Synergistic Integration of Biophysics and Plasma Physics: Advancing Biomolecular Applications with Cold Plasma Technology

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The intersection of biology and plasma physics provides a ground-breaking platform for innovation across numerous scientific disciplines. Specifically, utilizing the smallest molecular building blocks, cold atmospheric plasma (CAP) has become a viable non-thermal and non-invasive bottom-up molecular self-assembly method for creating biomaterials. Our research explores the basic and practical aspects of CAP-biomolecule interactions, demonstrating its enormous promise in areas including protein self-assembly, biomaterial production with special focus on environmental remediation.

One of the most appealing aspects of CAP is its ability to regulate the generation of reactive oxygen and nitrogen species (RONS), thereby directing the self-assembly process and allowing for the consistent formation of materials with uniform size distribution. We have shown that CAP can induce supramolecular assembly in aromatic amino acids such as phenylalanine, tryptophan, tyrosine, and Fmoc-modified amino acids, which self-assemble to supramolecular architectures after as little as 10 minutes of plasma treatment under helium feed gas conditions [2,3]. These assemblies are powered by CAP-generated RONS which promote non-covalent interactions, resulting in spherical, fibrous, or coacervate-like architectures. Notably, this technique eliminates the need for chemical crosslinkers or harsh solvents, providing a green and scalable alternative to conventional methods.

Beyond amino acids, CAP also facilitates the assembly of dipeptides and short peptides into supramolecular biomaterials, which are of particular interest for regenerative medicine and tissue engineering. These structures form rapidly and reproducibly, suggesting that CAP could serve as a platform for rapid prototyping of peptide-based biomaterials.

Our research further demonstrates the potential of CAP technology in biomedical applications by examining proteins like collagen, keratin, and serum proteins [4], paving the way for more effective wound-healing treatments with focused medication dosage.

Importantly, the versatility of CAP is not limited to biomedical applications. We have also explored its efficacy in environmental biotechnology, where CAP degrades chemical contaminants like ethidium bromide and inactivates pathogens with high efficiency [5,6]. These findings position CAP as a sustainable, chemical-free alternative for sterilization of medical devices and pollutant remediation.

Overall, our findings highlight CAP's transformative potential for developing next-generation biomaterials, improving healthcare solutions, and promoting environmental sustainability. By bridging physics and biology, CAP stands as a promising tool for future innovations across interdisciplinary domains.

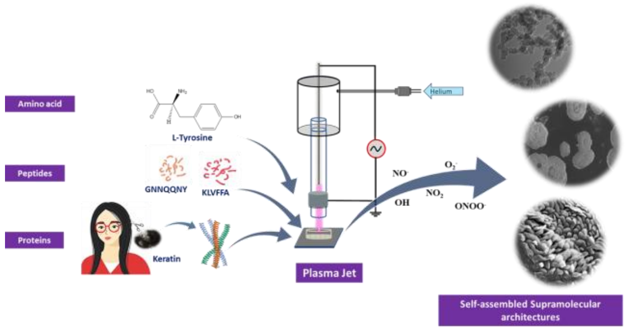

Figure: Application of Cold Atmospheric Plasma (CAP) in the development of next-generation biomaterials and advancement of sustainable environmental solutions.

References

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