Fabrication of Red Blood Cell-like Polyelectrolyte Microcapsules and Their Deformation and Recovery Behaviors through a Microcapillary

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Introduction

Red blood cells (RBCs) of unique biconcave discoidal geometry exist widely in mammality, representing a remarkable example designed for implementing sophisticated biological functionalities[1]. These functionalities include the flexibility of RBCs to squeeze through capillary vessels, long-time circulation in human body up to 120 days and oxygen delivery, all of which can be attributed to their special physical properties (size and shape) and chemical composition (about 35wt% hemoglobin in RBCs). Especially, the dominant factor for RBCs to circulate in mammality is their ability to deform and squeeze through restrictions in vasculature and then recover to initial shape after passing through the capillaries. Multilayer microcapsules, based on layer-by-layer (LbL) assembly of polyelectrolytes on sacrificial templates, are of great potential applications due to their functionality and diversity. However, great efforts still should be given to match the sophisticated situation in the real biological environments. In general, multilayer microcapsules come across the dilemma that how to smoothly pass through capillary vessels with smaller size. Therefore, the design of LbL microcapsules to surmount physical filtration barrier and extend circulation time can be inspired by RBCs mentioned above. The features of LbL method is powerful for the design and fabrication of RBC-like microcapsules due to its precise control of capsules' shape, size and functionality[2]. In present study, biconcave discoidal multilayer microcapsules, mimicking the shape, size and functionalities of RBCs, were fabricated via LbL technique templated on biconcave discoidal particles. Furthermore, oxygen delivery capacity of RBC-like capsules were endowed by additional hemoglobin assembly.

Fabrication and characterization of RBC-like microcapsules

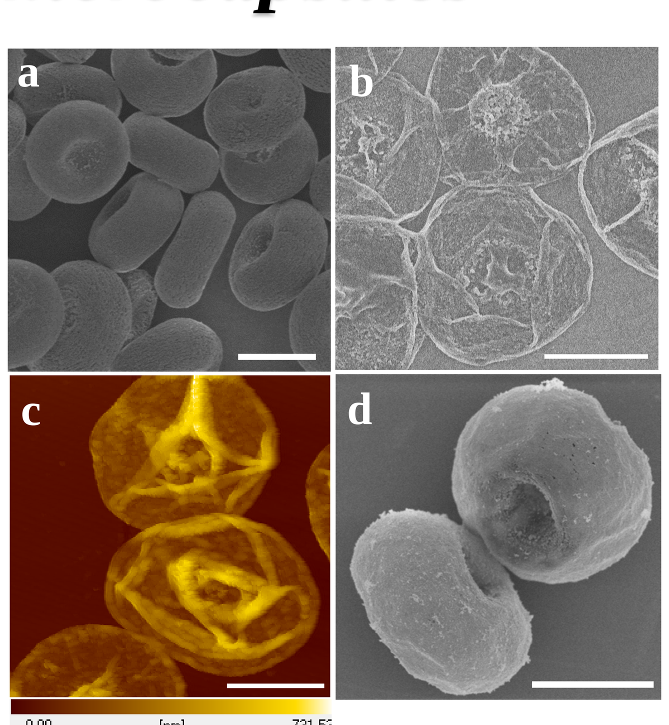

Fig. 1 (a) SEM image of RBC-like $Ca(OH)_2$ particles with a diameter of ~6.7 μm and thickness of ~2.8 μm. (b) SEM and (c) AFM images of collapsed $(PAH/GA)_{10}$ microcapsules after being dried in air. (d) SEM image of $(PAH/GA)_{10}$ microcapsules dried by critical point drying method. Scale bar: 5 μm.

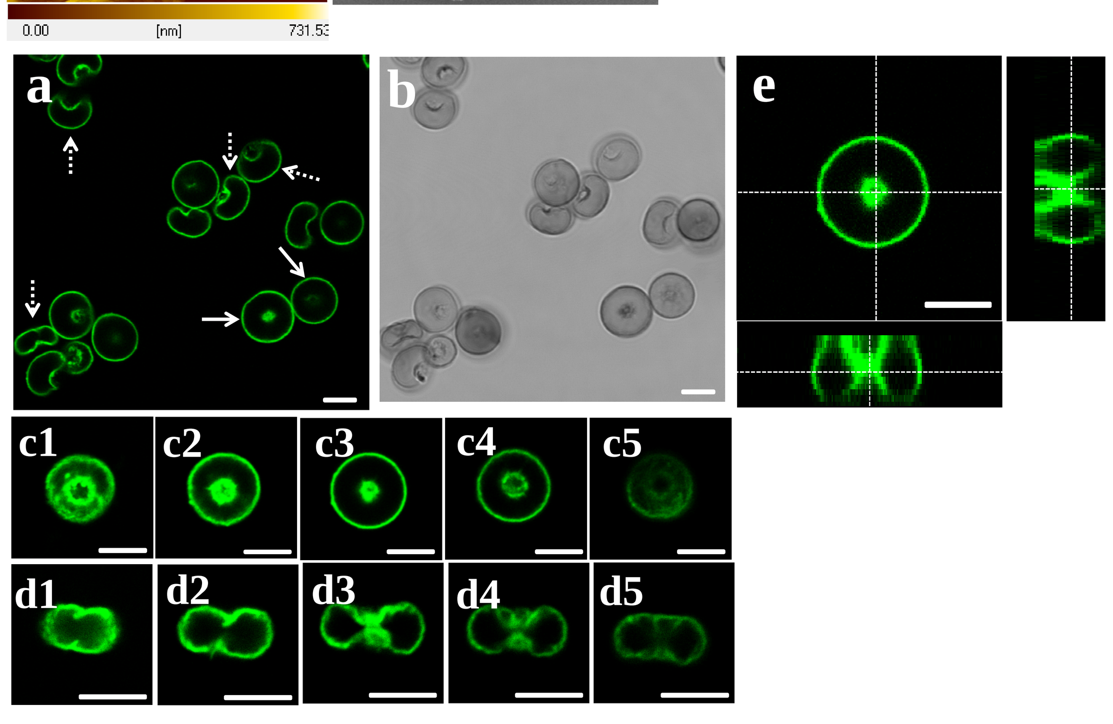

Fig. 2 CLSM image (a) and transmission mode image (b) of RBC-like microcapsules with a diameter of ~6.7 μm in water. Series Z-scanning CLSM images of the typical RBC-like microcapsules (c) lying and (d) standing on the substrate, respectively. (e) 3D reconstruction of the microcapsule shown in (c). Scale bar: 5μm

References

[1] Langer R et al, Nature 1998, 392, 5
[2] Shchepelina O et al, Macromolecular Rapid Communications 2010, 31, 2041

Flowing behavior in 5μm micro-capillary

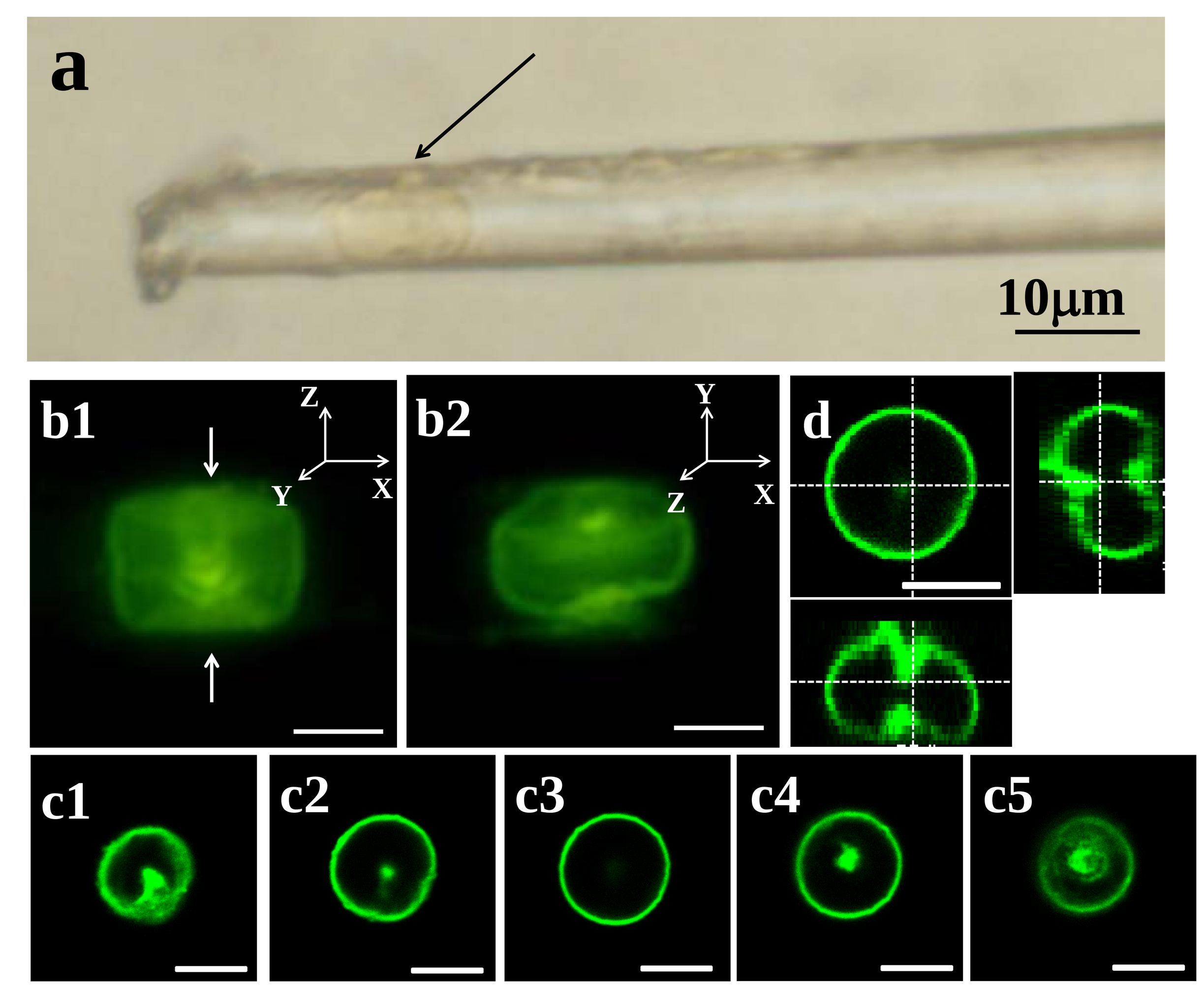

Fig. 3 (a) Optical image to show the position of RBC-like capsule trapped in a 5 μm capillary. (b1) Fluorescent image of a RBC-like microcapsule trapped in a capillary, and (b2) its counterpart after the capillary was rotated for 90º. (c) Series Z-scanning CLSM images of a typical RBC-like microcapsule after passing through a 5 μm capillary. (d) 3D reconstruction of the microcapsule shown in (c). Scale bar: 5μm.

Binding and releasing of oxygen

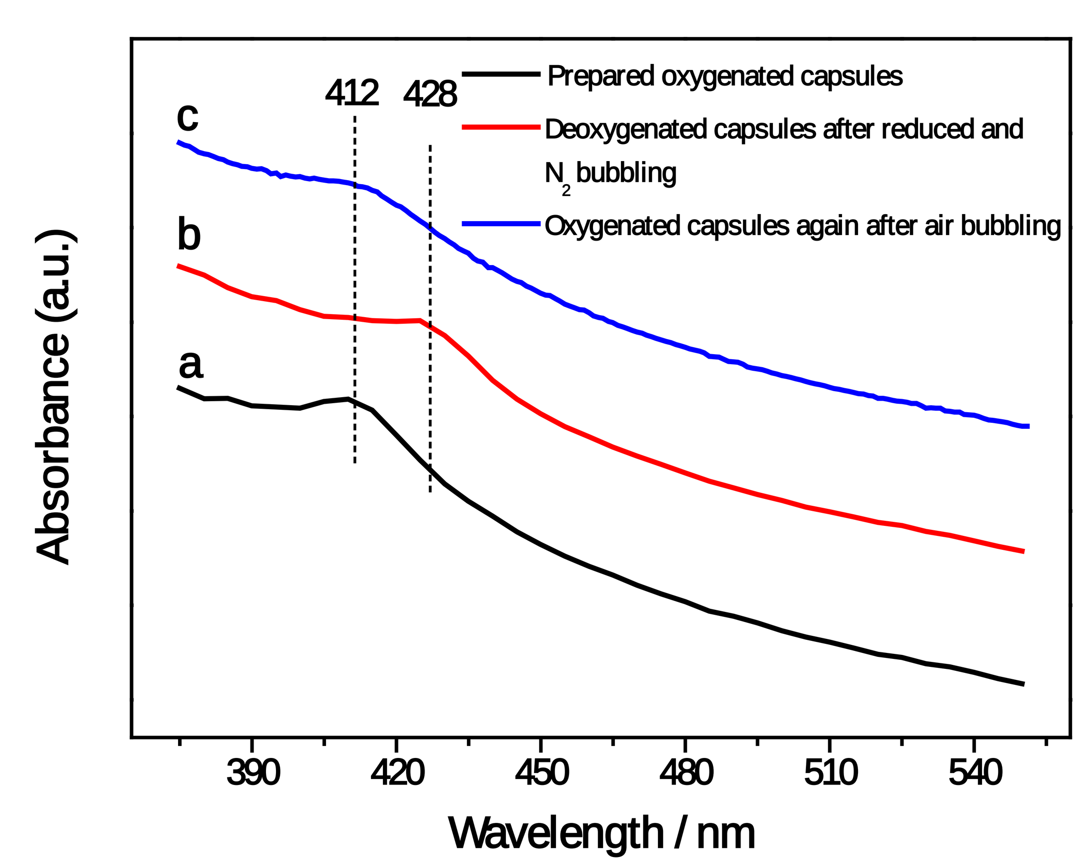

Fig. 4 UV-vis absorption spectra of RBC-like capsules coated with Hb. (a)The prepared capsules in oxygenated states, (b) capsules in deoxygenated state after reduced by sodium dithionite and N_2 bubbling, and (c) capsules in oxygenated state after air bubbling following N_2 bubbling.

Conclusions

- RBC-like multilayer microcapsules were fabricated via LbL technique by templating on RBC-like $Ca(OH)_2$ particles. Their biconcave discoidal characteristic were demonstrated and illustrated carefully by CLSM and SEM.
- The deformation and recovery behaviors of RBC-like capsules were estimated by flowing them into micro-capillary. Statistic data shows 90% of passed RBC-like capsules can recover their original shape.
- By assembling three additional Hb layers, the RBC-like capsules were endowed with oxygen binding and releasing capacity.

Acknowledgements

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