**Backgrounds:** Bacteria can attach and form multicellular structures, known as biofilms, on virtually any abiotic or biotic surface. Due to the protection of extracellular polymer substrates (EPS) and slow growth, biofilm cells are up to 1,000 times more resistant to antimicrobials compared to their planktonic counterparts. Biofilms related high-level drug tolerance causes serious problems of persistent biocorrosion and biofouling in industry, as well as chronic infections in humans. The significance of biofilm-associated problems has stimulated intensive efforts on developing new materials and surface modification techniques to prevent bacterial colonization. However, the studies to date are largely limited to static features, which can be overcome by microbes over time and does not provide long-term prevention. To better control biofilm formation, we engineered active surface topographies that can both effectively prevent initial bacterial adhesion and achieve on-demand removal of mature biofilms. **Methods:** Rationally designed micron-scale antifouling surface topographies harboring magnetic nanoparticles were actuated by external stimuli with programmable beating frequency and force level to repel bacteria from adhesion and disrupt mature biofilms. Specifically, systematically designed micron-scale poly(diethylsiloxane) (PDMS) surface topographies filled with biocompatible superparamagnetic Fe₃O₄ nanoparticles were actuated with an external magnetic field (5 mT). Bacterial adhesion and biofilm removal were characterized using florescence microscopy. **Results:** The antifouling effect of this approach was first validated using 48 h *Pseudomonas aeruginosa* PAO1 biofilms. By actuating the square-shaped surface topographies with a height of 10 µm, side width of 2 µm, and inter-pattern distance of 5 µm for 3 min, more than 99.9% (3 logs) biofilm cells were removed. **Conclusions:** A new strategy has been successfully developed to achieve long-term biofilm control with constant beating of micron-scale surface topographies. This method can be readily tailored to apply to different materials.