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Preparation and characterization of high-spinnability isotropic pitch from 1-methylnaphthalene-extracted low-rank coal by co-carbonization with petroleum residue

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ABSTRACT

Coal extract produced by solvent extraction of low-rank coal is not suitable for spinning due to its high oxygen content. In order to effectively overcome this limitation, soft pitch was produced by co-carbonization of coal extract and petroleum residues. The decrease in oxygen content was confirmed by physical property analyses of the soft pitches blended at different mixing ratios. A bridge/hydro-aromatic structure of the soft pitch was observed during the co-carbonization. The produced spinnable pitch had a high spinnability and a softening point of 230 °C. This spinnable pitch, prepared by solvent extraction of low-rank coal, showed excellent spinnability and was heat-treated at 800 °C for 5 min to produce isotropic carbon fibers having diameters of 7 μm and a tensile strength of 1189 MPa. Thus, the co-carbonization of coal extract and petroleum residue is an effective method for the production of inexpensive spinnable pitch for isotropic carbon-fiber manufacture.

1. Introduction

Coal was used as the power source for the steam engine of the Industrial Revolution and it has been regarded as one of the most important energy sources in the world, a major energy source that has grown up with mankind, in various fields, up to modern society [1]. It is classified into high-rank coal, such as bituminous coal, and low-rank coal, such as lignite, depending on its heating value and moisture content [2]. Recently, due to the depletion of coal resources and the increase in demand caused by the economic growth of various developing countries, it has become difficult to secure the supply of high-rank coal. Low-rank coal, which is an alternative to it, has a low price and possible reserves of 50 billion tons. However, it has a very high moisture content of more than 30%, low calorific value, high possibility of spontaneous ignition, and very limited uses due to the rapid increase in carbon dioxide emissions during power generation, caused by its high oxygen content [3,4]. In order to solve these problems, attempts have been made to manufacture coal extract from low-rank coal by using a chemical refining technique [5,6].

Carbon fiber is an endlessly connected fiber of aromatic compounds, which is ten times stronger than iron but very lightweight, weighing only a quarter the weight of iron [7]. In particular, various technological needs from industry, such as high-emission automobile and aircraft steel plates, high-efficiency blocking walls, heat-insulating materials, and electromagnetic shielding materials, have led to the development, by many researchers in universities and industries, of isotropic carbon fibers based on relatively inexpensive pitches [8–10], Replacing a structure made of steel with a carbon fiber composite can reduce its weight by about 30%, but, at present when the price of formed carbon fiber in the market is about 12–20 $/kg, it poses the problem of this price being about 9 times higher than that of steel. In order to secure the carbon-fiber market it is necessary to reduce its manufacturing cost to less than 10 $/kg [11]. Coal extract, which does not contain metallic ash, has good fluidity, and is manufactured by solution extraction from low-

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