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► **To cite this version:**

Edith Hadamcik, Jean-Baptiste Renard, Laifa Boufendi, Guy Cernogora, Anny Chantal Levasseur-Regourd, et al. Light Scattering Measurements with Dust of Interest for IMPF/IMPACT. 4th International Conference on the Physics of Dusty Plasmas, Jun 2005, Orléans, France. 4 p., 10.1063/1.2134617. insu-02926333

HAL Id: insu-02926333

<https://insu.hal.science/insu-02926333>

Submitted on 31 Aug 2020

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Light Scattering Measurements with Dust of Interest for IMPF/IMPACT

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Abstract. Light scattering can be used to characterise the physical properties of solid particles (size, refractive index) in dusty plasmas. In the present study, we have collected the dust made in one Argon-silane RF plasma and two Nitrogen-methane RF plasmas. We present polarimetric phase curves of the scattered light obtained ex-situ by the PROGRA² experiment. We propose some interpretations in terms of physical properties of the studied particles.

INTRODUCTION

Numerous measurements have been performed with the PROGRA² experiment (French acronym for Propriétés Optiques des Grains Astronomiques et Atmosphériques) to build a database and to allow the determination of the physical properties (size, morphology) of dust particles of astrophysical and atmospheric interest [1] and to prepare the IMPACT-ICAPS experiment on board the ISS [2]. New series of measurements, including measurements on dust particles produced by RF plasmas are now taking place.

The PROGRA² experiment measures the phase and wavelength dependence of the linear polarization of the light scattered by dust particles. The particles in a vial are lifted either in microgravity conditions (during CNES/ESA airplane campaigns) or by an air-draught in ground-based conditions. The light sources are randomly polarized lasers (red 633 nm and green 543.5 nm). Measurements can be made in a 5°-170° phase range. Two CCD cameras measure the component parallel and perpendicular to the scattering plane [3]. As previously done for other samples [4,5], the goal of this study is to correlate the phase curves parameters with the physical properties of the sample, such as the size and size distribution of the constituent grains, the refractive index and the morphology of the particles. We present here first results for dust lifted by an air-draught.

TABLE 1. Plasmas conditions for dust production

Plasmas Composition	Pressure	Temperature	Absorbed power	Duration	Particles size and colour
20 sccm Ar, 1.8 sccm SiH ₄	122 μ bar	ambient	10 W	30 s pulse x 256	(90 \pm 20) nm reddish
98% N ₂ , 2 % CH ₄ total 55 sccm	1 mbar	ambient	30 W	continuous	(720 \pm 200) nm dark brown
90% N ₂ , 10 % CH ₄ total 55 sccm	1 mbar	ambient	30 W	continuous	(650 \pm 400) nm pale brown

SAMPLES

The samples are dust particles produced by RF capacitively coupled low-pressure plasmas. The first one was produced in an Argon-silane mixture at GREMI. Two Titan's aerosols analogues (tholins) were also produced in Nitrogen-methane mixtures with the PAMPRE experiment at Service d'Aéronomie. The conditions of production are given in table 1 (see also [6], for the description of the PAMPRE experiment).

The Argon-silane dust is composed by grains with a (90 \pm 20) nm size range (Fig. 1 a), with a core obtained by coalescence and a surface deposition of SiH_x species on individual grains [7]. The colour is reddish.

The two Nitrogen-methane samples (tholins) have brown colours. The dust produced with 2 % methane is darker than the dust produced with 10 % methane. The size distribution of the 2 % sample is narrower than of the 10 % sample, (720 \pm 200) nm; although some micron-sized grains are observed; the grains are individual. The size distribution of the 10 % sample is larger, (650 \pm 400) nm, a large number of sintered grains is found in micron-sized aggregates (Fig. 1c).

The particles in the field of view of the PROGRA² cameras are loose agglomerates (50-100 μ m) of the constituent grains. The phase curves depend mainly on the size on the constituent grains, on the refractive index of the materials and on the wavelength [4,5].

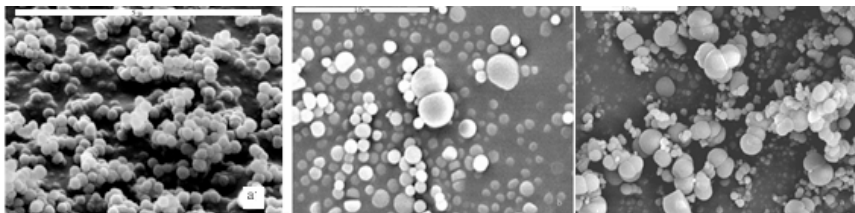


FIGURE 1. SEM images. a. Dust grains from Argon-silane plasma (scale 5 μ m)
 b. Dust particles from Nitrogen-methane (2 %) plasma (scale 10 μ m)
 c. Dust particles from Nitrogen-methane (10 %) plasma (scale 10 μ m)

RESULTS AND DISCUSSION

Differences are observed between the phase curves of the studied samples: the phase angle at maximum (influence of the real part of the refractive index) and the inversion angles are different for the silane dust and the tholins (Fig. 2 and 3). The three polarimetric phase curves present a negative polarization in the back scattering region up to a phase of about 20° for the silane dust and 50° for the tholins. The positive branch is bell shaped. By comparison to previous studies some characteristics of the particles can be deduced from the phase curves.

For the silane sample, the negative branch could be the result of the coating by the SiH_x radicals, such results were obtained by numerical simulations for aggregates of silicate coated spheres [8]. To interpret the deeper negative branch for the 2 % tholin as compared to those obtained for the 10 % one, more investigations are necessary (e.g. refractive index determination).

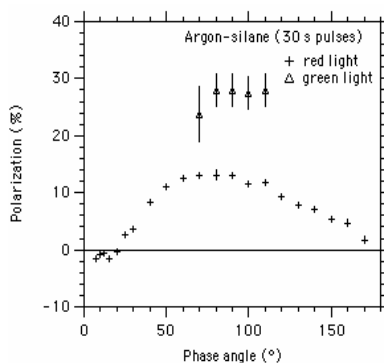


FIGURE 2. Polarimetric phase curve, dust from an Argon-silane RF plasma

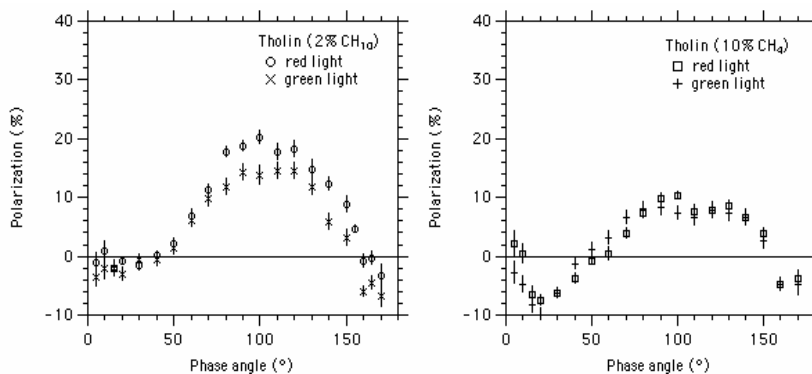


FIGURE 3: Polarimetric phase curves, dust from a Nitrogen-methane RF plasmas.

The fact that the polarization at maximum is higher in green than in red is likely to be the result of larger absorption in green than in red (reddish colour of the sample). The lower polarization at maximum for the 10 % sample reflects the presence of micron-sized single or aggregated grains and a lower absorption as compared to the 2 % sample. For light scattering, a key parameter is the size parameter (ratio of the perimeter to the wavelength). It could be the reason why the maximum polarization is higher in red than in green for the 2 % sample (which presents a relative narrow size distribution) and why it is lower for the 10 % sample (lower number of micron-sized particles).

CONCLUSION

Significant differences are noted between the retrieved phase curves, and the wavelength dependence thereof, for the three dust samples produced by RF plasmas. Up to now, the size distribution is too large, the refractive index is not known and it is difficult to go further in the interpretations. Mono-disperse grains are needed to build a database for RF produced plasmas, and then it will be possible to study the particles growth in the reactors.

ACKNOWLEDGEMENTS

This work was supported by CNES.

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