Silicate mineralogy of embedded YSOs and the ISM as revealed by mid-IR spectroscopy and spectropolarimetry

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Utilizing a range of instruments on 4-10 m telescopes we observed a large sample of objects in the mid-infrared (8-13 μm) in conventional spectroscopic as well as spectropolarimetric modes, with a spectral resolution of around 100. The target list comprises a few OH/IR stars where dust is formed, many envelopes or disks of embedded Young Stellar Objects (YSOs) where dust may begin its transformation into eventual planetary systems, and several objects viewed though dense and diffuse sight-lines of the interstellar medium (ISM). The latter is where dust resides between its formation in evolved stellar outflows and deposition in molecular clouds. In all objects we detect the typical absorption feature of amorphous silicates around 9.7 um. But clearly apparent in most objects is a second absorption band centred around 11.1 μm. Using a variety of approaches we confidently assign this feature to crystalline olivine, and probably the Mg-rich end-member forsterite. In some targets which have high S/N we also detect features around 10.4 and 11.9 um, supported by ISO and/or Spitzer observations of the same and/or related (by class) objects and all but confirming the forsterite identification. Modelling using a mixture of dust components and sizes shows that in most YSO and ISM cases the abundance of forsterite is around 1-2%. However, several sources show much stronger features and thus higher abundances. This includes the BN Object in Orion, the archetypal cold molecular cloud source, the massive YSO AFGL 2591, as well as the supposed Herbig Be star AFGL 2789 (V645 Cyg). We propose that crystalline silicates are essentially ubiquitous in the embedded YSO phase. Along with its presence in the ISM toward the Galactic Centre, particularly intriguing is the first detection of crystalline silicate in the diffuse ISM, toward the Wolf-Rayet star AFGL 2104. In discussing the significance of our findings in the context of the cosmic dust life-cycle we pose the following questions i) do they set back the evolutionary stage in which silicates are crystallized, perhaps to the embedded phase or even before within the ISM, and if so then how given the expected low temperature means the annealing time -scale is prohibitively long , or ii) do silicates ejected from the outflows of evolved stars retain some of their crystalline identity during their long residence in the ISM, and if so then how given the expected fast-acting amorphization processes, or iii) do silicates formed within the ISM – which they must do based on lifetime estimates – condense as partially crystalline and if so then how given the probable low temperature?