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Reduction of Bacterial Colonization on Buckling-induced Wrinkled Surfaces Under Fluid Shear

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Microbial colonization and biofilm formation are major contributors to infection persistence and antimicrobial resistance. The presence of fluid flow, common in medical devices and natural environments, further exacerbates this challenge. In this study, we combine surface modification via spontaneous buckling instabilities with microfluidic techniques to investigate bacterial adhesion under flow conditions using clinically relevant motile and non-motile strains, Pseudomonas aeruginosa and Staphylococcus aureus. We fabricated wrinkled surfaces with wavelengths ranging from 0.5 to 20 μm and evaluated bacterial adhesion under shear rates of 0.4 to 200 s−1. Phase-contrast and fluorescence microscopy were used to assess bacterial spatial distribution, while atomic force and scanning electron microscopy provided high-resolution surface and characterization. Our results demonstrate that sinusoidal wrinkled surfaces with wavelengths of 2 μm significantly reduce bacterial colonization at high shear rates, particularly when oriented perpendicular to flow. Folded wrinkled patterns of 5 μm further enhance this effect, reducing colonization across a broader range of shear rates by more than 90% for both strains and limiting biofilm formation by over 85% compared to flat substrates.