

Indeed, the high D-band intensity and I_D/I_G ratio of 1.09 for P-400-M confirm the development of defects and graphitic disorders. The presence of shoulder peak in the region of 1150 cm^{-1} is referred to the carbon-hydrogen bonds [14–15] which can be reflected from the certain condensed polyaromatic structures formed due to the activation of lignocellulosic biomass by phosphoric acid [7].

The nitrogen adsorption isotherms in Fig. 2(a) present high adsorption capacity of the ACs. Nearly unchanged BET surface area $\sim 2000\text{ m}^2\text{ g}^{-1}$ shows the essential development of porous structure confirmed by changing meso- and micro-pore volumes with increasing activation temperature from 400 to $800\text{ }^\circ\text{C}$ (Table 1). This trend is probably caused by cleavage of bonds connecting the biopolymer

fragments and subsequent collapse of porosity and burnout of narrow pores leads to merging into larger pores. Additionally, Fig. 2(b) confirms that the pore size distributions from polymodal structure attributed to AC at $400\text{ }^\circ\text{C}$ is gradually shifted to bi-modal with increasing of activation temperature. Furthermore, the post-treatment of AC (prepared at $400\text{ }^\circ\text{C}$) performed at $800\text{ }^\circ\text{C}$ promotes the reorganization of porosity with a mesopore volume of $0.86\text{ cm}^3\text{ g}^{-1}$ and average micropore size of 0.88 nm which is appropriate for ionic adsorption. Noticeably, the post-treatment enables highest surface area calculated by 2D-NLDFT (SDFT) confirming the high effective surface utilized in capacitive charging for P-400-M (Table 1).

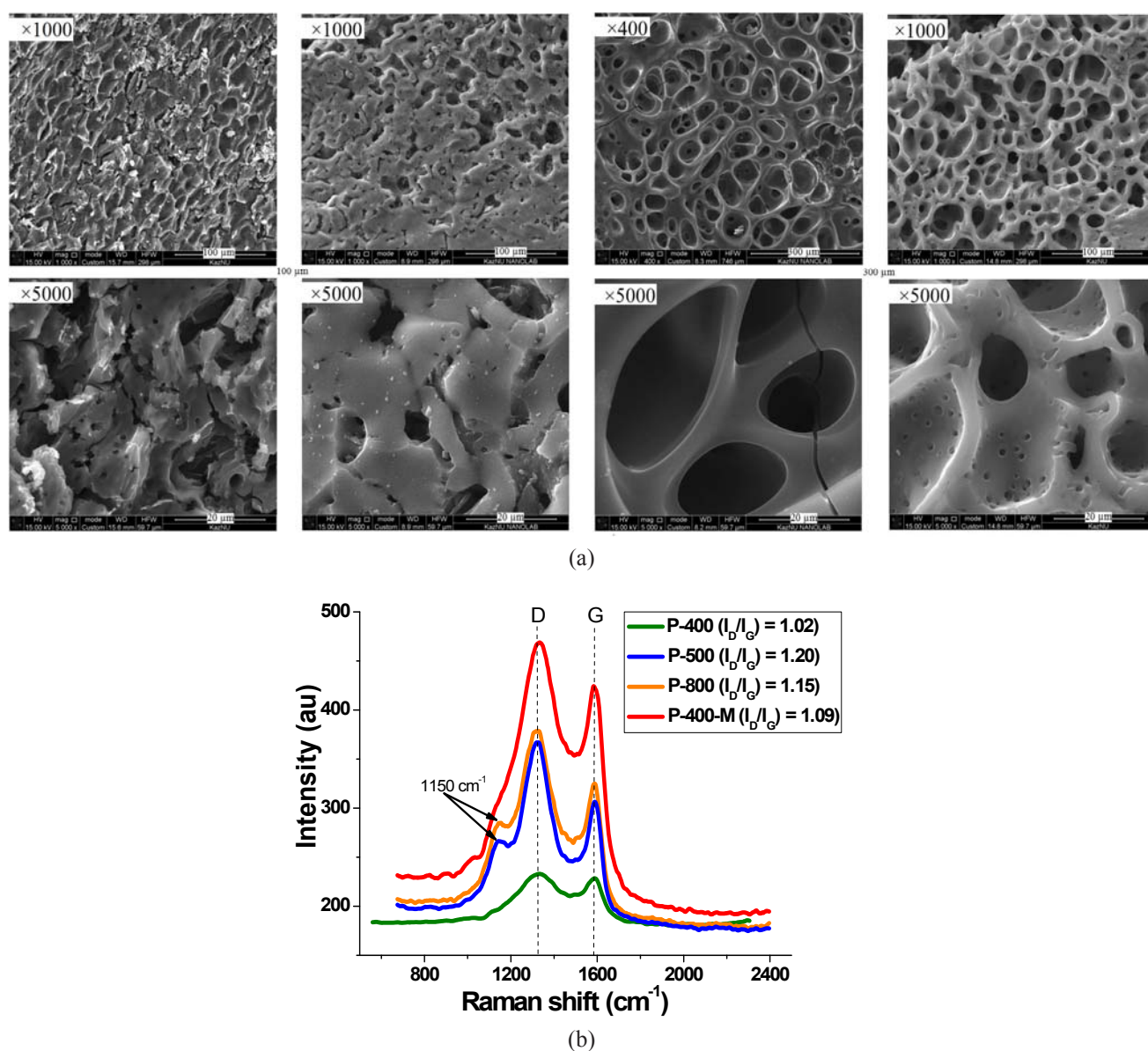


Fig. 1. (a) SEM images and (b) Raman spectra of H_3PO_4 -impregnated walnut shell based ACs P-400, P-500, P-800 and P-400-M.