Interstellar dust analogues synthesized in plasma

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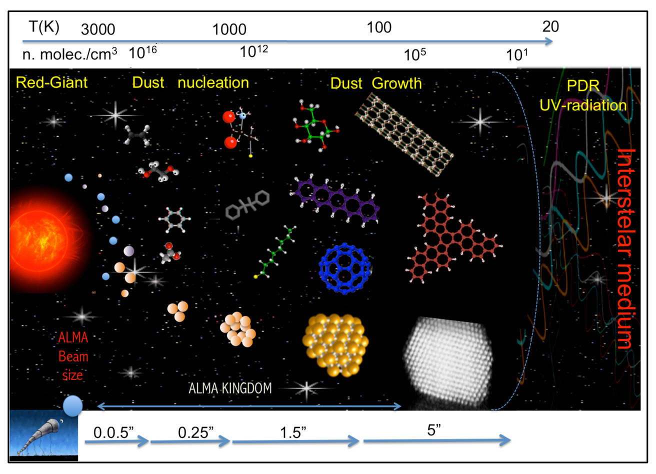
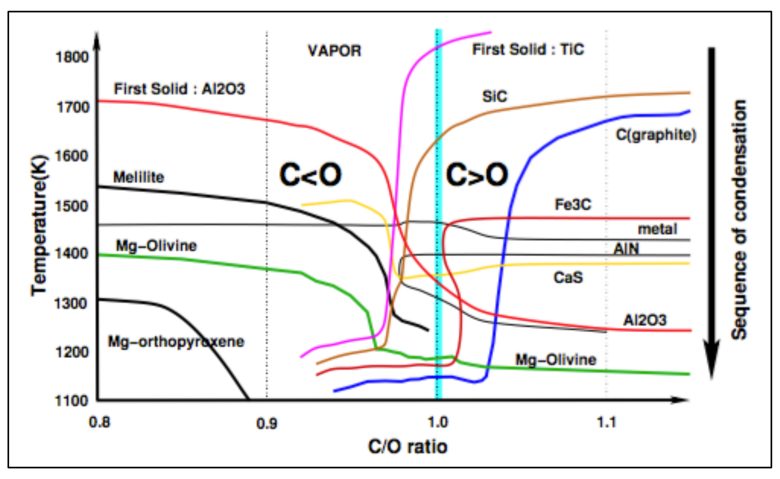
Context and aim of the project

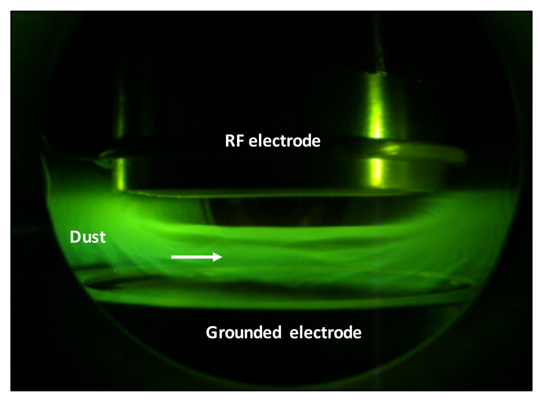
The aim of the **Nanocosmos** project is to understand the **composition** and the **evolution** of dust formed in the envelopes of evolved stars. This dust is made of nanograins that are formed through two different chemical pathways depending on the **C/O** ratio. A ratio **C/O > 1** leads to carbonaceous grains, whereas a ratio **C/O < 1** leads to oxides (mainly silicates). In addition **metals** (Mg, Fe, Ti, Al) are involved. In my PhD project, I explore the impact of C/O ratio and metals on dust formed in a **plasma** environment.



Simplified scheme combining C-rich and O-rich chemistries of dust formation in an evolved star (AGB)



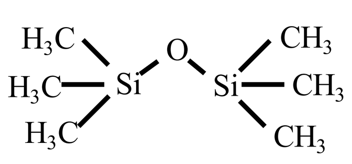
Classical model for dust condensation sequence as a function of the temperature and varying C/O ratio (from Ref 1)



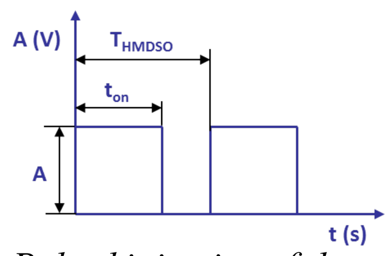
Dust scattering observed in the discharge (false colour)

Dust synthesis

Dust nanoparticles are produced in an argon **plasma** with **pulsed injection** of hexamethyldisiloxane (**HMDSO**) (Ref 2). The **axial-asymmetry** of the discharge allows the injection of **metals** in the plasma by sputtering of a metal target.

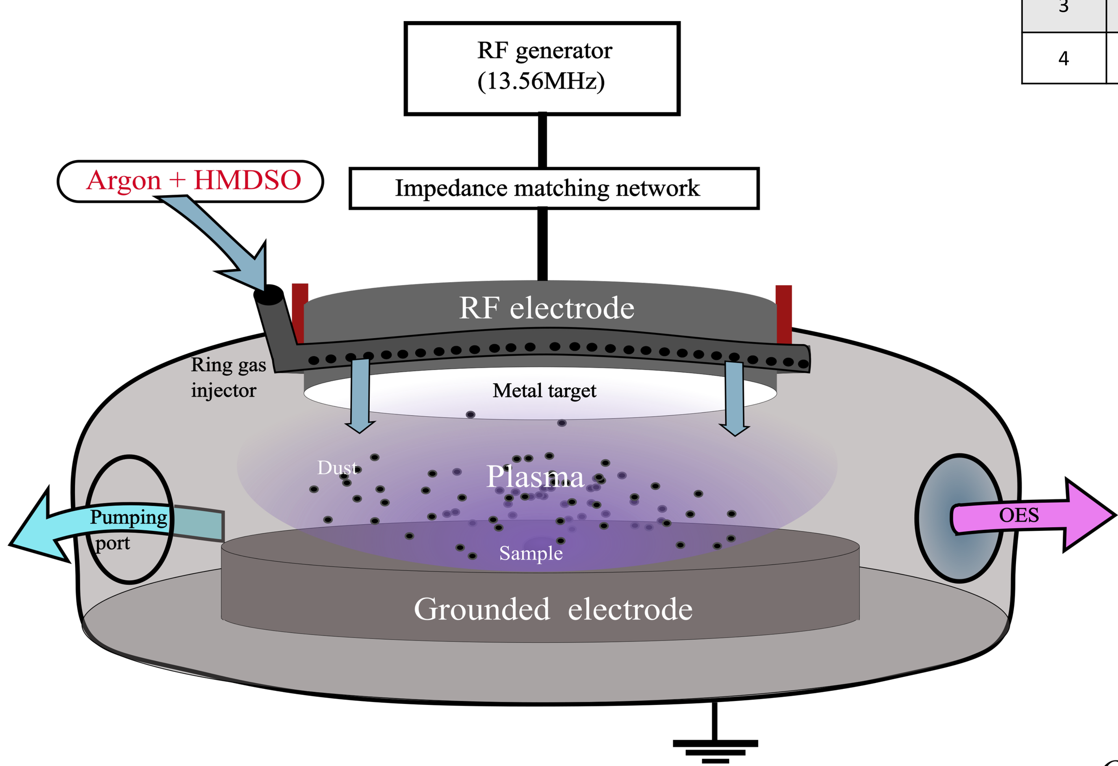


Hexamethyldisiloxane (HMDSO), C/O=6



Pulsed injection of the precursor

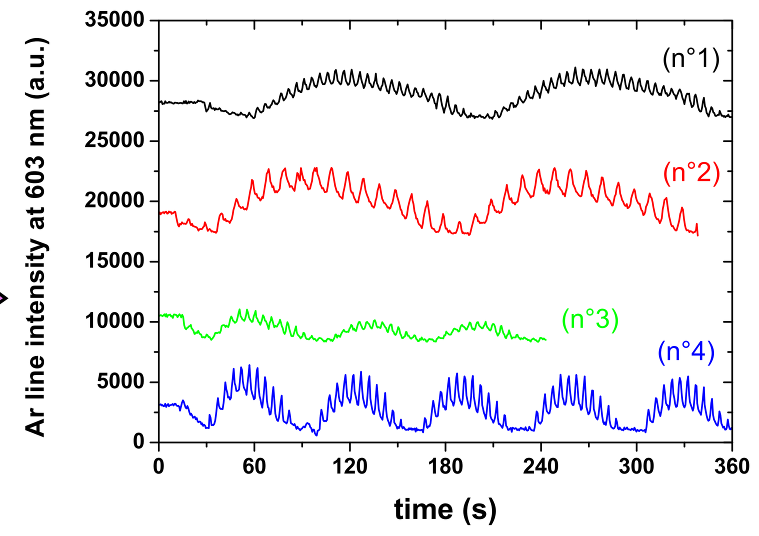
General characteristics:
- Axially-asymmetric capacitively-coupled RF discharge (13.56 MHz)
- Pressure argon: 40mTorr (2.8sccm)
- Power: 10 – 60 W
- Pulsed injection of HMDSO
- O_2 influence
- Metal target (Silver or Iron)



Plasma reactor scheme

case n°	Power, P (W) V_{DC} (V)	HMDSO average flow (sccm)	HMDSO pulse t_{on}/T	Dust period T_{dust}
1	10 W (-360V)	0.28	3.5s/ 5s	160 s
2	10 W (-370V)	0.28	7.0s/10s	160 s
3	10 W (-377V)	0.56	3.5s/ 5s	70 s
4	60 W (-750V)	0.56	3.5s/ 5s	70 s

Plasma conditions explored



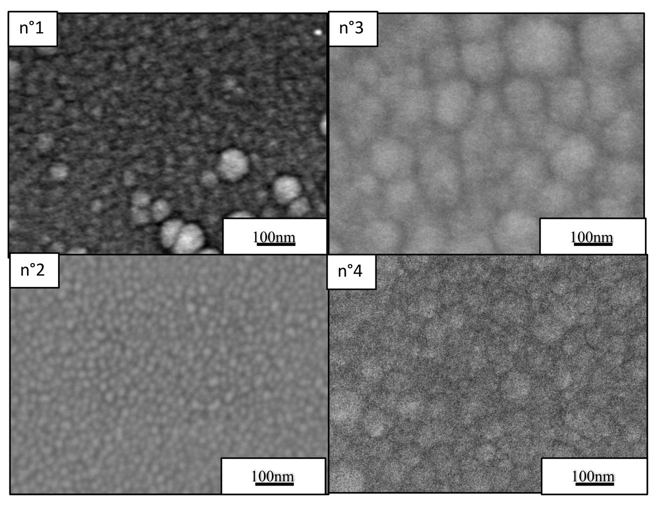
Optical emission spectroscopy of Argon line (603 nm) following dust formation

Optical emission spectroscopy shows a **double cyclic** behaviour.
- **Cyclic injection** of HMDSO (higher frequency).
- **Cyclic dust appearance-disappearance** (lower frequency).

Dust morphology

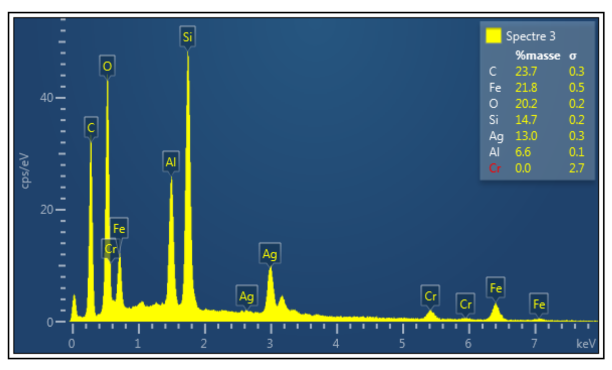
Scanning electron microscopy (SEM):
- **Dust size** depends on experimental conditions.
- **Larger** particles are formed for **higher HMDSO flow**, however other parameters such as RF-**power** and **duty cycle** may also have a role.
- What is the size of primary particles ?
- Are large particles made of primary particle aggregates?

45 nm
126 nm
18 nm
65 nm



SEM observations and average size of dust

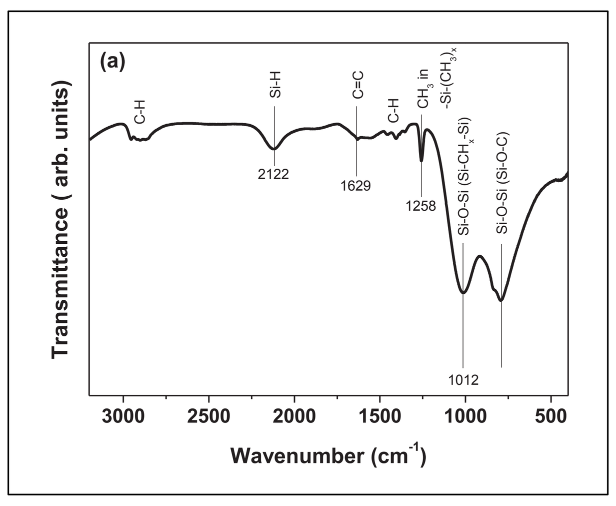
Dust composition



EDX analysis of the dust on a stainless steel substrate

Energy dispersive X-ray spectroscopy (EDX) shows:
- A bulk composed of **carbon**, **oxygen** and **silicon** resulting from the **HMDSO precursor.**
- **Silver** atom from the **metal target.**
- Aluminium, chromium and iron from the substrate.

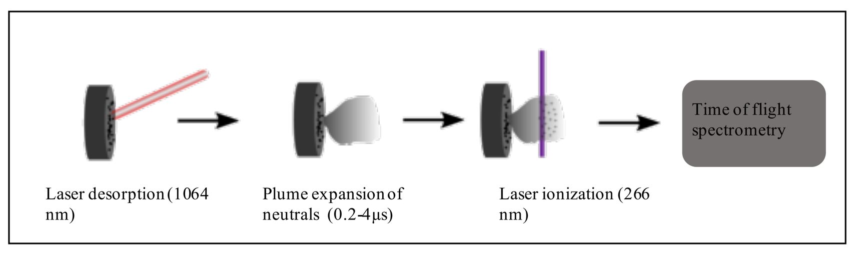
ESPOIRS set-up, IRAP



Infrared analysis (ESPOIRS set-up, IRAP).

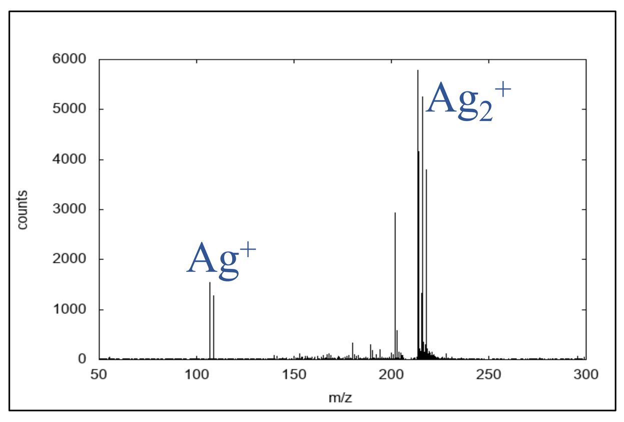
Infrared spectroscopy analysis of a HMDSO deposition shows:
- A thin film, composed of CH_x bonds and Si-O bonds related to HMDSO groups.
- C=C bonds witch implies chemistry inside the plasma.

Dust molecular content



AROMA set-up (LCAR/IRAP)

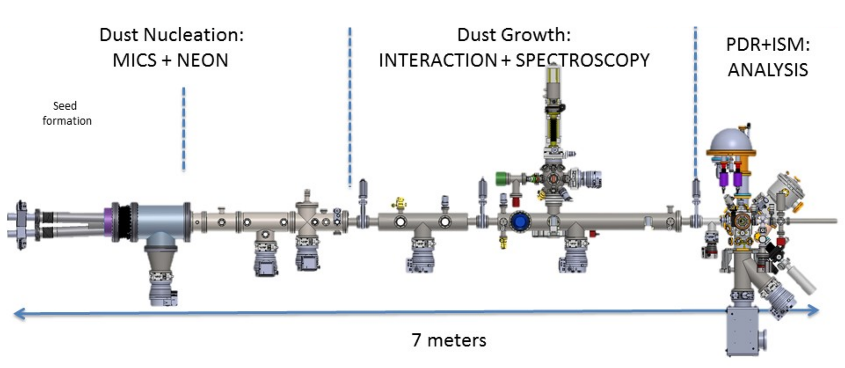
Mass spectrometry:
- **Two-step laser desorption-ionization.**
- **Silver atoms and clusters** identified.
- No molecular compounds observed. The peak at m/z=202 is a contaminant from a previous experiment.



Mass spectrum analysis

Summary and perspectives

With HMDSO as precursor in an **argon plasma**, we produced dust nanoparticles containing **atoms of carbon, silicon, oxygen and silver.** We presented here the methodology to characterise the dust size, and molecular composition. In the future, we will change the C/O ratio by injecting O_2. **Iron** will be used instead of silver to be more relevant to **cosmic environments**. Our results will be used in synergy with the experiments using the stardust machine, a reactor developed to simulate dust formation in evolved stars.



Stardust machine (ICMM-Madrid)(Ref 3)

References

1- E.Dartois,, ASP Conference Series, Vol. 344. 2005
2 - B. Despax, K. Makasheva and H. Caquineau, J. Appl. Phys., 112, 093302, 2012
3- http://www.icmm.csic.es/nanocosmos/

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