Hypervelocity impact on amino acids-water ice targets leading to the formation of crystalline biomolecular dust.
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Introduction: Impacts are prevalent in the solar system and have played a profound role in the evolution of the solar system bodies. Moreover, the delivery of prebiotic compounds through impact events is thought to be a crucial step in developing habitable conditions on a planetary surface [1]. Impact events are, therefore, crucial in our understanding of the origins of life on Earth and elsewhere [2]. Icy bodies in the solar system are the next potential target for the search for signatures of life. The observation of large scale craters on the surface of the icy satellites reminds us the role of impact processes in planetary and lunar evolutions whilst many cometary bodies appear to the result of collision of constituent bodies. Such impacts release significant amounts of energy and therefore may provide pathways for large scale molecular synthesis. However, such impacts and the impact associated shock processing of molecules in extreme conditions are unknown to us. Here we present results from hypervelocity impact on amino acids embedded in water ice.

Experimental setup: The hypervelocity impact experiments were performed utilizing a two-stage light gas gun facility at the University of Kent. The detailed instrument parameters and capabilities can be found in Burchell et al. [3]. In the present investigation, we impacted a spherical bullet (stainless steel 420) of size 1 mm at velocity of approximately 5 km s^{-1} on the targets containing amino acids embedded in water ice at 140 K. For target preparation, the amino acids were dissolved in 150 ml HPLC grade water using a magnetic stirrer in a glass beaker to prepare a saturated solution and then cooled to 1.5°C. In a separate steel beaker, water ice is prepared frozen at -20°C. The solution of amino acid-water is poured into the beaker containing the water ice, and this whole mixture is cooled to 140 K in a freezer. The targets were kept in the freezer for almost 15-20 hours and removed from the freezer just before the firing to be mounted in the target chamber. Chamber walls are covered with aluminium foil to collect the ejecta from the target after projectile impact. After the impact, the ejected materials from the target are left on the aluminium foil in the chamber to be dried out entirely at room temperature and then collected for further analysis. Various targets containing single amino acids as well as mixtures of amino acids were studied.

Results and discussion: FESEM observation shows that remarkable morphological features are present in the ejecta. The morphological properties of ejecta from various targets were distinct. The ejecta residue showing the complex macroscale structures were analysed using LCMS. The LCMS analysis revealed the presence of various long peptide sequences in the ejecta. Further, the ejecta material after impact is analyzed using SCXRD (Figure 1). In the case of glycine target, we observed that the crystal structure obtained during the impact experiment has led to the α-form of glycine, which is the most common and the polymorphic form of glycine. The crystal structure consists of strong hydrogen bonds between the glycine chains, forming a closed loop 3D network. The intermolecular N-H---O interaction stabilizing the network. The obtained crystal structure belongs to the P21/n space group, β=111.7 (monoclinic) revealing an isostructural nature with the already reported polymorph of α-glycine [4,5]. Further, to quantify all the intermolecular interactions and their energies in the crystal packing, Hirshfeld analysis and two-dimensional fingerprint plot analysis is carried out.

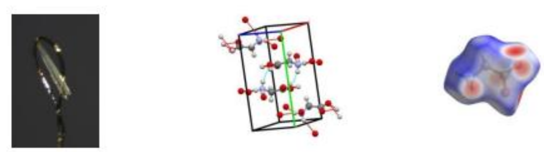

Figure 1: [Left] Ejecta sample mounted on to the 500 µm holder, [Center] Crystal packing of glycine and [Right] Hirshfeld analysis (dnorm).

The preliminary results suggest the plausible formation of biomolecular crystals from hypervelocity impacts. Such a formation might lead to the chemical transfer between the moons of the icy giants as these biomolecular dust are relatively stable to the extreme conditions.

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