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HIGH-SURFACE-AREA BIOCARBONS FOR REVERSIBLE ON-BOARD STORAGE OF NATURAL GAS AND HYDROGEN

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ABSTRACT

An overview is given of the development of advanced nanoporous carbons as storage materials for natural gas (methane) and molecular hydrogen in on-board fuel tanks for next-generation clean automobiles. The carbons are produced in a multi-step process from corncob, have surface areas of up to 3500 m^2/g, porosities of up to 0.8, and reversibly store, by physisorption, record amounts of methane and hydrogen. Current best gravimetric and volumetric storage capacities are: 250 g CH_4/kg carbon and 130 g CH_4/liter carbon (199 V/V) at 35 bar and 293 K; and 80 g H_2/kg carbon and 47 g H_2/liter carbon at 47 bar and 77 K. This is the first time the DOE methane storage target of 180 V/V at 35 bar and ambient temperature has been reached and exceeded. The hydrogen values compare favorably with the 2010 DOE targets for hydrogen, excluding cryogenic components. A prototype adsorbed natural gas (ANG) tank, loaded with carbon monoliths produced accordingly and currently undergoing a road test in Kansas City, is described. A preliminary analysis of the surface and pore structure is given that may shed light on the mechanisms leading to the extraordinary storage capacities of these materials. The analysis includes pore-size distributions from nitrogen adsorption isotherms; spatial organization of pores across the entire solid from small-angle x-ray scattering (SAXS); pore entrances from scanning electron microscopy (SEM) and transmission electron microscopy (TEM); H_2 binding energies from temperature-programmed desorption (TPD); and analysis of surface defects from Raman spectra. For future materials, expected to have higher H_2 binding energies via appropriate surface functionalization, preliminary projections of H_2 storage capacities based on molecular dynamics simulations of adsorption of H_2 on graphite, are reported.

INTRODUCTION

According to the State Alternative Fuels Plan [1] of the California Air Resources Board and California Energy Commission, adopted October 31, 2007, in response to Assembly Bill 1007, the State of California will take action to increase its use of natural gas (NG, methane, CH_4) as motor fuel from currently 0.6% to 19% (aggressive scenario) of the state's on-road