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## Floating beyond limits: A review on engineered floatable hydrogel platforms and emerging sustainable applications

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## 摘要

Hydrogels, featuring tunable porous structures and efficient mass transport, are promising materials for floatable platforms that improve light absorption, enable continuous operation at gas-liquid interfaces, and protect encapsulated materials and enhance recycling efficiency. Floatable hydrogels notably maximize the use of sunlight at the air-liquid interface, significantly improving solar energy capture and efficiency in photocatalytic and photothermal processes. This review systematically summarizes recent advancements in floatable hydrogels, highlighting three major fabrication strategies: chemical cross-linking, pore structure regulation, and surface engineering. Chemical cross-linking is the predominant method, offering strong stability and versatility through monomer selection and cross-linking conditions, though quantitative buoyancy control remains challenging. Pore-structure regulation, including mechanical foaming, agent-based foaming, and bubble locking, enables precise buoyancy control but may compromise structural integrity. Surface engineering usually serves as a complementary strategy by modulating hydrophobicity or hydrophilicity. Advanced fabrication methods such as 3D printing offer promising opportunities. Multifunctional applications of floatable hydrogels are comprehensively reviewed, covering photocatalysis, solar-driven water purification, photothermal energy conversion, wastewater treatment, environmental remediation, and renewable energy harvesting. Emerging fields, including photo-electrocatalysis, electrochemical energy storage, and biomedical engineering, are also discussed. Finally, analytical challenges regarding floating durability, accurate buoyancy tuning, anti-fouling properties, and scalability are critically examined, providing strategic insights for future research directions.

## 关键词

**作者关键词:** Floatable hydrogels; Gas-liquid interface; Buoyancy enhancement; Porous structure; Water treatment; Energy conversion**Keywords Plus:** INVERSE EMULSION POLYMERIZATION; COMPOSITE HYDROGEL; SOLAR; TISSUE; FOAMS; ADSORPTION; NETWORK; WOOD; BIOMATERIALS; AEROGELS

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