3D MoS_2 Foam For Point-of-Use Water Purification Application

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Introduction. Molybdenum disulfide (MoS_2) has been widely explored for myriad of applications including catalysis, solid lubrication, antibacterial activity, sensing and hydrogen evolution reaction due to its unique and exquisite optical and electronic properties when exfoliated into ultrathin layer.[1, 2] However, there are no reports on the heavy metal remediation using MoS_2 or any other transition metal dichalcogenide. Furthermore, 3D monolithic or foam structure of MoS_2 has been limited to hydrothermal method using bulk MoS_2, and carbon template-based approach requiring chemical vapour deposition of MoS_2 layer.[3] We have recently reported the first example of the 3D MoS_2 foam fabricated from exfoliated single-layered sheets.[3]

Aims. To develop a point-of-use 3D MoS_2 foam-based filter for heavy metal remediation with antibacterial activity.

Methods. MoS_2 was exfoliated in a liquid exfoliation approach using bovine serum albumin as a surfactant and subsequently lyophilised to obtain the highly porous 3D foam. The heavy metal remediation efficiency was determined using an inline adsorption-based pre-filtration kit under continuous flow system. The antibacterial efficacy of the foam was assessed using the standard Dichlorodihydrofluorescein diacetate (DCFH-DA) assay. The cytocompatibility towards human cells was determined using the WST-1 cell proliferation and Calcein AM/Ethidium bromide live/dead assay.

Results. The 3D foam rapidly reduced contaminant Pb (II) and As (III) concentration by 99.9% and 98.7%, respectively. The foam demonstrated high selectivity towards heavy metal contaminants and retained remediation efficiency at >98% through multiple reuse cycles. Moreover, the foam exhibits selective toxicity towards bacterial cells while showing no observable cytotoxicity towards human cells making the foam optimal for water purification application.

Discussion. The rapid removal of heavy metal impurities by the foam was attributed to the size-dependent sieving due to reduced d-spacing of MoS_2 layers caused by the lyophilization step during foam formation. The smaller (MoS_2) interplanar space restrict the movement of larger size heavy metal ions into the permeate. The antibacterial activity of the foam was attributed to the combination of physical interactions due to the piercing effect and chemical interaction attributed to the affinity of MoS_2 to generate reactive oxygen species.

Conclusion. For the first time a 3D porous MoS_2 foam has been fabricated from exfoliated single-layered MoS_2 sheets with selective remediation against heavy metal ions for water purification application. The fabricated foam exhibited over ~99% remediation of heavy metal ions (Pb (II) and As (III)). The foam demonstrated selective toxicity against bacterial cultures killing ~99% of bacterial cells within 4h while maintaining 100% human cell viability over the period of 72h.

References

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