layers and a core either of α-Fe phase or of Fe_3C phase. Such particles possess a large coercive force ($H_c = 866.64$ Oe) and good ferromagnetism ($M_r/M_s = 0.325$). Due to the simplicity of the apparatus and good productivity of the present technique, it offers a very attractive way for the production of CEMNPs on large scale.

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Development of carbon precursor from bamboo tar

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Bamboo is a renewable resource that can provide an available energy source when the cycle of its plantation and use is properly scheduled. Its pyrolysis in the

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absence of air provides bamboo tar as well as bamboo charcoal. The charcoal is used as an effective adsorbent for removal of humidity and odors as well as a convenient solid fuel. The by-product tar with high oxygen content contains a mixture of phenols [1–3] and may be applied as a precursor for carbon products, considering its molecular structural characteristics. The pretreatment and carbonization properties of eucalyptus pitch have been reported to yield an interesting precursor for this possible application [4,5].

Generally, polymerization of phenols with formaldehyde is employed to synthesize phenolic resin, an important precursor for many carbon products. The composition of bamboo tar suggests its suitability as a competitive and renewable substitute for phenolic resin in the manufacture of carbon materials. In the present study, our target is to prepare bamboo tar based resin through a chemical modification of bamboo tar. Such biomass resin is expected to be used as a new carbon precursor for carbon materials.

Bamboo tar used in the study was provided by Kansai Electric Power Company and prepared through the following processes: Phyllostachys pubescens, one main bamboo in Japan, was carbonized in a kiln at 700–750 °C for 4 days in the absence of air; gaseous components yielded during the carbonization were condensed in chimney into liquid by outside air; the liquid was collected in a tank through a branch placed at the below part of chimney; the collected liquid was separated into two layers through static precipitation; less dense liquid phase containing water, acetic acid and other components was removed for some application; bamboo tar was obtained from more dense liquid phase.

Compositional and structural properties of bamboo tar were analyzed by the aid of ^{1}H-NMR, FT-IR, GC-MS, TOF-Mass spectrometry and TPD. Elemental analysis of bamboo tar indicates its high oxygen content of ≈30% (C: 62%, H: 7.35%, N: 0.42%; C/H: 0.47%; C/O: 2.7). Its ^{1}H-NMR spectra exhibit peaks at chemical shifts of 1–4 ppm and 6–9 ppm, which are attributed to aliphatic and aromatic hydrogens, respectively. Compared with the content of aromatic hydrogen in coal tar (aromatic hydrogen: ≈80%) [6], that in bamboo tar is low (≈26%), whose aromaticity (fa) is only 0.47.

As shown in Fig. 1, FT-IR spectrum of bamboo tar exhibits a lot of oxygen-containing functional groups, especially –OH groups in bamboo tar. Strong absorption is observed at 3200–3600 cm^{-1}, attributed to free phenolic OH and COOH groups. Two carbonyl bands demonstrate the presence of carboxylic acid and ketone at 1700 cm^{-1}, ether and phenolic OH at 1100–1200 cm^{-1}. The peaks at 1400–1600 cm^{-1} are certainly ascribed to aromatic structures. The molecular weight of bamboo tar ranges from 200 to 600 from TOF-Mass spectrum, and its average molecular weight is calculated as 315. GC–MS spectrum demonstrates that bamboo tar contains many organic species, especially phenol, methyl phenol, 4-ethyl-4-methoxy phenol, and 2,6-dimethoxy phenol.

Bamboo tar of 120 g was polymerized with aq 37% formaldehyde solution of 120 g in a flask with stirring by using oxalic acid and HCl as catalysts at 90 °C for 1 h and 35 min (two-stage polymerization), respectively, to synthesize resin. Bamboo tar resin was obtained by removing water under a vacuum.

The polymerization of bamboo tar with formaldehyde yield resin with an improved softening point of 80 °C at yield of 80%. Compared with original tar, the resin shows higher carbon content of ≈70% and lower oxygen content of 23% (C/H: 0.89; C/O: 4.08). It gives

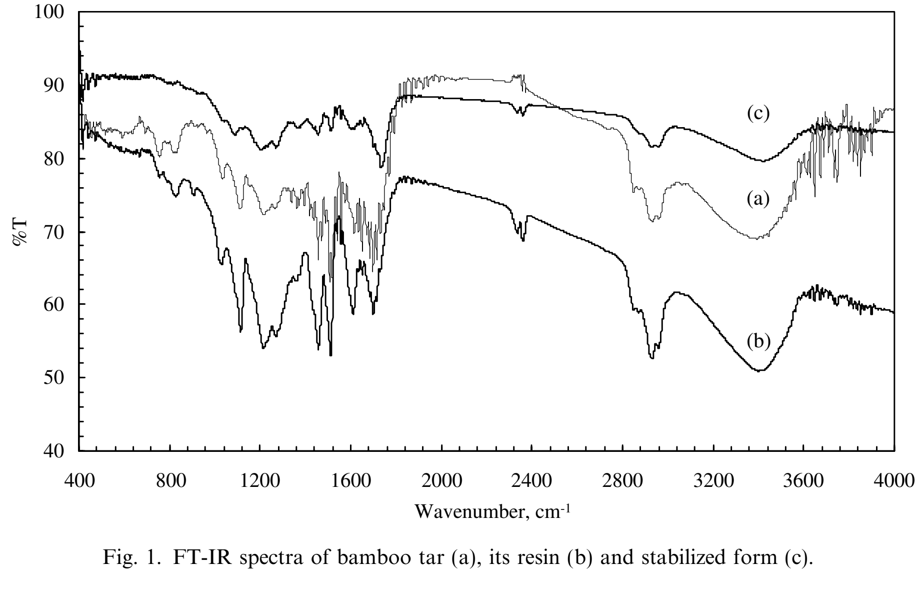

Fig. 1. FT-IR spectra of bamboo tar (a), its resin (b) and stabilized form (c).