reported zoned mineralogy may record the thermal gradient or heterogeneities at the scale of protoplanetary disks.

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