Electronic Supplementary Information (ESI)

Large area, flexible ordered mesoporous carbon films from soft templating on polymer substrates

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1. Coated film thickness

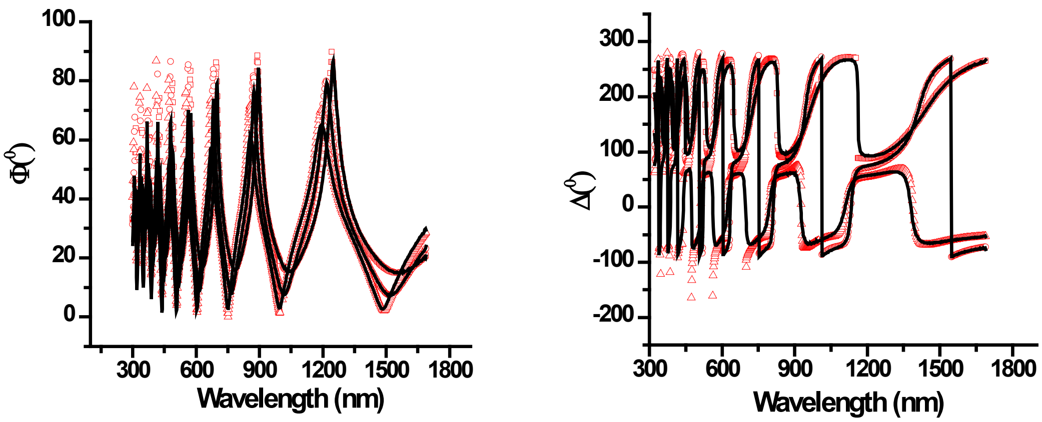

Fig S1. Measured (symbols) fits (solid black lines) of the ellipsometric angles associated with a dip coated film on a silicon wafer.

The thickness of the films produced by dip coating is estimated from analogous coating on silicon wafers. Due to the local heterogeneity and anisotropy of Kapton, direct measurements were not performed. Figure S1 illustrates the ellipsometry measurements after thermopolymerization. The measurements were performed at 3 angles with the fit of ellipsometric angles performed simulteneously to yield an estimated thickness of 1.3 μm.

2. Carbon yield

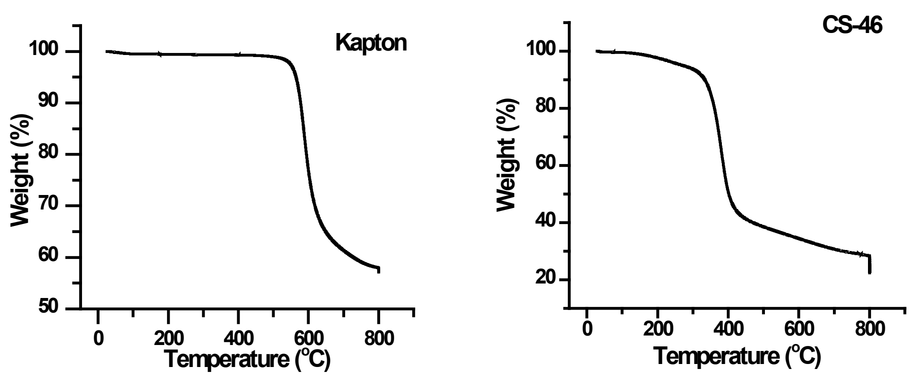

Fig S2. TGA curves for Kapton and silicate-resol-Pluronic F127 (CS-46) under N2 upon heating to 800 °C

The carbon yield is determined by thermogravimetric analysis (TGA). For the pure Kapton, the carbon yield is approximately 60 % at 800 °C. For powders of the carbonized silicate-resol-Pluronic F127 (CS-46), the carbon yield is estimated to be 30 % at 800 °C. In order to understand the fraction of carbon from the mesoporous coating, the mass of material at different stages of processing is measured. We began with a 15.50 mg piece of Kapton that after coating and thermopolymerization has an increase in mass to 22.73 mg (7.23 mg from the silicate-resol-Pluronic). The expected carbon yield from the Kapton alone is 9.3 mg with an actual measured mass after carbonization being 9.2 mg, which is in good agreement with the calculation based on TGA. For the coated Kapton, the actual mass is 11.72 mg after carbonization at 800 °C, which compares well with the calculated value, 11.5 mg) based on the TGA measurements of the Kapton and silicate-resol-Pluronic F127 composite. After etching of the silicate in base, the mass of the carbonized coated Kapton decreases to 10.71 mg (1.54 mg of mesoporous carbon). From these measurements, we can estimate that 14.4 wt% of the ultimate carbon yield is from the templated mesoporous carbon, while the remainder is the carbon yield from the Kapton.

3. Properties of carbonized Kapton

As the Kapton produces significant carbon yield, it is important to understand the properties of the carbonized Kapton to assess any influence of the Kapton on the properties of the carbonized films. Figure S3 illustrates the CV curve for carbonized Kapton using the same electrodes (Pt counter, $Hg/HgSO_4$ reference) and electrolyte (1 M Na_2SO_4) as used for the characterization of the mesoporous films. It should be noted that the potential range has been increased from 0 − 0.5 V to 0 – 0.8 V to illustrate that the carbonized Kapton can transport charges, but the intrinsic capacitance is extremely low (0.346 μF/g). This is orders of magnitude less than what is observed for the mesoporous carbon films, so we attribute the observed capacitance fully to the mesoporous material.

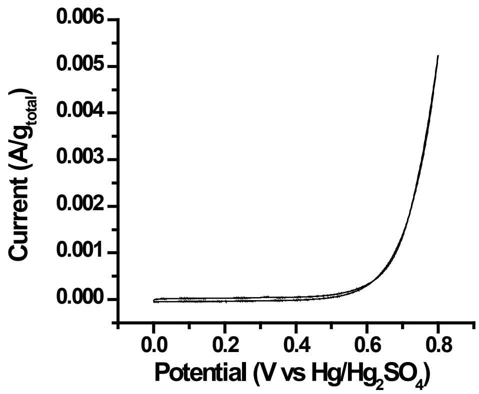

Fig S3. CV curve for a piece of carbonized Kapton at a scan rate of 100 mV/s.

The mesoporous carbon coating does contain silica, which may provide strength to hold any pores in the Kapton through the carbonization process. To address any concerns, we have coated Kapton with silica sol (TEOS) using the same dip coating process and subsequently carbonized and removed the silica. Figure S4 illustrates the surface morphology of this carbonized Kapton. There are some asperities on the surface, which we attribute to the stresses evolved during carbonization from differences between the silica (rigid) and Kapton (contracts and deforms). These features are similar to some found for wrinkling of polymers.[1]

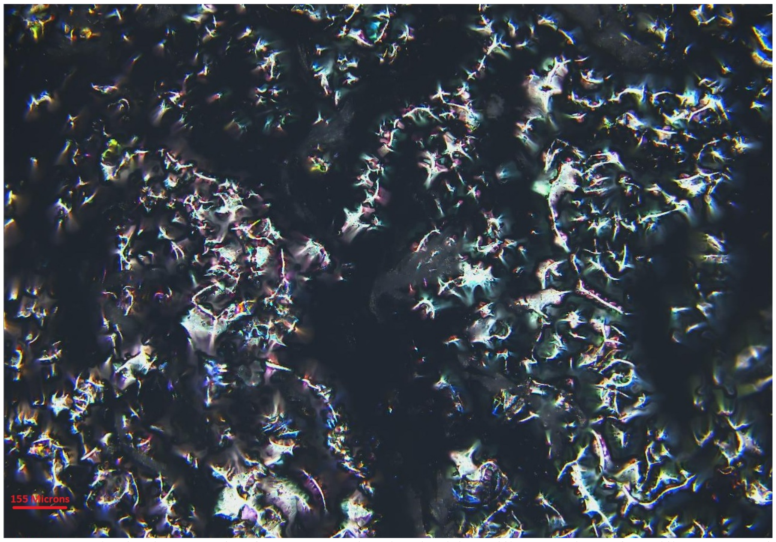

Fig S4. Optical micrograph of Kapton carbonized with a silica coating after silica removal.

4. Electrochemical properties of carbonized mesoporous carbon - Kapton

The carbonization temperature significantly impacts the electrochemical performance of these materials, especially at high rate. Figure S5 illustrates these differences in the CV curves for a fixed rate. At low rates, all curves are fairly rectangular with better performance for the lower carbonization temperature due to its higher surface area. At high rates, the CV curves become significantly distorted for the lower carbonization temperature with better performance from the higher carbonization temperature.

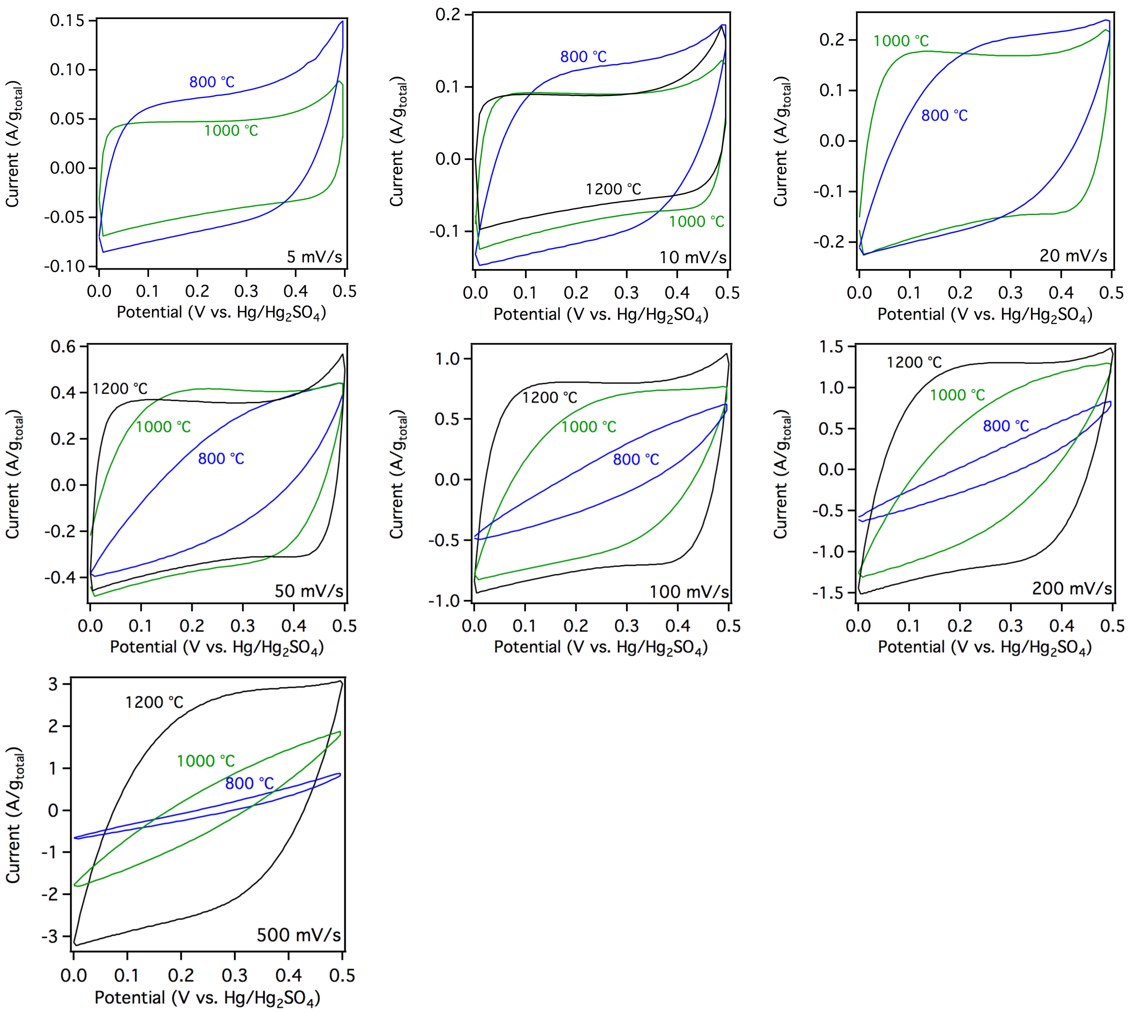

Fig S4. CV curves of the mesoporous carbons fabricated on Kapton at different scan rates.

5. Properties of multiple coated layers on Kapton

In the preparation of multiple layers, four blade coating steps are utilized with a quick crosslinking of the phenolic resin after each coating. By examination of the mass of the Kapton before and after the application of the coating, the loading of the mesoporous carbon precursor is found to increase significantly. The initial mass for the Kapton film is 1.1267 ± 0.003 mg/cm^2. After the deposition of 4 layers, this mass increases to 2.222 ± 0.054 mg/cm^2. Thus, the mass of the resol-silica-pluronic coating is 49 wt % of the material. This is approximately double the mass of the resol-silica-pluronic coating obtained on dip coated Kapton. On carbonization at 1000 °C, the uncoated Kapton yields 0.6071 mg/cm^2; this is 54 wt% carbon yield, which is slightly less than the 59 wt% yield obtained at 800 °C. For the coated multilayers, the yield of the mesoporous carbon (less the Kapton) is 0.554 mg/cm^2 (50.5 wt % yield) and 0.452 mg/cm^2 (41.2 wt%) at 800 °C and 1000 °C, respectively. After etching in base, the mass of the mesoporous carbon is decreased to 0.469 mg/cm^2 and 0.367 mg/cm^2 at 800 °C and 1000 °C, respectively. This means that the mesoporous material is 41.4 wt % and 37.7 wt % of the total carbon yield, respectively. However based on the dip coated films, the etch step should remove 39 wt % of the mesoporous material as the silica is etched. For these multilayer films, only 15 wt % is removed. This means there is a substantial fraction of silica remaining in the coating that cannot be readily removed using standard etching protocols for analogous mesoporous powders.[2] This is consistent with challenges associated with gas desorption from multilayer mesoporous silica films that have been reported previously.[3] Figure S5 illustrates the CV curves obtained from these multilayer films.

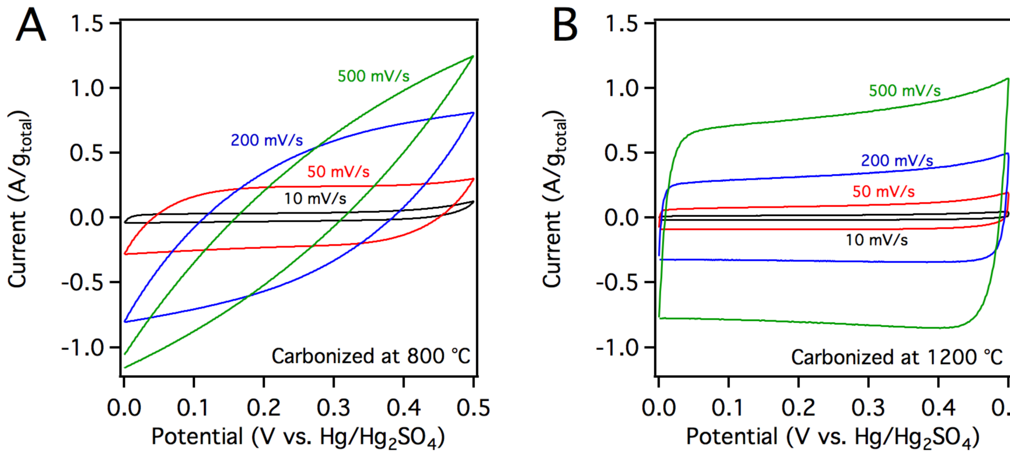

Fig S5. CV curves of the multiple layer mesoporous carbons fabricated on Kapton at different scan rates.

References
1. D. Chen, S. Cai, Z. Suo and R. C. Hayward, *Phys. Rev. Lett.*, 2012, **109**, 038001.
2. R. Liu, Y. Shi, Y. Wan, Y. Meng, F. Zhang, D. Gu, Z. Chen, B. Tu and D. Zhao, *J. Am. Chem. Soc.*, 2006, **128**, 11652-11662.
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