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Peptide containing complex macroscale structures synthesized in shock processing of amino acids: A pathway for the origin of life

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Abstract

During the evolution of life on Earth 3.8□Gyr ago, the Earth was heavily bombarded to impact events, like Late Heavy bombardment, bombardment by comets, meteorites, and asteroids that delivered necessary life ingredients such as amino acids to the Earth which are the basic building blocks of life[1,2]. The famous Miller's experiment also demonstrated the possible mechanism for abiotic synthesis of amino acids under prebiotic conditions on the Earth[3]. However, there is little information available on the subsequent steps, i.e., the formation of polypeptides, which play a critical role in mediating cellular structure, function, and interaction[4]. The presence of impact craters on planetary bodies remind the role impact events may have played in Solar System formation and evolution. The impact-induced shock in such events could be a profound source for complex chemistry to occur on planetary bodies. Previous studies suggest that such a process can synthesize biomolecules such as amino acids, nucleobases and peptides[5-7]. However, the role of impact processes and its subsequent steps, in prebiotic evolution are poorly understood. In the present investigation, we performed a series of experiments to study the effect of impact shock on amino acids.

We exposed various single amino acid and as well as mixtures of amino acids containing two, four, eighteen and twenty different combinations, to strong shock waves at different Mach number ranging from 4-6 with reflected shock pressure of about 12-40 bar and temperature of about 2500 K-8000 K (estimated) for 1-2 ms time scale utilizing shock tube facility at IISC Bangalore and PRL Ahmedabad, India. Infrared signatures of shock processed solid residue revealed the signature of peptide bond on exposure to impact shock. Analysis using electron microscopic analysis provided insights into the structure and self-assembly of the formed peptides. The SEM micrographs of shock processed residue suggest that amino acids polymerized to create ordered arrangments containing twisted and folded threads, floral structures, globule, and tubular structures with complex textures (Fig 1). We performed a series of experiments containing the various amino acid mixtures at various shock conditions. A variety of structures were observed with a different combination of amino acids. The developed structures in shock processing of amino acids have striking similarities with various supramolecular structures possessed by peptide assemblies[8]. Our results are the first detailed report on the synthesis of self-assembling peptides from simple amino acids using an impact shock

generated in a shock tube.

We know life as a chemical building block of organic molecules. Molecules such as amino acids are considered as essential precursors of life and are known to be synthesized in various astrochemical environments. However, the prebiotic origin of biological structures containing proteins or polypeptides, nucleic acids, lipids, etc., which are the necessary component of cellular life, is still missing. Our experiments provide a possible route for the formation of complex macroscale structure that shows the evidence for the evolution of the building blocks of life under impact shock condition and provides new insights into the potential role of impact-driven shock processes in prebiotic evolution.

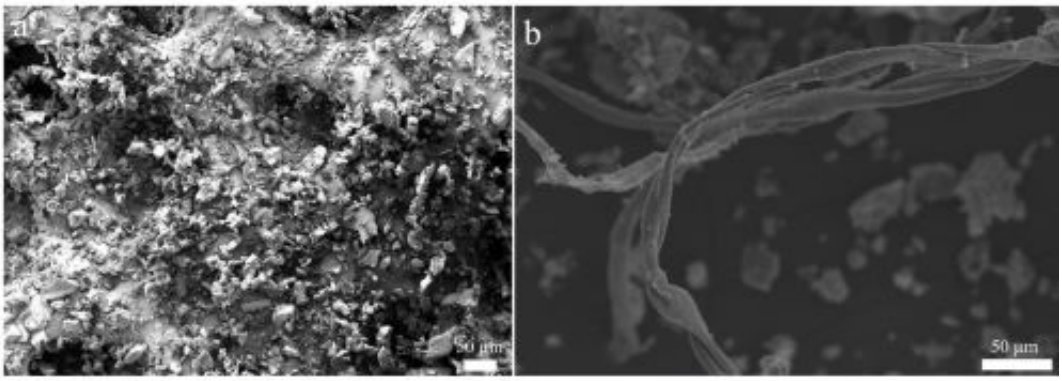

Fig. 1 SEM micrographs of (a) mixture of amino acids sample before shock (control) show micron-size particles, (b) complex structures in shock processed residue of 18 mixture of amino acids show the formation of helically twisted threads and flat ribbon structures.

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