

## BAB V

### KESIMPULAN DAN SARAN

#### 5.1. Kesimpulan

Berdasarkan hasil penelitian yang telah berlangsung ini, dapat diambil beberapa kesimpulan sebagai berikut:

1. Modifikasi pati dengan urea mengakibatkan penurunan *yield hydrochar* menjadi 16,76% dan 20,33% apabila dibandingkan dengan hasil dari *hydrochar* tanpa urea. Selain itu, *yield N-doped hard carbon* dari proses aktivasi langsung sekitar 28%. Hasilnya lebih tinggi dibandingkan *yield* dari proses HTC dan aktivasi yaitu 7,7% dan 9,93%.
2. Variasi proses mengakibatkan perbedaan morfologi *N-doped hard carbon*. Sampel dengan aktivasi langsung menghasilkan bentuk *irregular shapes* atau *flakes*. Sedangkan, sampel yang melalui tahap HTC menghasilkan bentuk *microsphere* yang mengalami aglomerasi dan terdapat *edge defect*. Modifikasi penambahan urea menyebabkan *edge effect*, dibandingkan *hard carbon* tanpa modifikasi urea yang morfologinya *smooth*.
3. *Doping* nitrogen pada *hard carbon* yang melalui proses aktivasi langsung belum berhasil karena tidak terdeteksi nitrogen. Sebaliknya, berdasarkan analisis EDS, *N-doped hard carbon* dari proses HTC berhasil menambahkan nitrogen sebesar 1,94% dan 2,67% secara berurut untuk variasi urea:pati 1:1 dan 2:1
4. Modifikasi penambahan urea menghasilkan *N-doped hard carbon* dengan *interlayer spacing* sebesar 0,388 – 0,392 nm. Hasil XRD menunjukkan bahwa *N-doped hard carbon* yang melalui proses HTC lebih amorf dengan tingkat amorf 69% dan 71,3% dibandingkan tanpa HTC dengan 63,7% dan 66,2% amorf.
5. Analisis Raman *spectroscopy* menunjukkan *N-doped hard carbon* yang melalui proses HTC memiliki rasio  $I_D/I_G$  yang lebih besar yaitu 1,29 dan 1,38 untuk variasi urea:pati 1:1 dan 2:1. Sedangkan, rasio  $I_D/I_G$  *N-doped hard carbon* dari proses tanpa HTC hanya mencapai 1,17.

## 5.2. Saran

Berdasarkan penelitian yang telah dilakukan, terdapat beberapa saran yang dapat dipertimbangkan untuk mengembangkan penelitian selanjutnya agar lebih baik:

1. Perlu dilakukan studi lebih lanjut mengenai modifikasi pati dengan urea dan analisis pati hasil modifikasi pati untuk memastikan keberhasilan modifikasi pati.
2. Karakterisasi lebih lanjut dapat dilakukan terhadap *hydrochar* untuk mengetahui perubahan karakteristik sebelum dan sesudah aktivasi.
3. Sampel *N-doped hard carbon* sebaiknya dilakukan analisis XPS untuk identifikasi komposisi dan jenis gugus fungsi sehingga hasil lebih akurat.
4. Perlu dilakukan uji lebih lanjut seperti *cycling performance* untuk menelusuri karakteristik *N-doped hard carbon* yang diinginkan untuk SIBs.

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