Discovery of complex macroscale structures in impact induced shock processed biomolecules - Implications to the Origins of life. V S Surendra1,*, V Jayaram2, S Karthik3, S Vijayan1, V Chandra Sekaran3, R Thombre4, T Vijay5, B N Raja Sekhar6, A Bhardwaj1, G Jagadeesh1, K P J Reddy1, N J Mason4, B Sivaraman1,*, 1Physical Research Laboratory, Ahmedabad, India, 2Indian Institute of Science, Science, Bangalore, India, 3Vellore Institute of Technology, Vellore, India, 4Modern College of Arts and Science, Pune, India, 5Indian Institute of Technology Gandhinagar, Gandhinagar, 6BARC at RRCAT, Indore, India, 7Indian Institute of Science, Bangalore, India, 8University of Kent, United Kingdom. *Email: surendra@prl.res.in, bhala@prl.res.in

Introduction: Impacts play a profound role in planetary system formation and evolution. A wide variety of impact features have been observed on the Solar System bodies showing evidence of impact activity in the past. Such impacts will create shock wave because of sudden compression and produce sharp increase in pressure and temperature, and subsequent cooling due to the expansion, which induces chemical pathways for complex molecular synthesis. Shock driven synthesis, thus can be a possible inventory for synthesis of complex molecule on Solar System bodies. Previous experiments have reported that impact-shock processing of simple molecules can lead to the synthesis of building blocks of life such as amino acids [1]. A recent study reported molecular dynamics simulation that shows that shock wave drives the synthesis of glycine containing complexes when passed through an icy mixture representative of a comet [2]. However, the fate of these amino acids remains unexplored when subjected further to impact-shock conditions. Blank et al. [3], performed an impact experiments on aqueous solution of amino acid at room temperature and observed the signature of peptides. While Sugahara and Mimura [4], performed impact experiments under cryogenic condition and also found signature of peptides. Here, we set out to experimentally verify shock processing of amino acids and nucleobases.

Experimental set-up: The experiments were performed in a 7-meter-long, gas-driven shock tube with driven side pumped down to 10^-4 mbar and purged with argon to avoid any contamination of gases and 40-60 bar on the driver side. The driven and drive section is separated by an aluminium diaphragm of 2 mm thickness using high pressure helium gas cylinders. Samples were placed in a reaction chamber at the end of the driver section separated by a ball valve. Shock temperature ranges from 1500 K to 8000 K over 2 ms timescale. Starting with the simplest amino acid glycine, we have used different combination of mixtures containing 2, 4, 18 and 20 different amino acids and mixture of nucleobases in equal weight proportion [5]. The shock processed samples were further analyzed using Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) to understand the effect of shock on biomolecules.

Results: Shocked samples are subjected to SEM analysis, and we have observed the formation of complex macroscale structures. We also observed certain geometric structure like threads, ribbons with smooth texture. On increasing the combination mixture of amino acids, we observed more complex structures. While adding glutamic acid to glycine, a bunch of flower petals appeared. With further adding two more amino acids, we observed cylinder tube with complex patterns. With 18 mixtures of amino acids, complex structure containing tubes, folded and twisted threads were observed (Fig. 1). Similar patterns were also observed with nucleobases and other amino acid mixtures.

Discussion: Our experiment provides compelling evidence of a synthetic pathway of complex macroscale structures from the building blocks of life under impact-shock condition. The results are a significant step towards our understanding of origins of life. Given plethora of Solar System bodies with necessary composition, impact-shock could have act as a driving force to form more complex assemblies. Furthermore, our experiment could also be a possible explanation for the thread like features reported in the meteorites [6], which were initially suggested to be fossilized life form, which could be the aggregation of molecules, that have been shock processed during impact events. Further experimental investigation are under pipeline which will enhance our understanding in this field.