

Self-replicating autocatalytic peptides on 2D sheets for emergent properties

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Did rocks harbour abiotic molecules and facilitate their assembly that eventually led to the origin of life on earth? Or, was there some other mechanism that kick-started life here? We would never know because several hypotheses hint at the origins of life, including metabolism first and ribonucleic acid first mechanisms that do not provide conclusive evidence yet. The recent explosion of research interests in studying the origin of life on earth has attracted several researchers already, especially young researchers, into this evergreen field with the currently unanswerable question regarding the origin of life on earth. The field has garnered curiosity among not just biologists, but also several chemists and geologists worldwide, as well as physicists and engineers.

Among the four generally accepted properties attributed to life that fall into broad categories such as metabolism, information transfer, self-replication and evolution, achieving self-replication in non-living materials is not just intriguing, but beneficial too if harnessed appropriately. For example, self-replicating systems combined with information-transfer mechanisms could render such systems to be utilized as animate materials for future applications such as compartmentalized chemical reactions. Self-replicating autocatalytic peptide networks form one such area of research that some groups of researchers have focused upon. Self-replicating peptides captured the imagination of the chemists, especially to probe the origin of life research with renewed interest. For example, Lee *et al.*¹ showed experimentally in 1996 that a 32-residue alpha-helical peptide based on the leucine-zipper domain of the yeast transcription factor GCN4 autocatalytically templates self-synthesis. This occurs through speeding up the thioester-promoted amide-bond condensation of 15- and 17-residue fragments in neutral, dilute aqueous solutions in a non-enzymatic manner.

This was followed by several other discoveries on self-replicating peptides². However, utilization of the self-replication property of peptides in technological applications was rather rare. As some hypotheses impart rocks as the harbours of the origin of life and peptides having lately gained

much interest owing to their autocatalytic self-replication, combining both these candidates could lead to an unforeseen display of useful properties. For example, two-dimensional (2D) nanosheets made of transition metal chalcogenides can act as or can be assumed as layers peeled-off from rocks that could become substrates for the autocatalytic self-replicating peptides³.

Such self-replicating autocatalytic peptide networks on 2D nanosheets might lead to emergent properties. Chiroselective⁴ peptide self-replication on the template 2D nanosheets could provide scope for dynamic interactions of multiple autocatalytic peptide systems on these nanosheets. This is due to structural alterations occurring on the 2D sheets. The structural alterations could occur due to the chirality of the self-replicating peptides on the 2D sheets and due to the additional feature of the 2D nature of the sheets themselves. The two-dimensional sheets differ in their electronic structure, viz. metal 2D sheets and semiconducting 2D sheets, such as in the case of 1T MoS₂ and 2H MoS₂ nanosheets⁵. The several possible interactions as noted above might provide for never-seen-before structures with unprecedented emergent properties in these systems. This could be a novel and timely research arena in the wake of renewed interest in the origin of life research, both in the organic/biological research community and the inorganic research community. So, tackling this challenge of technological utilization of the self-replicating nature of the peptides on the 2D nanosheets would be novel, enriching, and commercially important.

The formation of different architectures due to the self-replicating peptides on the 2D nanosheets can be harnessed for the novel properties they could display. Certainly, the structural and electronic properties of the two types (metal and semiconducting) of MoS₂ differ. On the metallic 1T MoS₂, rate of self-replication would vary from that on the semiconducting 2H MoS₂ nanosheets. This variance could act as a basic quality of the interacting self-replicating peptides on different nanosheets to prepare novel architectures on them. Once new architectures are formed on the nanosheets, emergent and technologically important

properties will certainly arise at least in certain cases.

An exciting line of research could be controlling the rate and amount of self-replication of the peptides on the 2D nanosheets. Some reports show the self-replication of peptides follows a parabolic growth and obeys the power law. Thus, it seems possible to control the rate at which the peptides self-replicate on the template 2D nanosheets. One factor that could control this rate might be the nature of the template 2D nanosheets, whether metallic or semiconducting as in the case of 1T or 2H MoS₂ nanosheets. We might have combinations of templates with different architectural types (due to chirality) of the peptides on these nanosheet templates resulting in emergent properties.

In conclusion, harnessing the unique characteristic of self-replication in peptides could produce different nanoscale architectures on structurally and electronically different (viz. 1T metallic MoS₂ and 2H semiconducting MoS₂) 2D nanosheets. The variety of architectures that could be possible is limitless due to several factors that influence self-replication, such as the chirality of the peptides, for example, homochiral peptides, and the different types of templating 2D nanosheets. This could give rise to several technologically applicable properties emanating from the interface of the self-replicating peptides and the underlying 2D nanosheets, and thus they can be harnessed as useful systems.

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