Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

Magnetic PiezoBOTs: A Microrobotic Approach for Targeted Amyloid Protein Dissociation

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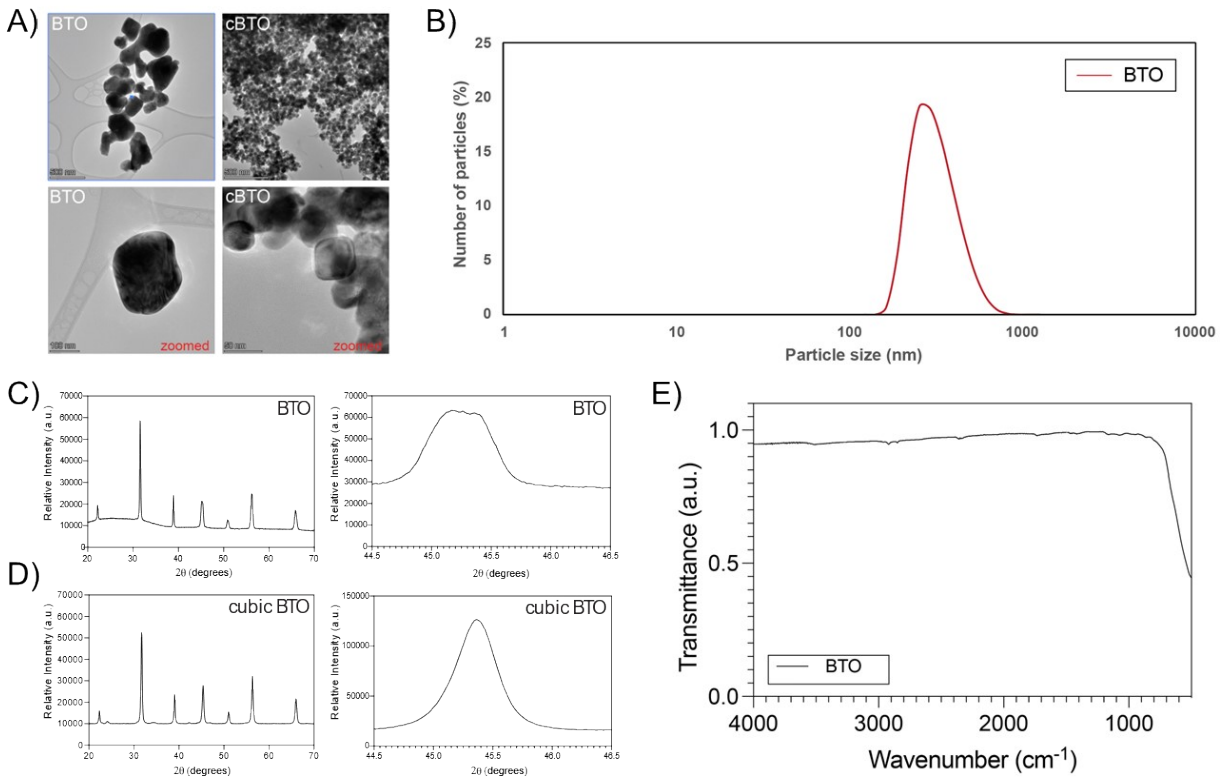

Figure S1. Physical characterization of BTO and cubic BTO nanoparticles. A) TEM images of BTO and cubic (cBTO) particles, B) DLS measurement of BTO particle size distribution, C-D) PXRD patterns for BTO and cBTO and E) FTIR measurement of BTO particles.

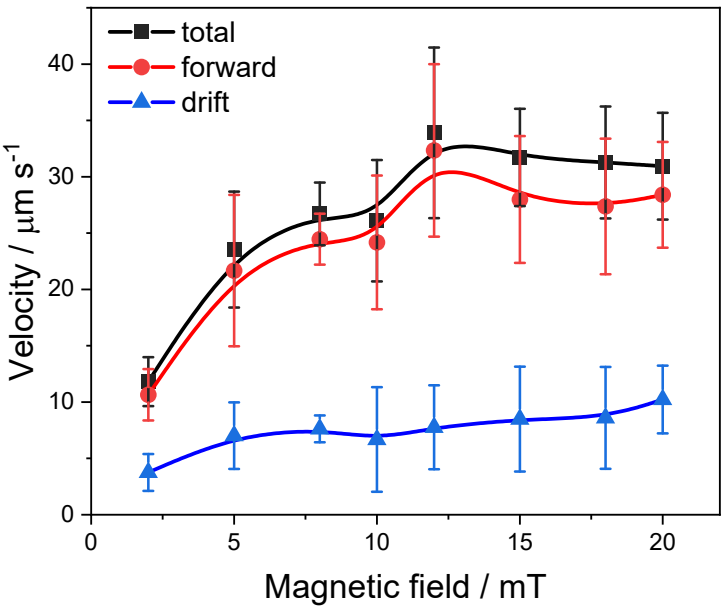

Figure S2. Swimming velocities of PiezoBOTs as a function of the applied magnetic rotating field (applied frequency of 2 Hz); each data set corresponds to mean ± SD (n = 5). Note that the error bars are considerably large due to the varying sizes of the spirulina templates.

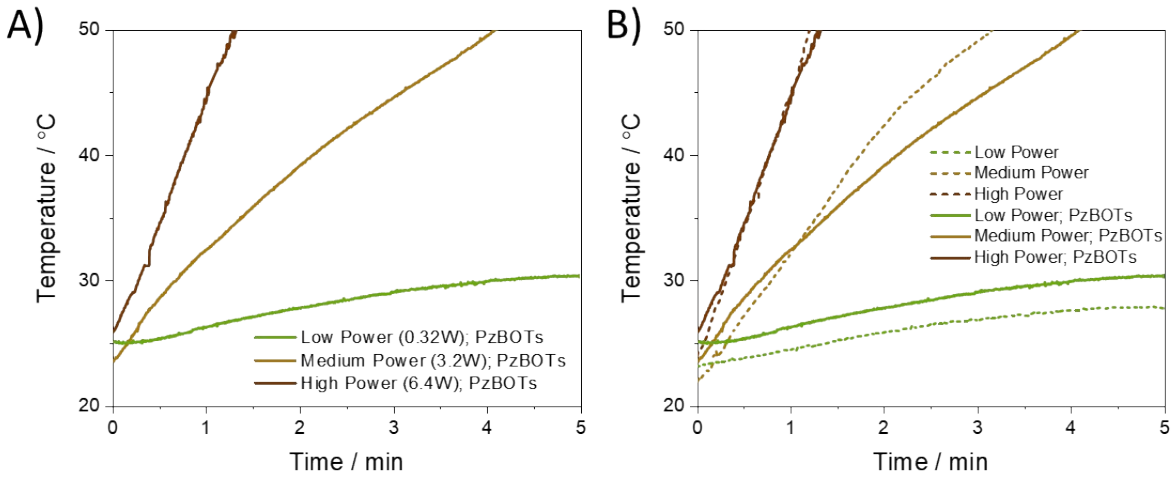

Figure S3. A) Variation of the temperature over time when applying different ultrasound power levels in the presence of PiezoBOTs. B) Comparison of the temperature variation in the presence and absence of PiezoBOTs.

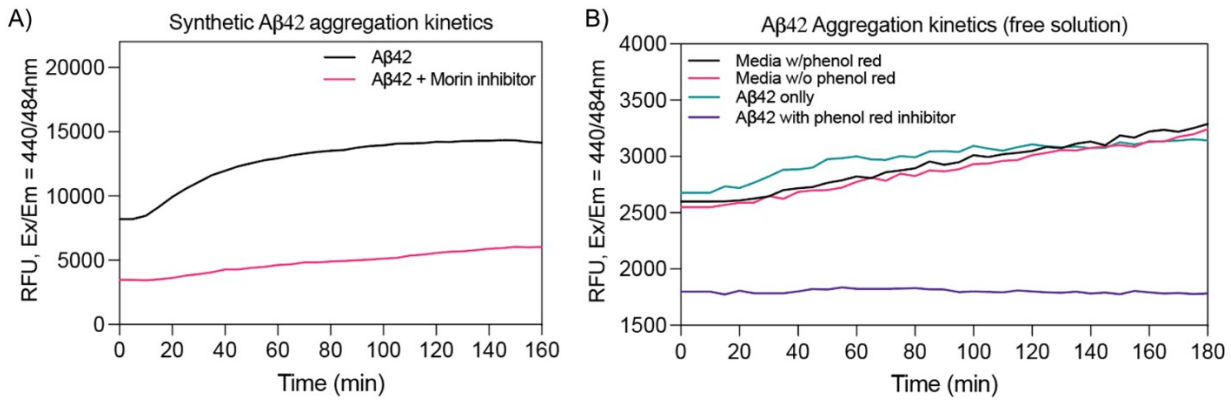

Figure S4. Aβ 42 aggregation Kinetics. 10 µL of 2 mM ThioT was added to 90 µL of the diluted Aβ42 peptide. The solution was placed in a fluorescence plate reader at 37 °C with 15 second shaking and read every 10 minutes at Ex/Em = 440 nm/484 nm for 4 hours. A sigmoidal kinetic graph can be seen with and without morin as an inhibitor for negative control. The sample without morin demonstrates an increase in ThT fluorescence following a sigmoidal curve that is inhibited in the sample with morin. Phenol red inhibitor is also tested in B.

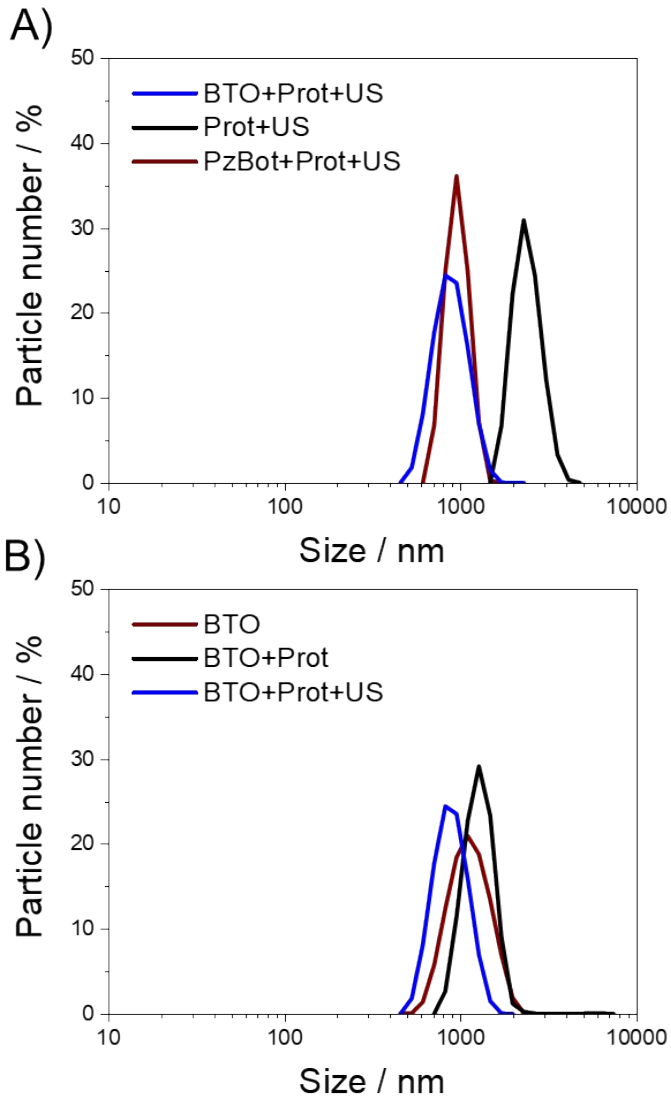

Figure S5. A) Comparison of the particle distribution obtained by DLS of different samples after ultrasound stimulation. B) Comparison of the particle distribution obtained by DLS of different BTO samples.

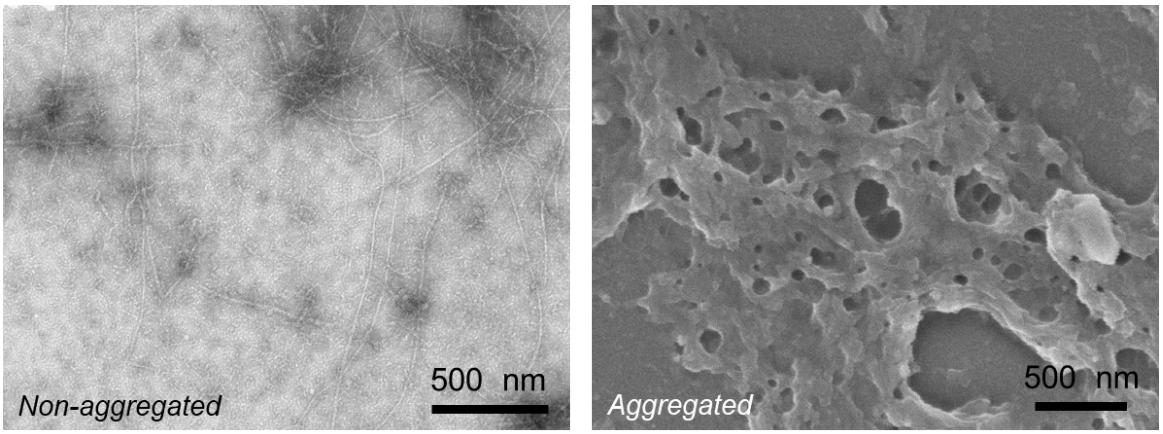

Figure S6. TEM (left) and SEM (right) images of the Aβ42 amyloids before and after the pre-aggregation treatment.

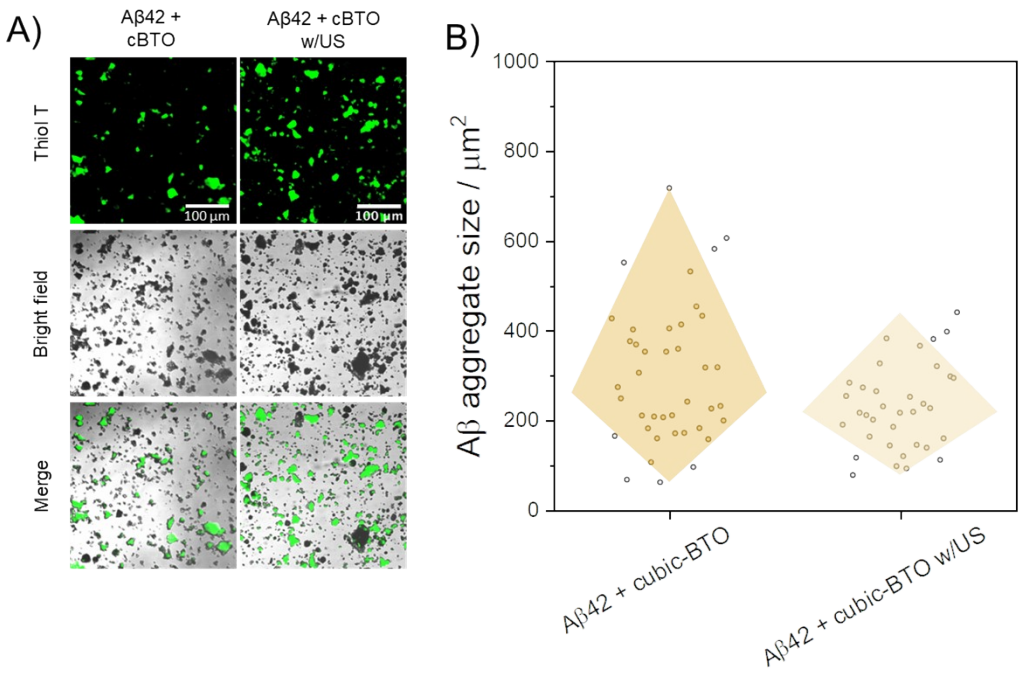

Figure S7. A) Confocal images before and after ultrasonic bath stimulation. B) Distribution plots of the aggregate size of Aβ42 with cBTO, before and after ultrasound stimulation.

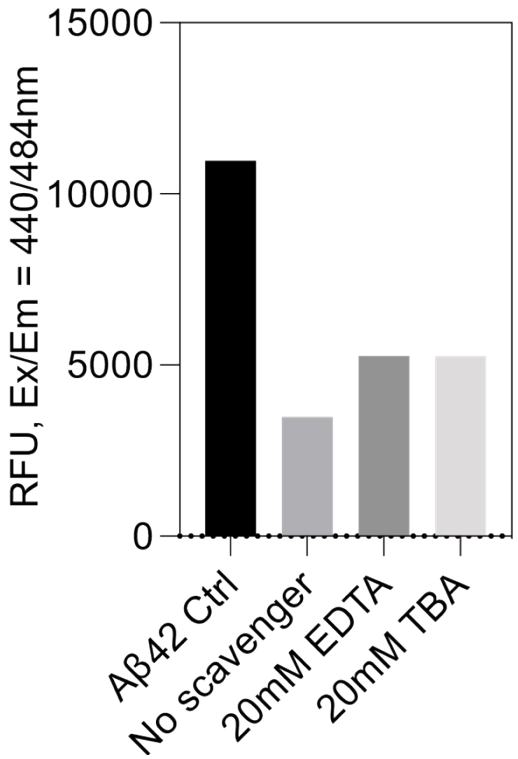

Figure S8. Scavenger-quenching experiments. These experiments were performed to assess the role of free radicals in the piezocatalytic degradation process of Aβ fibrils. Hence, several free radical scavenger molecules were introduced into the reaction media under the same ultrasonic actuation conditions. The protein degradation efficiency decreases drastically upon introducing *Tert*-Butyl Alcohol (TBA), whereas the addition of Ethylenediaminetetraacetic acid (EDTA) has far less influence on the degradation. As EDTA is an H^+ scavenger, •OH is the dominant reactive species during the BTO actuation and is responsible for Aβ42 degradation. However, the addition of benzoquinone (BQ) (an O_2^- trapping molecule) strongly affects the concentration measurement of Aβ42 fibrils. Thus, the generation of $•O_2$ and its influence on the degradation of the amyloid peptides cannot be directly confirmed by trapping experiments. Because $•O_2$ has been demonstrated to be generated by BTO nanomaterials under ultrasonic actuation in aqueous media, $•O_2$ free radical could also be participating in Aβ42 degradation.[6,19,20]

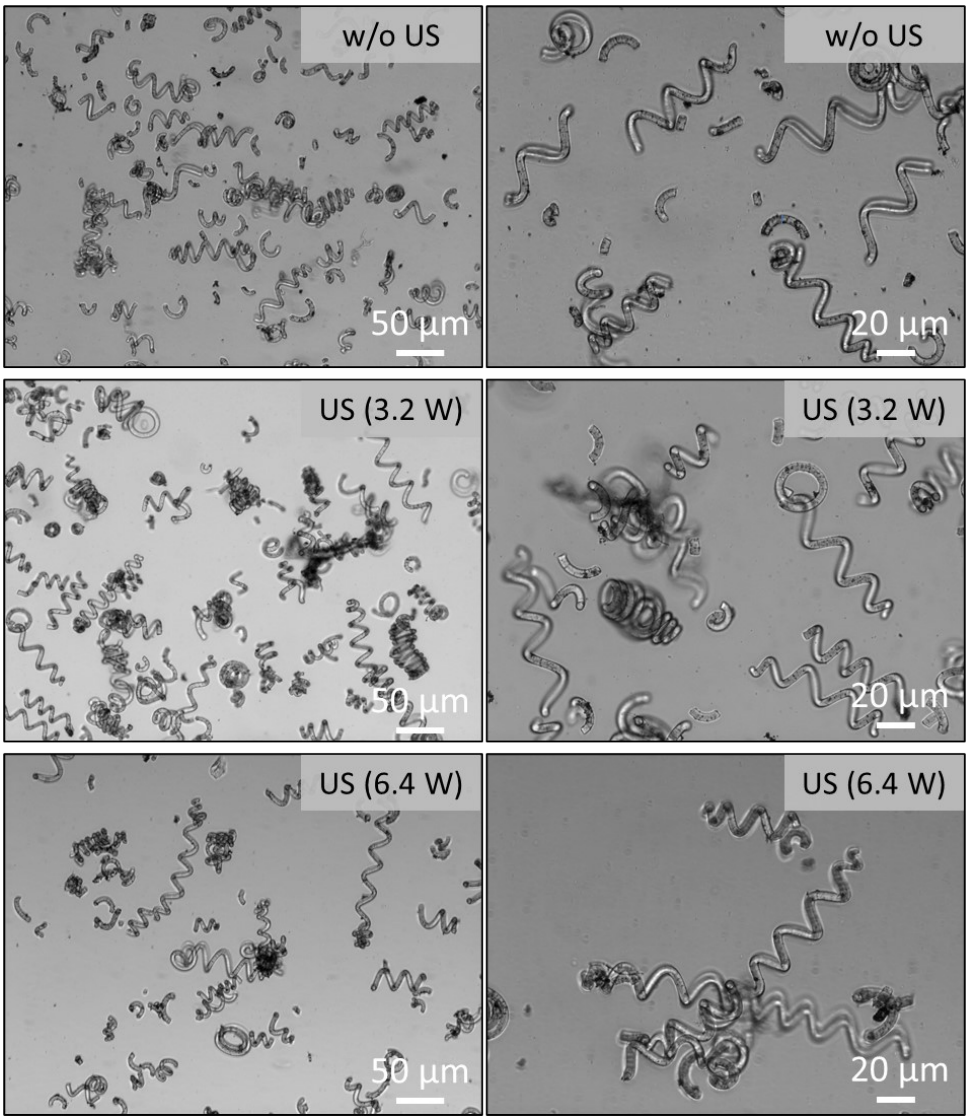

Figure S9. Optical images of the PiezoBOTs after being subjected to different ultrasound power levels. 10 cycles consisting of 1 minute of ultrasound stimulation and 2 minutes of interspersed resting periods were applied.

Video S1. Corkscrew motion of a PiezoBOT under magnetic manipulation in DI water.

Video S2. Trajectory of a PiezoBOT under magnetic manipulation in DI water.

Video S3. Trajectory of a PiezoBOT under magnetic manipulation in PBS solution in a microfluidic vasculature model.