Co-accretion of carbon molecules and silicate precursors at cryogenic temperatures

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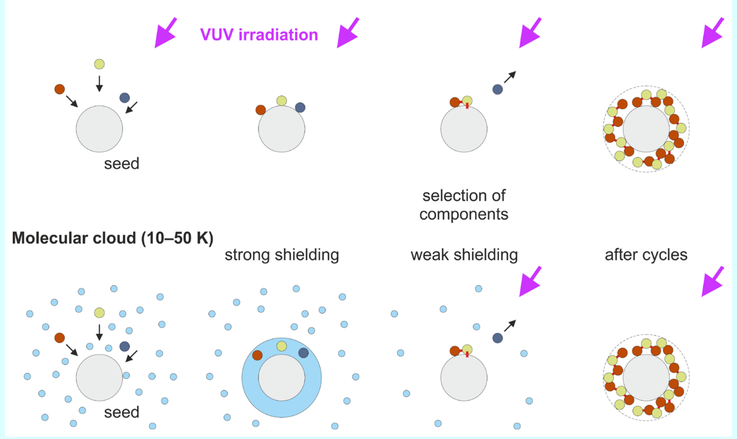
Context

Dust grains are destroyed by various mechanisms in the interstellar medium (ISM), especially sputtering in supernova-induced shockwaves. Together these mechanisms operate at a rate faster than the injection of grains condensed in stellar outflows and supernova ejecta. Nevertheless, comparatively long-lived dust populations are observed in the ISM. The local growth of grains has been proposed as a process that contributes to counterbalancing their destruction (e.g., Draine, B. T. 2009, ASP Conf. Ser., 414, 453).

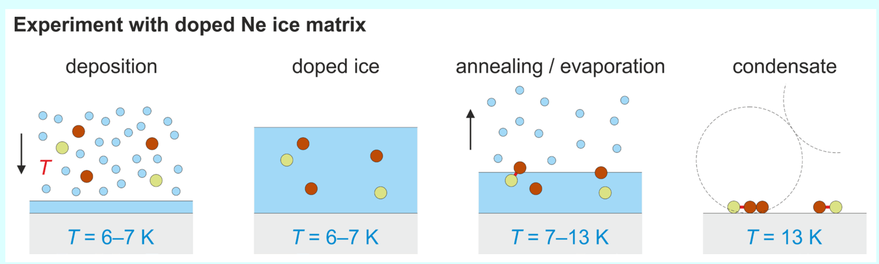
Hypothesis of growth mechanism in the ISM

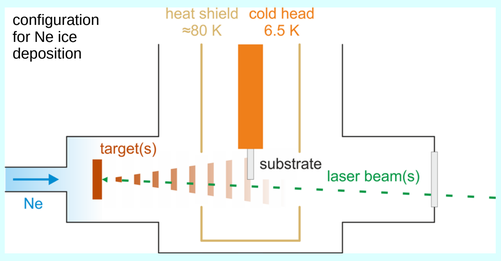
Growth of interstellar dust grains proceeds through the adsorption of atoms and/or molecules present in the interstellar gas phase, and subsequent chemical reactions that incorporate the adsorbed species to the grain. The reactions take place in the diffuse cold neutral ISM and/or in molecular clouds, i.e., at temperatures in the range 10 to 100 K.

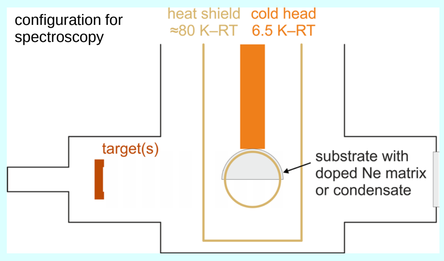


Cold condensation experiment

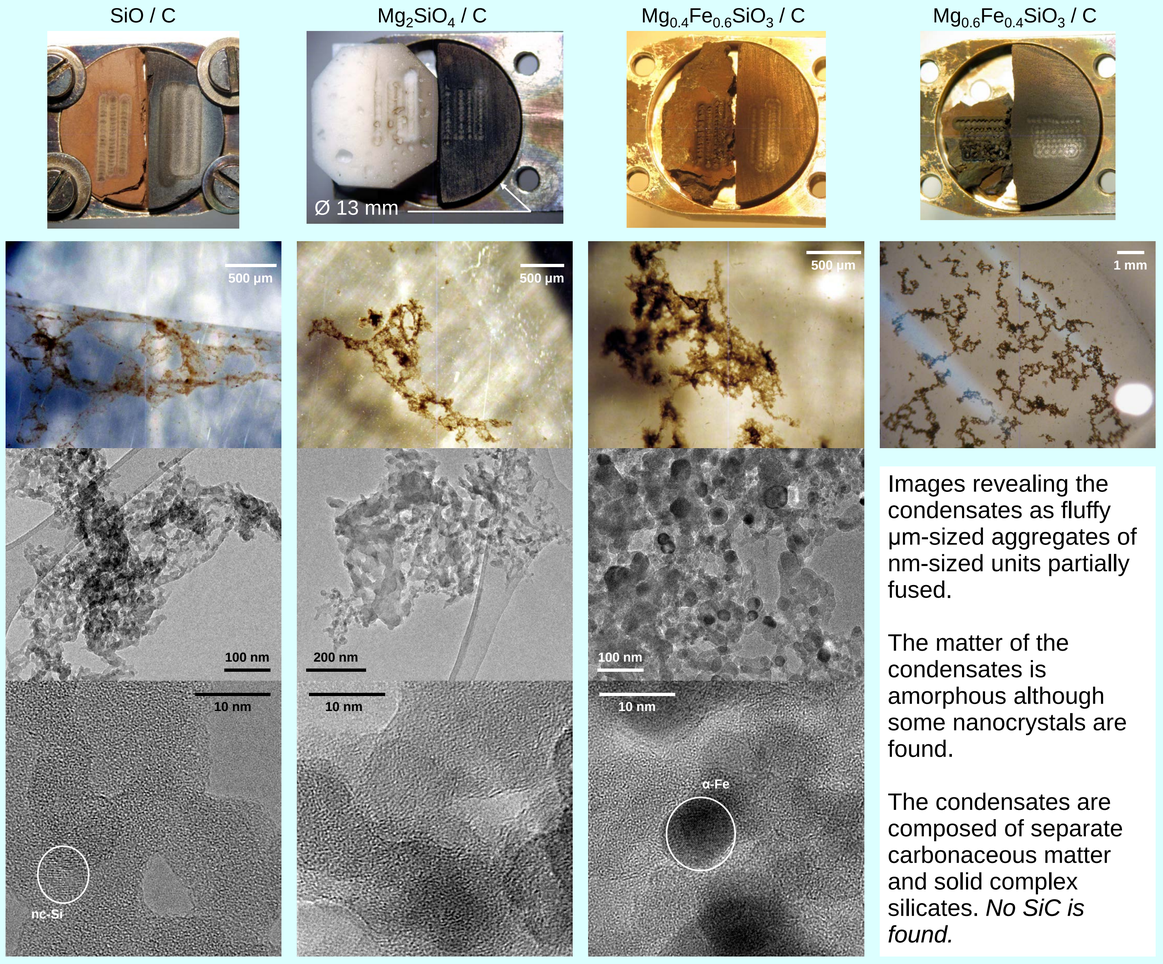
Atomic and molecular precursors of refractory materials are injected into the gas phase by laser vaporization of solid targets, then they are isolated and cooled in Ne ice. The Ne ice is annealed and slowly evaporated to make the cold precursors interact thus simulating reactions at the surface of a cold interstellar dust grain.







Targets after experiments and corresponding condensates.



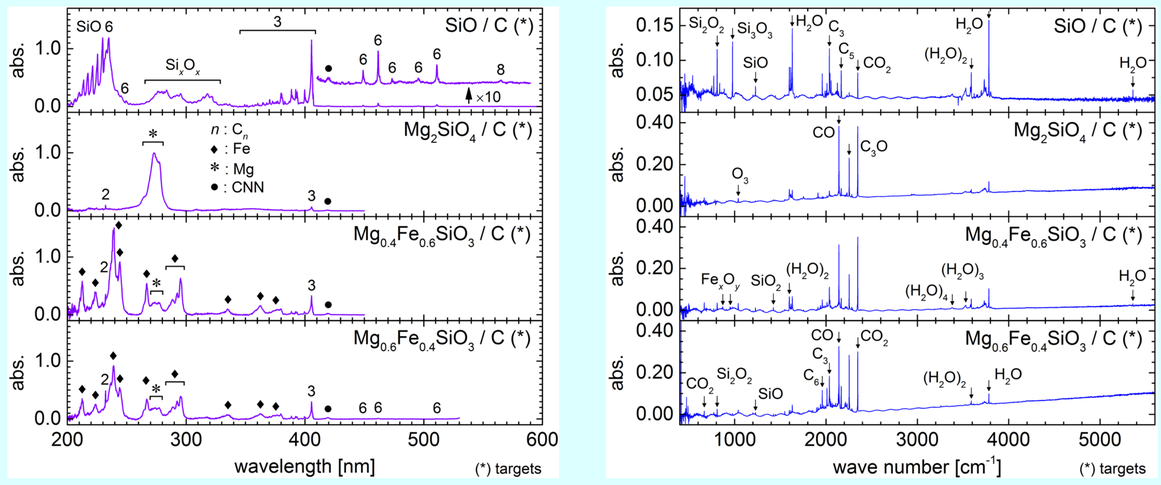
Images revealing the condensates as fluffy µm-sized aggregates of nm-sized units partially fused.

The matter of the condensates is amorphous although some nanocrystals are found.

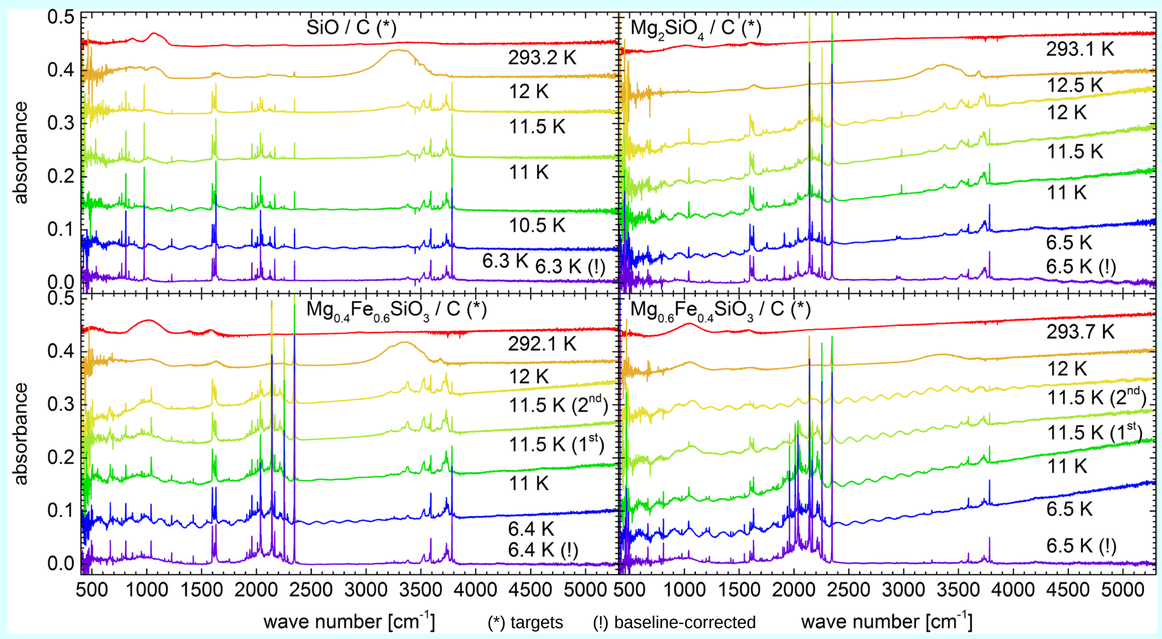
The condensates are composed of separate carbonaceous matter and solid complex silicates. *No SiC is found.*

Absorption spectroscopy

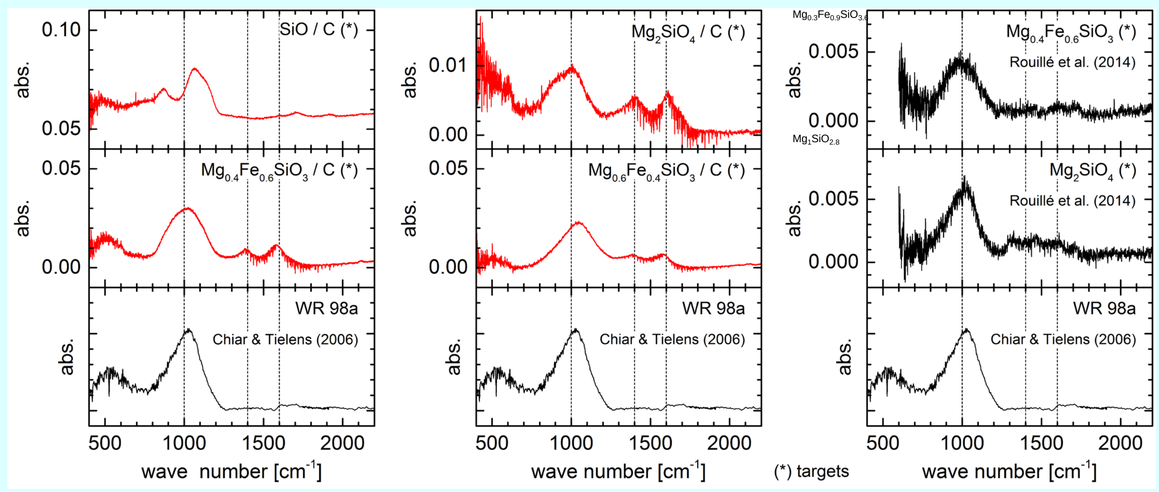
Spectra of Ne ices (≈ 6.5 K) doped with precursors of silicates and carbonaceous matter, H_2O, CO, CO_2, and other molecules.



Mid-IR spectra measured during the annealing and evaporation of the doped Ne ices.



Room-temperature spectra of condensates compared with extinction towards WR98a.



Results and astrophysical implications

(1) Refractory solids of amorphous complex silicates and carbonaceous matter are formed at cryogenic temperatures through accretion of atomic and molecular precursors and barrierless chemical reactions.

Silicate and carbonaceous grains can grow in the diffuse cold neutral ISM provided that precursors are present in the gas phase and a mechanism removes other adsorbed species.

(2) At cryogenic temperatures, precursors of silicates (resp. carbon) do not react with those of carbon (resp. silicates). Notably SiC is not formed.

Precursors of carbonaceous matter (resp. silicates) adsorbed on a silicate (resp. carbonaceous) seed are removed, thus causing the separate existences of carbonaceous and silicate grains.

(3) At cryogenic temperatures, the main ice-forming molecules H_2O, CO, and CO_2 do not react with the precursors of the refractory materials.

Silicates and carbonaceous solids can grow in dense media provided that accumulated ices are periodically sublimated.

Silicates and carbonaceous grains may grow in the diffuse cold neutral ISM and in dense clouds although the temperatures are low.

Acknowledgments

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Literature

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