

Thermal decomposition rate of $MgCO_3$ as representative carbonate in meteorites.

Gaia MICCA LONGO^{1,2}, Enrico BISCEGLIA¹, Savino LONGO^{1,2}

¹Dipartimento di Chimica, Università degli Studi di Bari, via Orabona 4, I-70126 Bari, Italy

²CNR-Nanotec, Bari section, via Amendola 122/D, I-70126 Bari, Italy

gaia.miccalongo@nanotec.cnr.it, enrico.bisceglia@studenti.uniba.it, savino.longo@nanotec.cnr.it

Introduction

Carbonate minerals, included into orthopyroxenite, have been extensively studied in the ALH 84001 meteorite. These minerals may play an important role in the delivery to the Earth of complex organic matter produced by different pathways in Space [1,2]. In particular, thermolabile organics associate to inorganic carbon may profit of the large decomposition enthalpy and facile decomposition of these minerals at moderate temperatures to gain considerable thermal protection during the entry process.

Thermal effects experienced by micro-meteoroids entering the Earth's atmosphere have been intensively studied [3,4] and these results have been preliminary reproduced by the authors assuming a silicate composition. Then, in view of the predominance of Mg in these carbonates, pure magnesite ($MgCO_3$) is proposed as a mineral model [5]. This mineral is much more sensitive to high temperatures reached during an entry process, compared to silicates, due to decomposition into MgO and gaseous carbon dioxide $MgCO_3 \rightarrow MgO + CO_2$. A most important quantity for further studies is the decomposition rate expressed as carbon dioxide evaporation rate J (molecules/ m^2s). An analytical expression for $J(T)$ is given using the Langmuir law, based on CO_2 pressure in equilibrium with $MgCO_3$ and MgO at the surface temperature T [6]. From this expression, the equilibration temperatures for micrometeoroids rich in carbonate are estimated.

Different entry scenarios are elaborated using a standard trajectory/thermochemical model.

Methods

The kinetic and thermochemical model for micrometeoroids entering Earth's atmosphere is fully described in [4]; this model has been used for silicate (validation and improvement) and carbonate micrometeoroids (for the first time).

To fully treat the energy loss, both radiative and evaporative contributions have been considered here:

$$P_{in} = 4\pi r^2 (\epsilon\sigma T^4 + H_v C p_v \sqrt{m_{mol}/T})$$

Concerning mass loss:

$$\dot{m} = 4\pi r^2 C p_v \sqrt{m_{mol}/T}$$

r = particle radius
 T = temperature
 H_v = latent heat of vaporization
 C = Langmuir formula constant
 p_v = vapor pressure
 m_{mol} = molecular weight

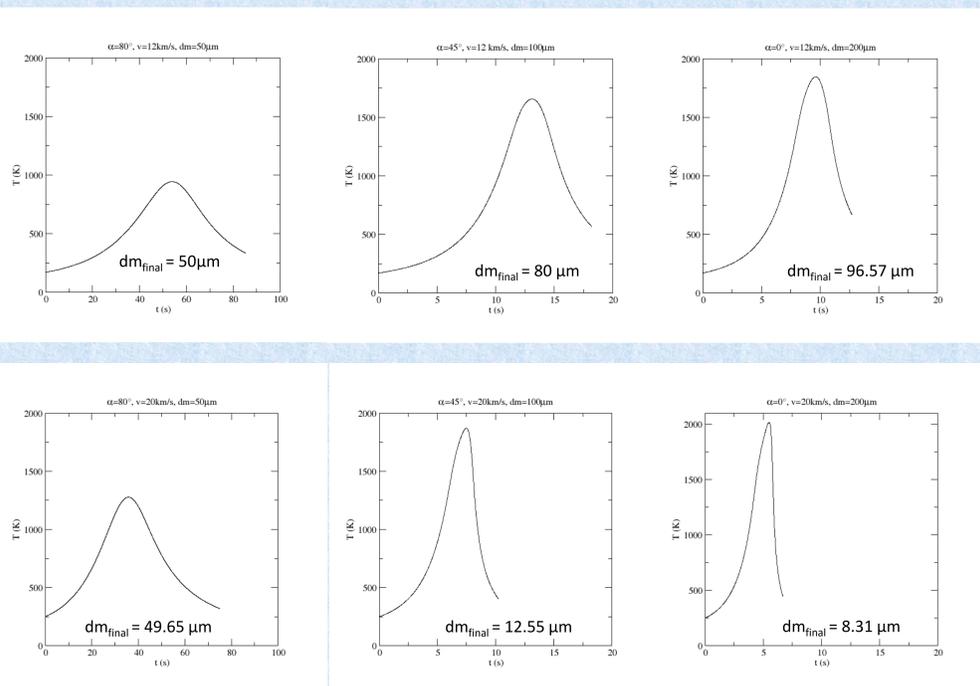
The simulations begin at 190 km altitude, with velocity and entry angles as free parameters. The micrometeoroid material density is set at 3 g/cm³, both for silicates and carbonates.

While studying carbonates, assumptions have been taken into consideration:

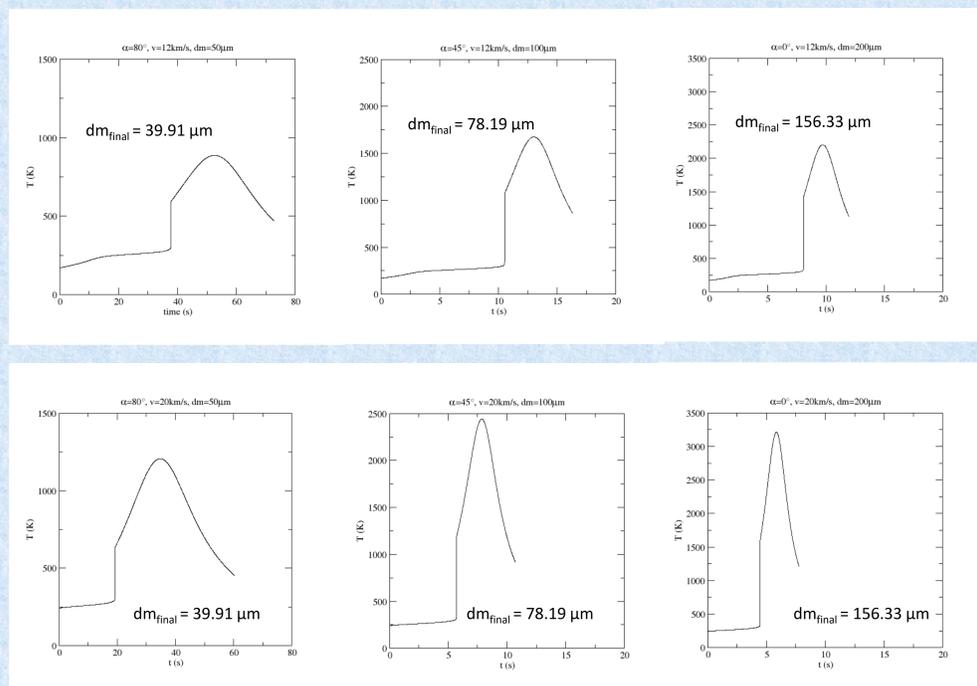
- $p_v = X_{MgCO_3} p_{vc}(T)$ (where X_{MgCO_3} is given by stoichiometric balance and p_{vc} is the pressure of CO_2 in equilibrium with the pure carbonate);
- pure $MgCO_3$ grain enters the Earth's atmosphere;
- the decomposition velocity is calculated using the Langmuir formula;
- there are no limits for CO_2 diffusion into the material;
- mass loss and evaporation continue until complete stoichiometric conversion to MgO is reached.

Results

SILICATES



CARBONATES



Conclusion

Results for silicates serve as validation and as an improvement for the model inspired by [4].

The carbonate grain, while entering the atmosphere, gradually release CO_2 and it becomes a solid mixture of carbonate and oxide. CO_2 evaporates until the grain becomes pure oxide. At this point, the grain mass does not change anymore and the temperature increases dramatically (only mitigated by black body radiation).

In perspective, other minerals, that might guarantee a better thermal protection, will be taken into consideration.

References

- [1] McKay D. S. et al. (1996) *Science* **273**:924-930.
- [2] McKay C. P. et al. (2003) *Astrobiology* **3**(2):263-270.
- [3] Öpik E. J. 2004 *Physics of Meteor Flight in the Atmosphere* Courier Corporation, New York
- [4] Love S. G. and Brownlee D. E. (1990) *Icarus* **89**:26-43.
- [5] Thomas-Keprta K. L. et al. (2009) *Geochim. Cosmochim. Acta* **73**:6631-6677
- [6] Bisceglia E., Micca Longo G. and Longo S. (2016) *Int. J. Astrobiol.*, FirstView:1-7, DOI 10.1017/S1473550416000070