

Supplemental Information

Natural karaya gum as an excellent binder for silicon-based anodes in high-performance lithium-ion batteries

Yitian Bie, Jun Yang, Yanna Nuli, Jiulin Wang

Shanghai Electrochemical Energy Devices Research Centre, School of Chemistry and Chemical Engineering, Shanghai Jiao Tong University, Shanghai, 200240, China

Corresponding author: J. Yang, yangj723@sjtu.edu.cn

Experimental

Preparation of electrodes

Silicon nanoparticles (50-200 nm, Alfa-Aesar), Super P (SP) (40nm, Timical) and binders were mixed by a 6:2:2 weight ratio in water. After stirring for 5 h, the slurry was coated on a Cu foil current and then dried at 70 °C in vacuum for 8 h. The foil was cut to Φ 12 mm sheets to assemble cells. The Si loading is 0.4~0.5 mg cm⁻² or 0.8~0.9 mg cm⁻². KG and CMC were purchased from Aladdin and SA was purchased from Aldrich.

For the practical thick Si/Graphite electrode, silicon nanoparticles, nano graphite (Timical), KS-6L (Timical), SP and binders were blended in a weight ratio of 40:25:15:5:15 in water. The rest routes are the same as above. And the mass loading of Si/Graphite electrode is 2.0~2.1 mg cm⁻² (Si loading: 0.80~0.84 mg cm⁻²).

Cells assembling and electrochemical tests

The electrochemical performances of the as-prepared anodes were tested via CR2016 coin cells with ENTEK ET20-26 as separator, and pure lithium foil as counter electrode. The cells were assembled in an argon-filled glove box (MB-10 compact, MBraun) using 1M LiPF₆/EC+DMC (1:1 by volume, ethylene carbonate (EC), dimethyl carbonate (DMC)) as electrolyte, including 10% Fluoroethylene carbonate (FEC). The cycling performances were evaluated by a LAND battery test system (Wuhan Kingnuo Electronics Co., Ltd., China) at 25 °C and constant current densities with the cut-off voltage of 0.01/1.2 V vs Li/Li⁺. The specific capacities were calculated on the basis of the weight of active materials for silicon anodes and of whole electrode materials for Si/Graphite anodes.

Morphology and structure characterization

The morphologies and microstructures of the electrodes were observed by a FEI Nova SEM 230 ultra-high resolution FESEM. The Fourier transform infrared (FTIR) spectra of the samples were recorded on a FTIR spectrometer (Bruker VECTOR22). To evaluate the binder strength of electrode films, an electrode sample in 20 mm width and 100 mm length was attached to 3M tape (12mm wide), and the peeling strength of the electrode specimens was measured with a high-precision micromechanical test system (FMT-310A5, Alluris). The nano-indentation tests were conducted using Hysitron TI 950 nanoindentation system with Berkovich indenter. To visualize the dispersion state of SP in different binder solutions, SP and the binders were blended in a weight ratio of 1:1 in water to form 1% slurries. The slurries were coated on Cu foil and filter paper to obtain the macroscopic pictures. Also the slurries were dropped on slide glass under the same conditions to obtain the microscopic images under an optical microscope. (VH-S5, Keyence corporation)

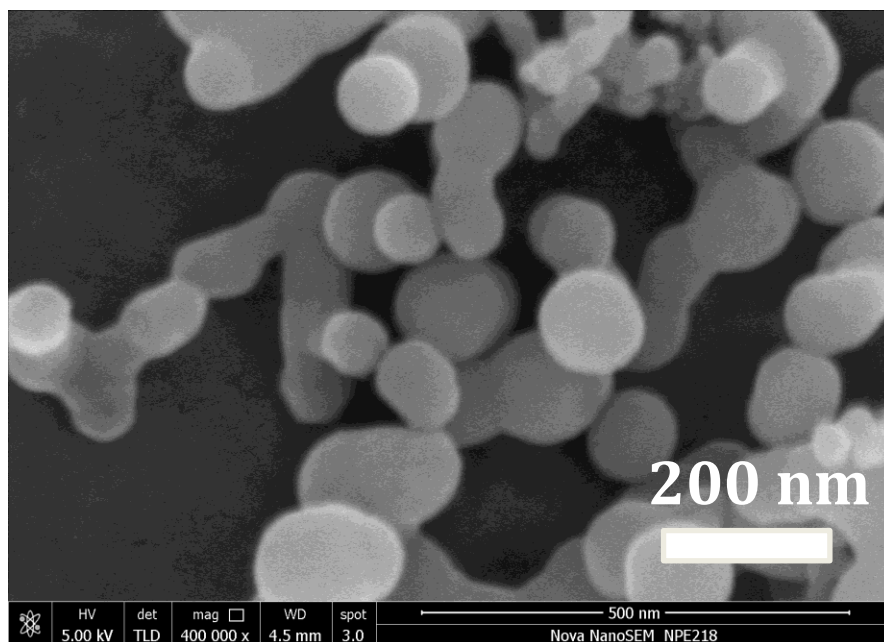


Figure S1 SEM image of Si nanoparticles.

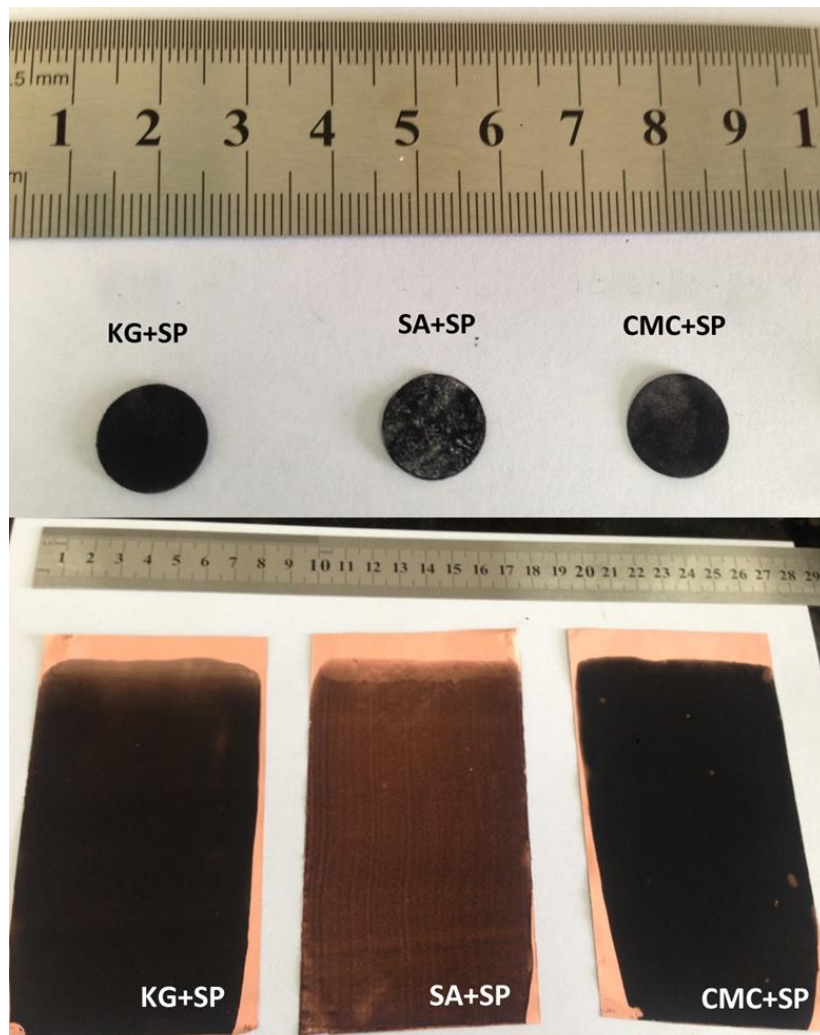


Figure S2 Pictures of Cu foils (down) and filter papers (up) coated by SP slurries with different binders.

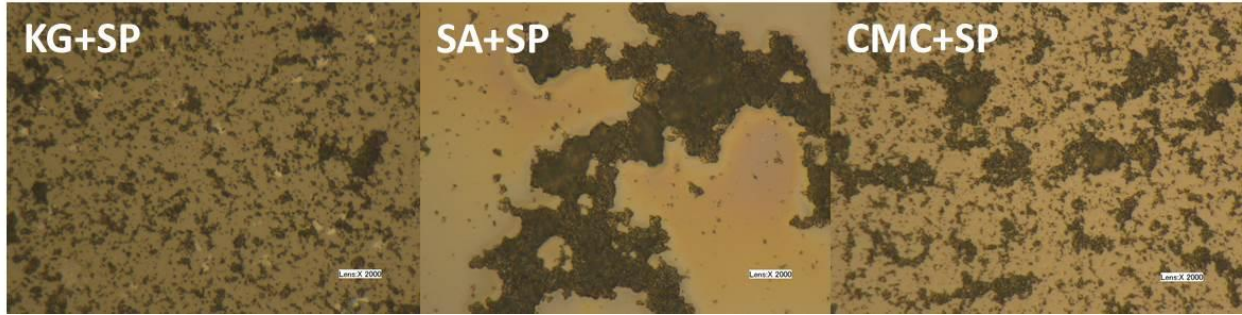


Figure S3 Optical microscopy images of SP slurries with different binders. (Lens×2000).

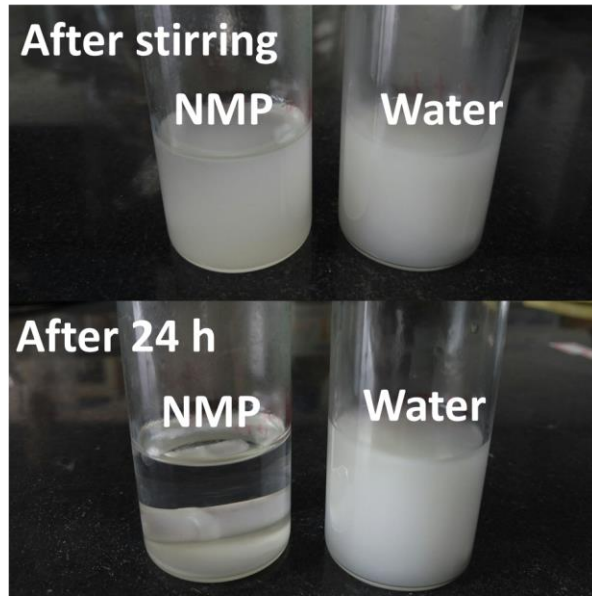


Figure S4 Pictures of KG in NMP and KG gel in water after stirring and after placing for 24 h.

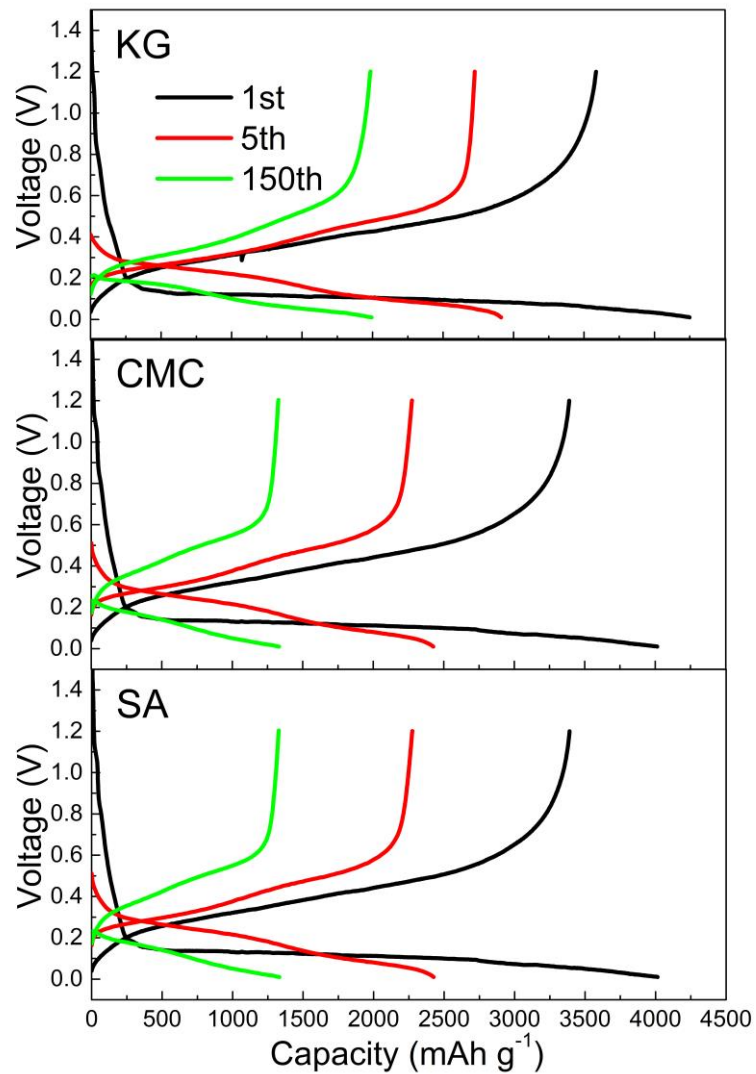


Figure S5 The charge and discharge curves of the electrodes with KG, CMC and SA binders corresponding to Figure 4a.

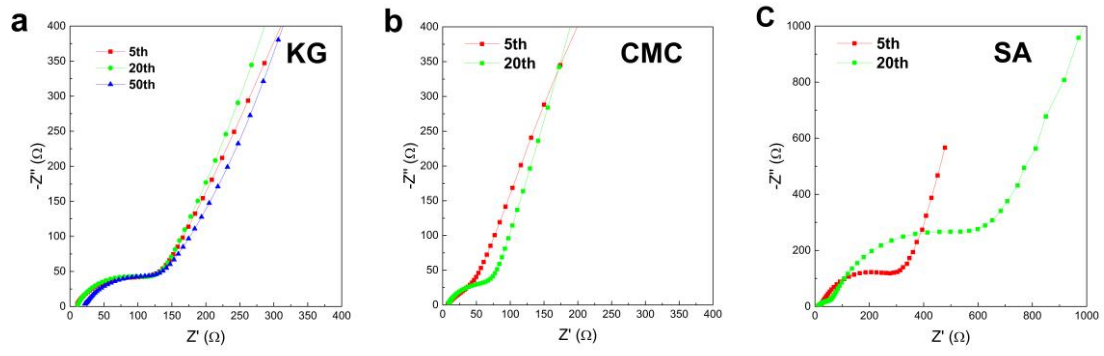


Figure S6 Nyquist plots of KG (a), CMC (b) and SA (c) electrodes during cycling at 1.5 A g^{-1} .

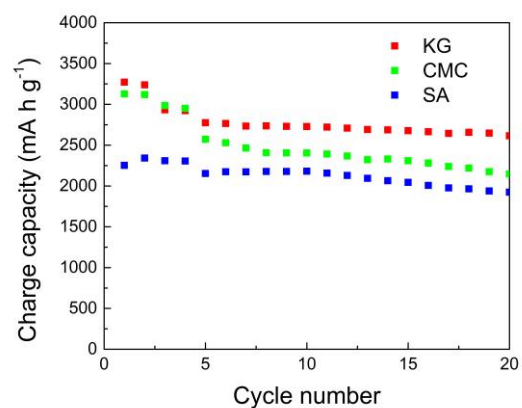


Figure S7 Cycle performance of KG, CMC and SA electrodes with silicon loading of 0.8~0.9 mg cm⁻². The current is 0.1 A g⁻¹ for the first two cycles and 0.3 A g⁻¹ for the following two cycles. For other cycles, discharge current is 0.5 A g⁻¹ and charge current is 2.0 A g⁻¹.

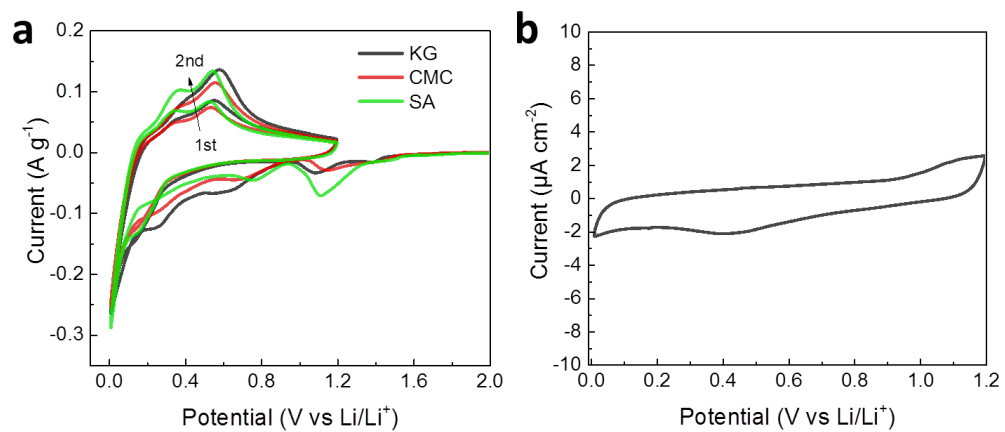


Figure S8 (a) CV profiles for the first 2 cycles of KG, CMC and SA electrodes. (b) CV profile of pure KG binder.