Shock Induced Formation of Cosmic Mineral Dust Analog in Laboratory using High Intensity Shock Tube for Astrochemistry. Arijit Roy[1,2], V S Surendra[1], J K Meka[1], R Ramachandran[1], D Sahu[1], W Khan[1], S Gupta[1], V Thiruvenkatam[2], J Cami[3], V Venkataraman[4], H Hill[5], P Janardhan[1], Anil Bhardwaj[1], N J Mason[6], B Sivaraman[1]. [1]Physical Research Laboratory, Ahmedabad, Gujarat, India, 380009 (arijit@prl.res.in, bhala@prl.res.in), [2]Indian Institute of Technology, Gandhinagar, India, [3] Western University, Ontario, Canada, 4 Space Physics Laboratory, Trivandrum, India, [5] International Space University, Strasbourg, France, [6]University of Kent, Canterbury, United Kingdom.

Introduction: Submicron to nanometer-size dust plays a significant role in the synthesis of molecules on the interstellar medium (ISM). A substantial amount of interstellar dust is thought to be produced via gas-phase condensation processes in the presence of winds of Asymptotic Giant Branch (AGB) stars [1]. The elemental abundance of these stars greatly affect the chemical compositions of these dust grains especially the C/O abundance ratio as these two elements are major after Hydrogen and Helium of these stars. For the case of C/O <1, the dust grains are mostly oxides like olivine, pyroxene, spinel etc.; for the possibility of C/O >1, dust grains are carbonaceous like SiC, C_{60}, and other carbon allotropes [1]. Signatures of the olivine and pyroxene class dust around O- rich AGB stars have been traced by studying infrared active features around 10, 18 μm, which have been assigned to the stretching of Si-O and bending motion of the O-Si-O bonds [2]. Carbonaceous dust like SiC has been detected around C- rich AGB stars using the 11.3 μm feature [3].

However, our understanding of the formation mechanism of these dust grains, especially for the mineral dust like olivine, and SiC in the stellar environment is limited. The formation of dust in the stellar envelope is a very complex process, which starts from molecular mixtures in the gas phase, and molecular clusters are made after a series of chemical reactions. The subsequent growth of molecular clusters fashions a solid dusty seed, which provides a finite surface for further dust growth [1]. The thermodynamic conditions, elemental mixing, metallicity and stellar radiation field influence the sequence of dust formation, which affect the structure, morphology and spectral properties of the product dust grains. A combined effort of theoretical and experimental studies is required to understand the formation pathways of dust formation, including information about the molecular precursor, intermediate products, and various possible end products.

Shock waves can play a vital role in the cosmic dust enrichment processes. Optical and infrared spectroscopic observations on the Nova V2891 have shown evidence of shock-induced dust formation [4]. Nebular shock heating of cometary materials has also been proposed to produce crystalline silicate grains [5]. Laboratory investigation of shock-induced dust formation is therefore an evolving topic in astrochemistry and laboratory astrophysics [6,7,8].

Low velocity ($3 < M < 10$) shocks in the ISM are known to enrich its propagating medium through thermal processing [9]. In this work, we studied low velocity (5.6 M) laboratory shock processing of stoichiometric mixtures of silicate dust and SiC dust. Processed samples showed the presence of mineral dust like forsterite and SiC.

Methodology: High-Intensity Shock Tube for Astrochemistry (HISTA) housed at PRL, Ahmedabad, India, was used to mimic low-velocity interstellar shock conditions. It is a 7 m long shock tube with a driver section, of length 2 m and a driven section of length 5 m, and an aluminum diaphragm of thickness 2 mm separates these two sections. Usually, the driver section is filled with high-pressure helium, and the driven section with low-pressure argon. A detailed explanation of the HISTA setup and procedure can be found in the literature [9,10]. Details of the different samples having stoichiometric mixtures of silicate dust (**S1-3**), and SiC dust (**C1**) used in this experiment can be found in **Table 1**. About 0.1 gm of the sample was used in every set of experiments and processed up to shock strength ~ 5.6 M for 2 ms, which elevated the gas temperature to ~ 7300 K. The processed materials were collected and stored in inert conditions and further structural and morphological analysis were carried out using X-ray diffraction (XRD), Infrared Spectroscopy (IR), Field emission Electron Microscopy (FE-SEM), High- Resolution Transmission Electron Microscopy (HR-TEM).

Results and Discussion: The X-Ray Diffraction (XRD) pattern of both the shocked and unshocked mixture of sample **S1** is shown in Fig1. Patterns in the lower panel belong to the unshocked sample whereas the upper panel consists of its shocked counterpart. The diffraction pattern of the unshocked sample consists of a broad feature spread around 20 º to 30 º as marked by a blue triangle indicating the presence of SiO_2, and very well-spaced sharp peaks marked by blue stars are within the range of $2\theta \sim 32$ º to 77 º indicating the presence of Mg. In the upper panel, the XRD pattern of the shocked sample is much more complex and contains a few new peaks marked by black and red colour stars along with the existing peaks of Mg. Those marked with a black star are assigned to the forsterite (Mg_2SiO_4) (CODID-1010497), whereas the red stars are for the Si. Phases like MgO or simplest Mg-rich pyroxene class dust Enstatite (Mg_3SiO_4) are not observed in the shocked sample.

The XRD pattern of the unshocked and shocked samples of C1 is shown in Fig 2. In the lower panel, the unshocked sample showed the presence of amorphous carbon around 26º, marked by a black star. The blue stars show the presence of Si. In the upper panel for the shocked processed sample, the blue arrows are assigned to the cubic SiC (CODID-1011031), whereas the red arrow around 33.8º indicates to hexagonal SiC. Reduction in the band area of the 26º feature for the shocked sample suggests the sample has gone through graphitization processes. The saffron colour tringles show presence of aluminium, a contamination the diaphragm.

Conclusion: We studied shock processing (5.6 M) of different stoichiometric mixtures of cosmic silicate and SiC dust analogue. The primary result from XRD shows the presence of Mg-rich olivine dust, forsterite in sample **S1** and SiC in the shocked samples of **C1**. No pyroxene class of dust has been observed. In this meeting, we will discuss the detailed results from all experiments (**S1-3, C1)** and their implications for cosmic dust formation through shock processing.

Table 1: List of experiments and the parameters involved.

No	Sample	Mach (M)	Processing Temperature (K)
S1	Mg + SiO_2 (1:1)	~ 5.6	~ 7300
S2	**S1**+ Fe (1:1)	~ 5.6	~ 7300
S3	Fe+ SiO_2 (1:1)	~ 5.6	~ 7300
C1	C+ Si (2:1) in H_2	~ 5.6	~ 7300

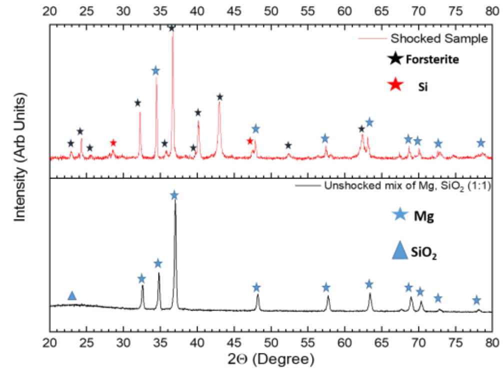

Fig 1: *XRD pattern of the unshocked and Shocked sample of **S1**.*

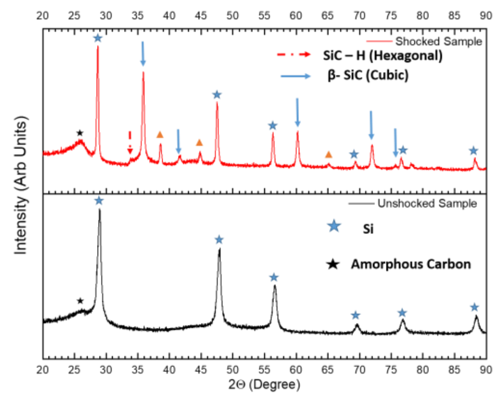

Fig 2: *XRD pattern of the unshocked and shocked sample of C**1**.*

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