DESIGNING 1D PARTICLE STRUCTURES

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RESEARCH AREA

1D conductive particle assembly holds promise for a variety of applications. However, synthesis of such chains with programmable shapes outside a liquid environment has proven difficult. We have recently developed a route to simply "pull" flexible granular chains out of a dispersion by combining field-directed assembly and capillary effects. The chains are automatically stabilized by liquid bridges formed between adjacent particles, without the need for continuous energy input or special particle functionalization. They can further be deposited onto any surface and form desired conductive patterns. We currently study various aspects of our route, including the role of particle size, shapes and the voltages needed to fabricate 1D structures.

SCHEMATICS OF CHAIN FORMATION

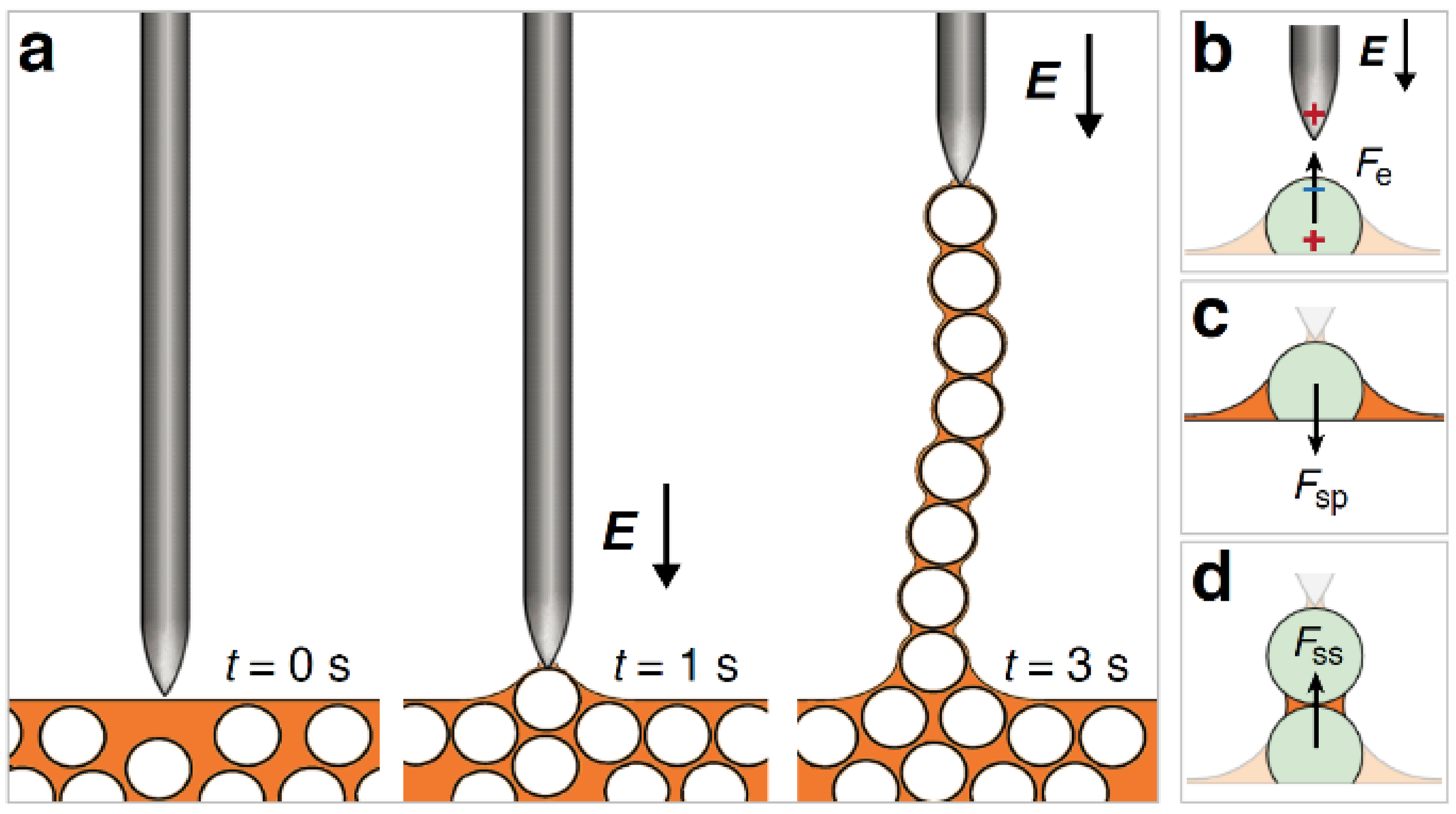

Fig. 1. (a) Particles are pulled out of a dispersion to form a 1D structure by applying an electric field through an electrode. (b,c) A particle at the air–liquid interface experiences an upward dielectrophoretic force F_e and a downward capillary force F_{sp} stemming from the sphere–plane liquid bridge. (d) Once the particle is pulled out, it automatically forms a sphere–sphere bridge with the particle below it, and pulls that particle upwards with force F_{ss}.

THEORETICAL STUDIES

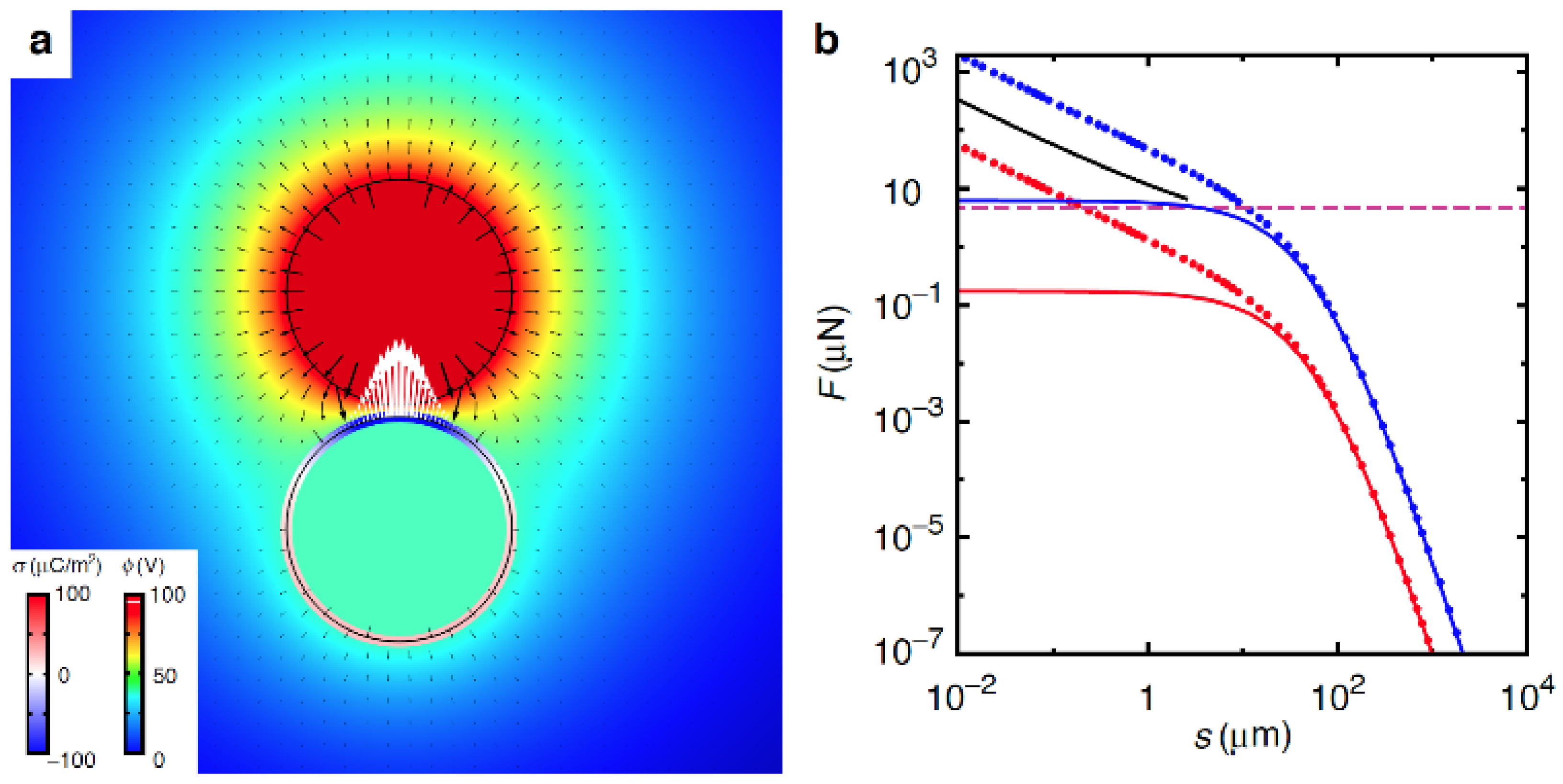

Fig. 2. Theoretical studies lead to understanding the role of electric fields and particle size on formation of 1D structures. (a) Finite element analysis performed to calculate the influence of the induced surface charges on particle surfaces on the magnitude of electric force, and (b) the results from the finite element analysis (dots) are compared to the results obtained from the conventional model for dielectrophoretic forces (solid curves) – The attractive force (F) vs. distance between spheres (s).

EXPERIMENTAL REALIZATION, PROPERTIES OF THE 1D PARTICLE STRUCTURES

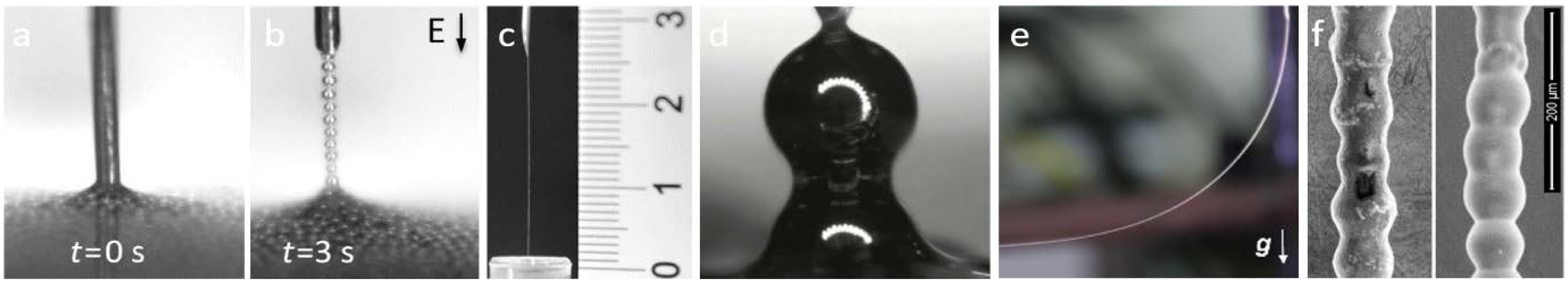

Fig. 3. (a,b) Pulling a 1D particle structure from a container filled with a dispersion of Ag-coated silica microspheres in silicone oil. The electrode is brought up after application of E-field (t>0), and a chain is pulled out from the dispersion. (c) A nearly 3 cm long chain comprising hundreds of particles can be formed within several seconds. (d) A well-resolved capillary liquid bridge formed between two particles. (e) Capillary bridges lend flexibility to the particle chain. (f) Scanning electron microscopy images of a particle chain embedded in solidified paraffin wax and in solidified resin.

1D STRUCTURES CAN BE USED IN MECHANICAL CONTEXT OR FOR FORMATION PARTICLE PATHS

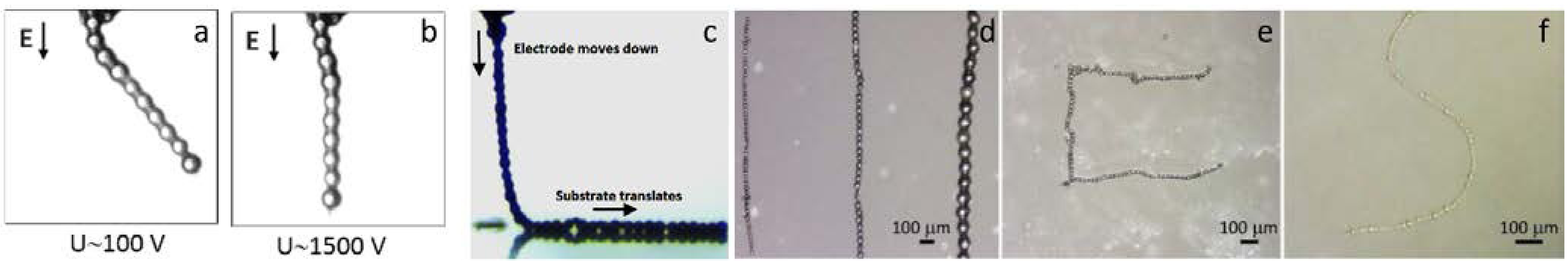

Fig. 4. (a,b) A short granular chain, which is actively bent and straightened by changing the magnitude of the applied electric field. (c) Deposition of particles: A particle-chain is formed and then deposited on a substrate that moves horizontally. (d) Example of parallel deposition of chains composed of particles with different sizes, and (e,f) examples of C-shaped and S-shaped pathways.

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For more details see the following research paper: https://www.nature.com/articles/ncomms15255