What is claimed is:

1. A nanoporous carbon cathode comprising a carbonized aerogel material having:

a pore structure comprising a fibrillar morphology with a substantially uniform pore size distribution, where pores accommodate formation of lithium peroxide particles;

a Young's modulus of at least 0.2 GPa; and

a density between 0.10 g/cc and 1.5 g/cc.

2. The nanoporous carbon cathode of claim 1, having an electrical conductivity of at least 1 S/cm.

3. The nanoporous carbon cathode of claim 1, wherein the carbonized aerogel comprises a polyimide-derived carbon aerogel.

4. The nanoporous carbon cathode of claim 3, wherein the polyimide-derived carbon aerogel is in a monolith form.

5. The nanoporous carbon cathode of claim 4, wherein the carbon aerogel is substantially or completely binder-free.

6. The nanoporous carbon cathode of claim 4, wherein the carbon aerogel has a thickness between 10 μm and 1000 μm.

7. The nanoporous carbon cathode of claim 1, wherein the pore structure is characterized by pores surrounding the lithium peroxide particles.

8. The nanoporous carbon cathode of claim 7, wherein the pores form interconnected structures around the lithium peroxide particles, characterized by a plurality of connection points between the lithium peroxide particles and pore walls of each pore in which the lithium peroxide particles are surrounded.

9. The nanoporous carbon cathode of claim 1, wherein the nanoporous carbon cathode accommodates 5%-90% of the lithium peroxide particles by weight of the carbonized nanoporous carbon material.

10. The nanoporous carbon cathode of claim 1, having a pore volume of at least 0.3 cc/g.

11. The nanoporous carbon cathode of claim 1, having a porosity between 10% and 90%.

12. The nanoporous carbon cathode of claim 1, having a capacity of at least 800 mAh/g.

13. The nanoporous carbon cathode of claim 1, wherein the pore structure comprises a full width at half max of 50 nm or less.

14. The nanoporous carbon cathode of claim 1, wherein the pore structure comprises a pore size at max peak from distribution of 100 nm or less.

15. The nanoporous carbon cathode of claim 1, wherein the fibrillar morphology comprises a plurality of struts, wherein the struts further comprise carbonized material and wherein at least some of the struts have an average strut width of 2-10 nm.

16. An electrochemical cell comprising the nanoporous carbon cathode of claim 1.

17. A lithium-air/oxygen or zinc-air/oxygen battery, comprising the electrochemical cell of claim 16.