Improving the Cycling Life of a Li-ion Battery

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National Nanotechnology Coordinated Infrastructure

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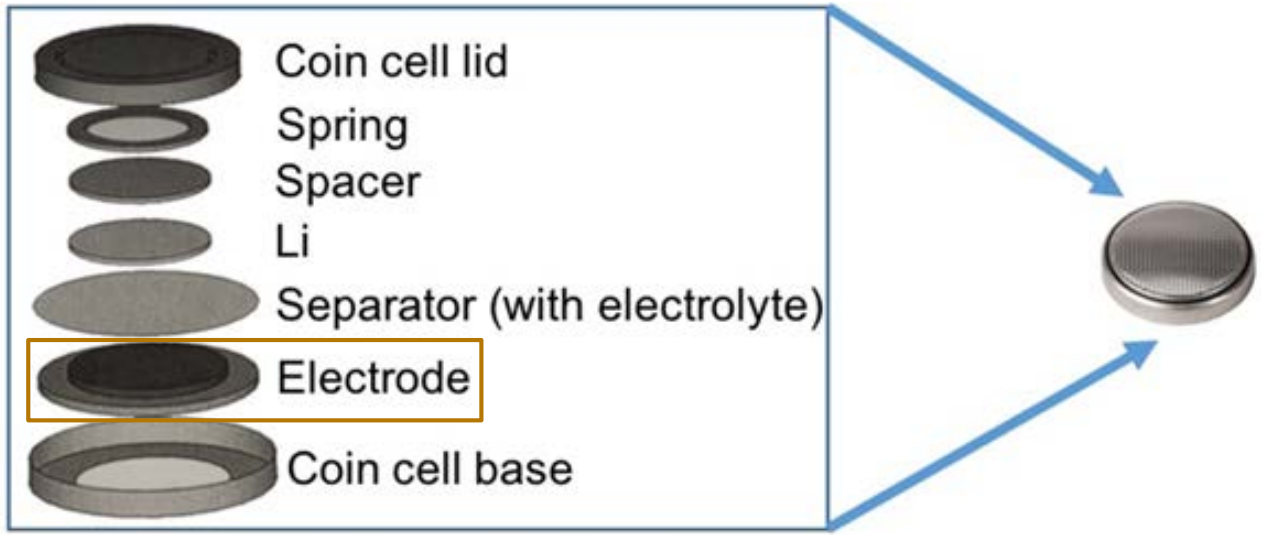
- Focus on anode to Li-ion battery
- Using a high capacity material for long battery life
- Volume Expansion leads to low electron transport
- Use a semi-conductive polymer as binder for the anode



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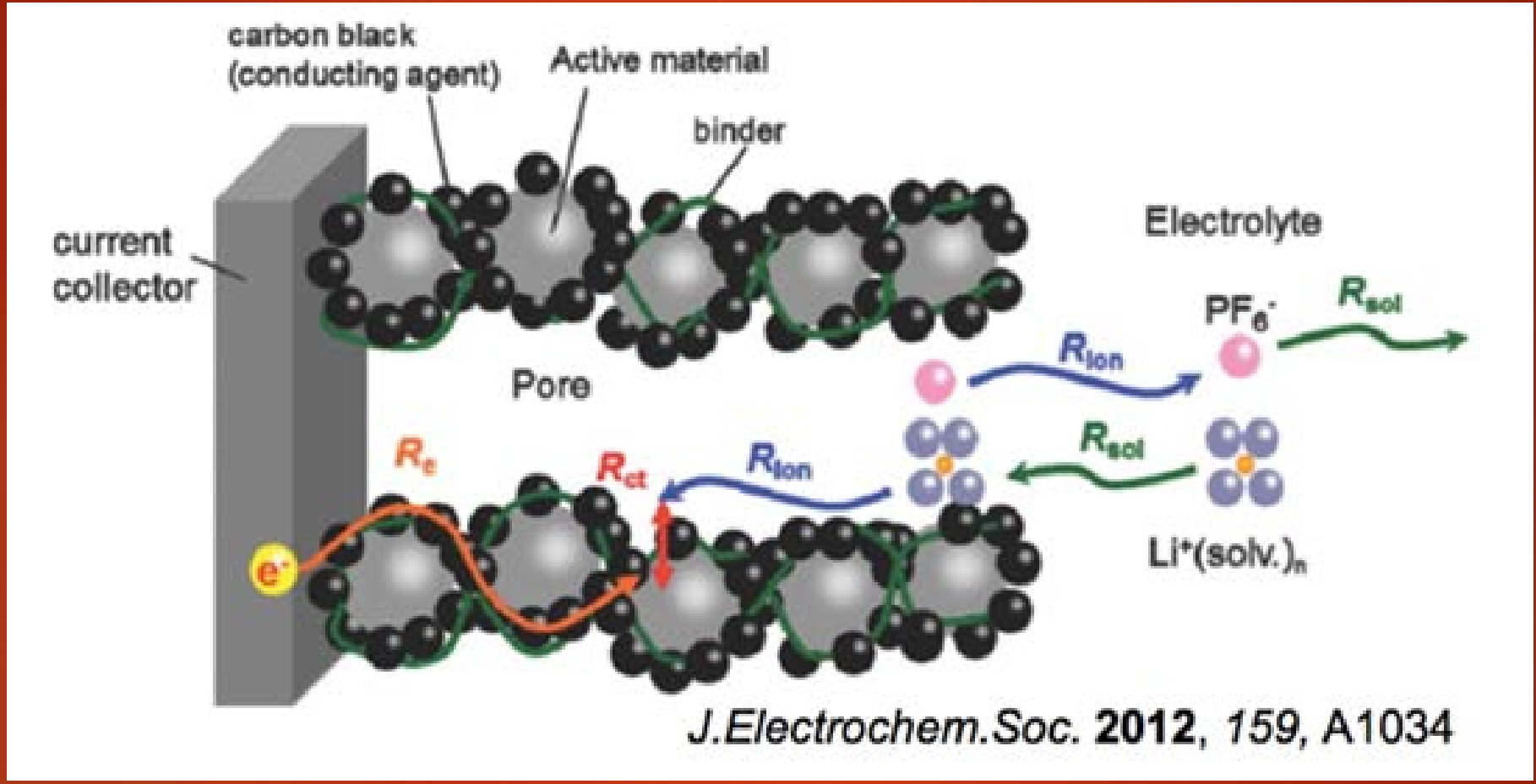

carbon black
(conducting agent)
Active material
binder
current
collector
Electrolyte
PF_6^-
R_{sol}
R_{ion}
Pore
R_e
R_{ct}
R_{ion}
R_{sol}
e^-
$Li^+(solv.)_n$
J.Electrochem.Soc. 2012, 159, A1034

Active Material: Magnetite

Pros

- Readily Available
- High theoretical capacity (926 $mAhg^{-1}$)

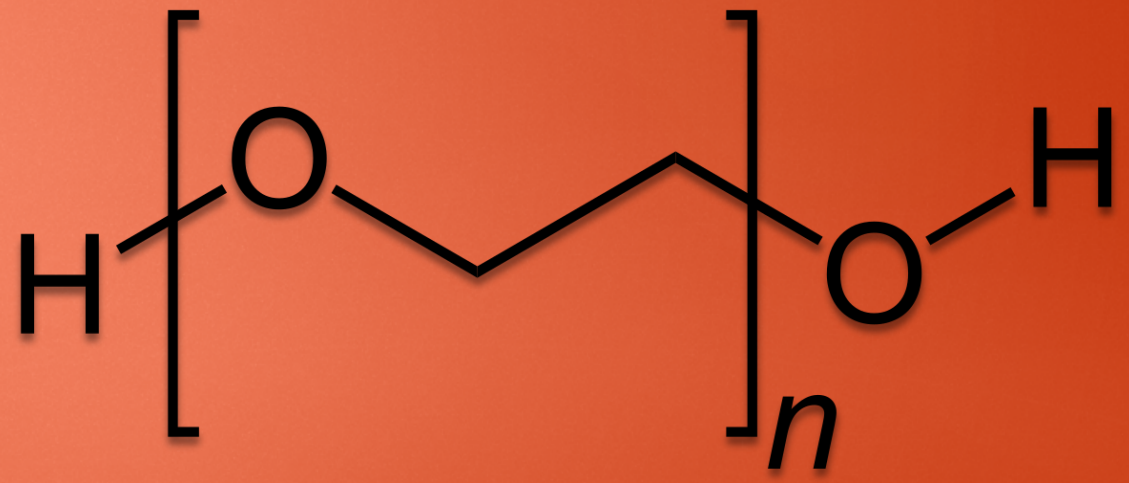
Cons

- Low conductivity
- Insertion process causes volume expansion which causes poor cycle life

Magnetite (Fe_3O_4)

Polyethylene Glycol (PEG) Coating

- Reduce aggregate size
- Improve dispersion
  - Shorten ion diffusion path
  - Homogenous current distribution



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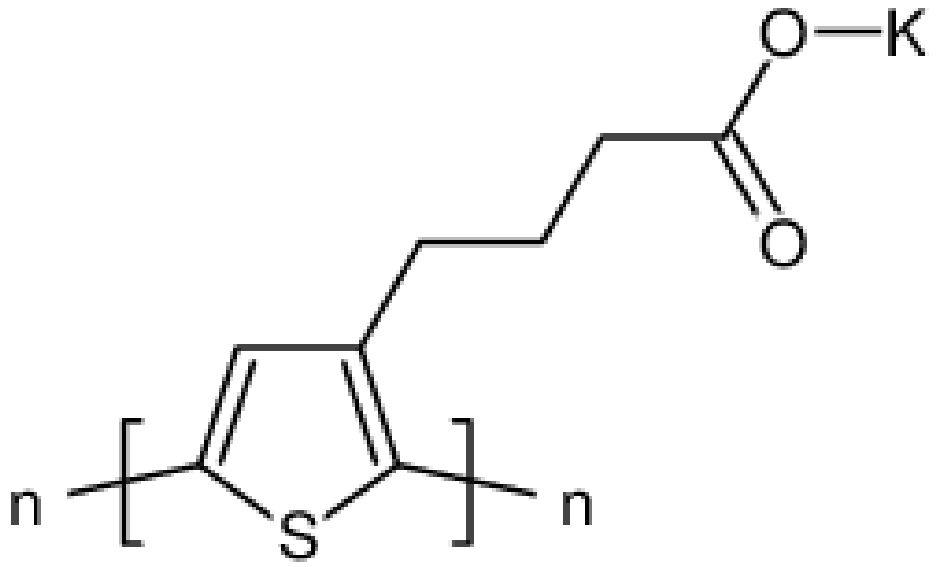
Semi-conductive Binder

- Provides alternative charge pathways
  - Increases electron transport
- Testing PPBT and derivatives (PNBT, PHBT, PKBT)



poly[3-(potassium-4-butanoate) thiophene] (PPBT)

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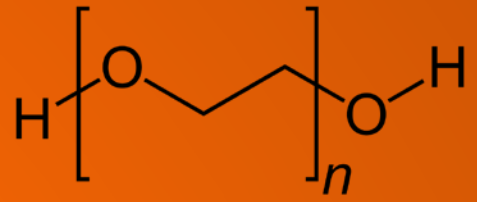
Overview: Anode Components

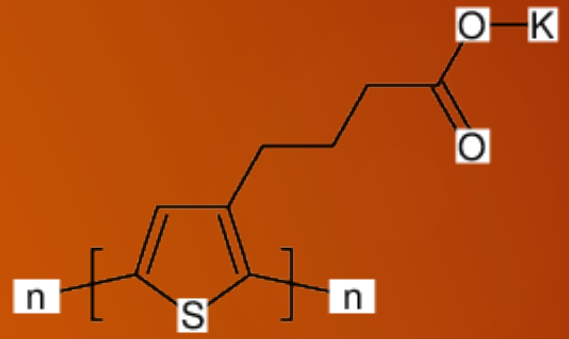
Magnetite (Fe_3O_4)

- Readily available
- High theoretical capacity (926 $mAhg^{-1}$)



Polyethylene glycol (PEG)

- Coating for Magnetite
- Increase dispersion



poly[3-(potassium-4-butanoate) thiophene] (PPBT)

- Semi-conductive binder
- Improve electron transport

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Procedure

Coat	Coat Fe_3O_4 with PEG to reduce aggregation
Formulate	Formulate the ion-exchange derivatives of PPBT
Mix	Mix PEG-Fe_3O_4, polymer binder, and Carbon Super P to create the slurry
Fabricate	Fabricate the electrode by blade coating the slurry

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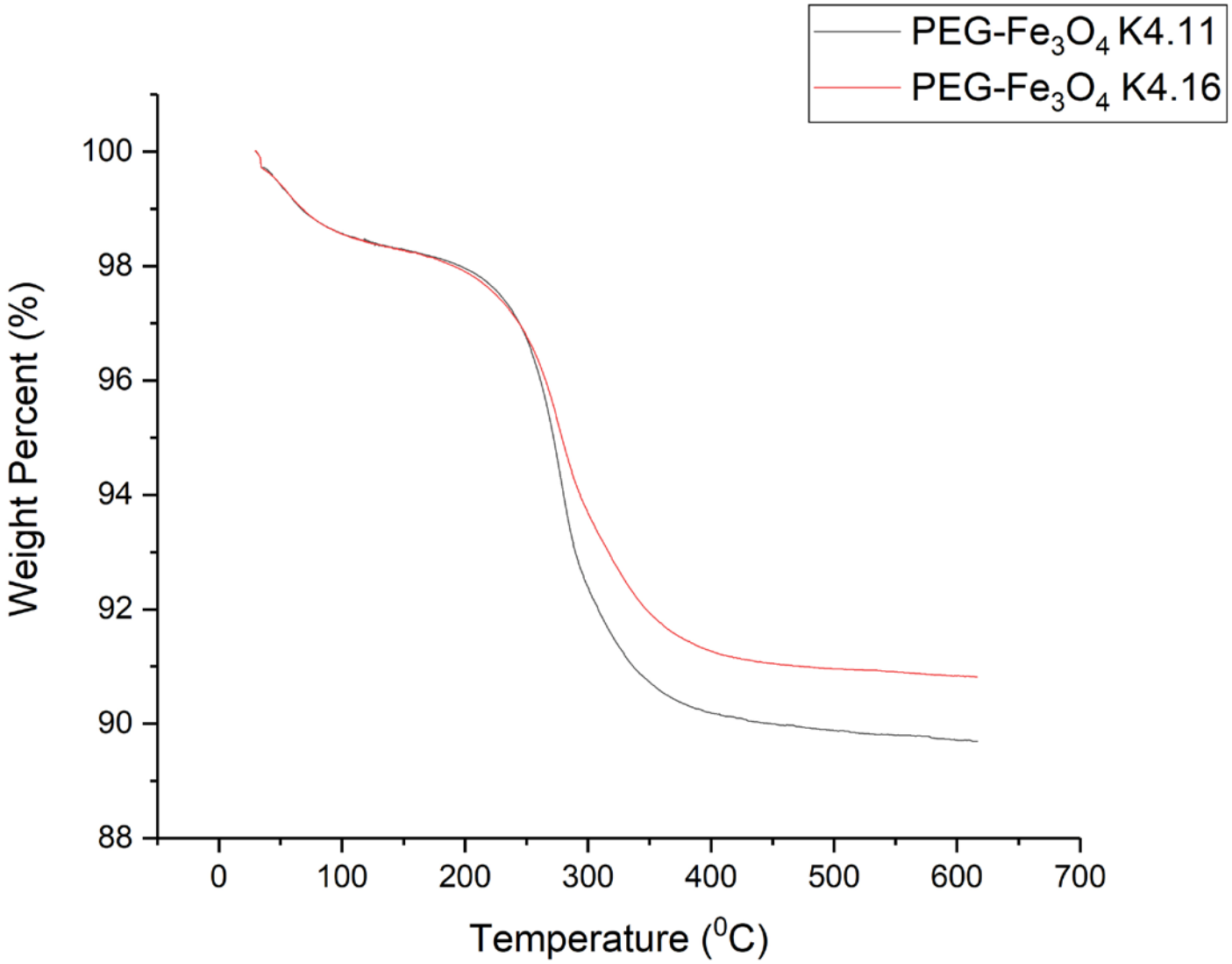

Thermogravimetric Analysis

K4.11: 10.3 wt% PEG
K4.16: 9.18 wt% PEG
AVG: 9.74 wt% PEG

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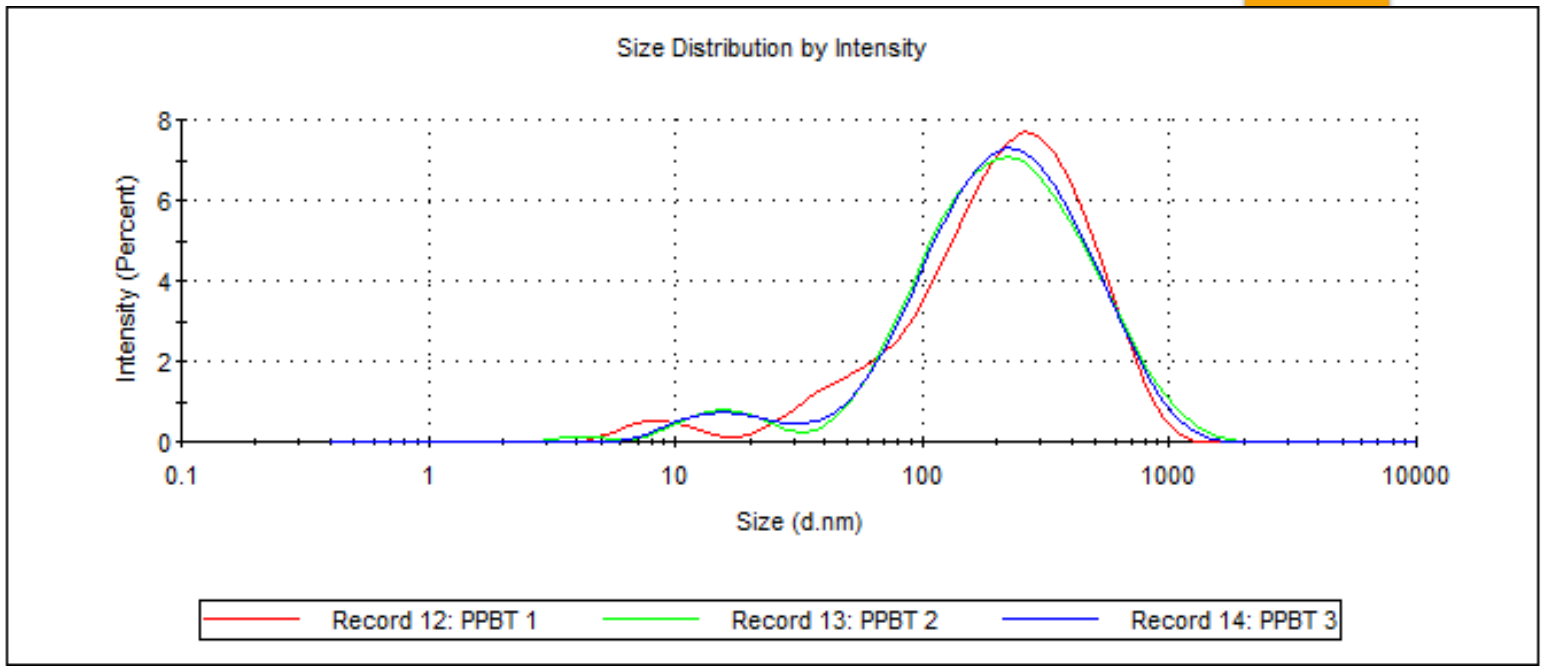
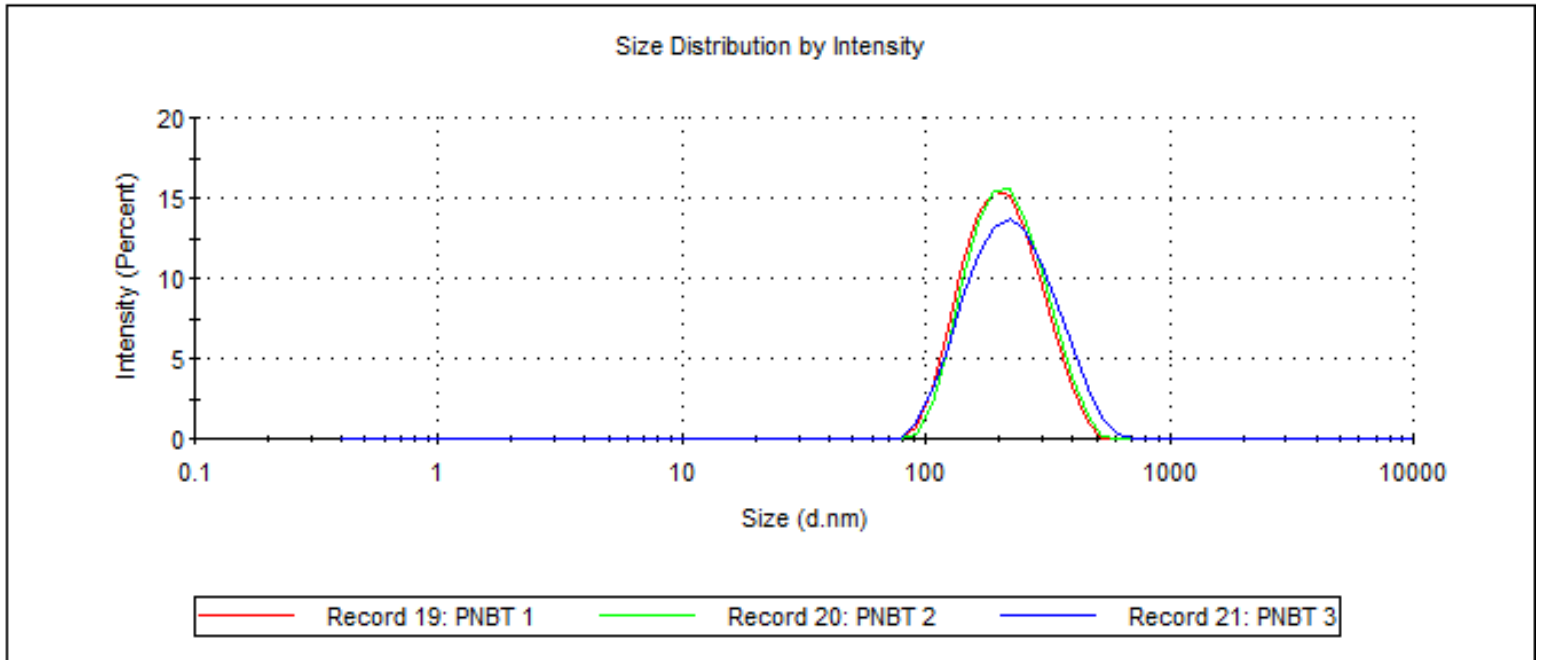
Particle Size

Average Particle Size:

P-K-BT: 14.5 nm ± 5.4, 279.8 nm ± 205.3 nm
P-NH_4-BT: 226.4 nm ± 83.2 nm





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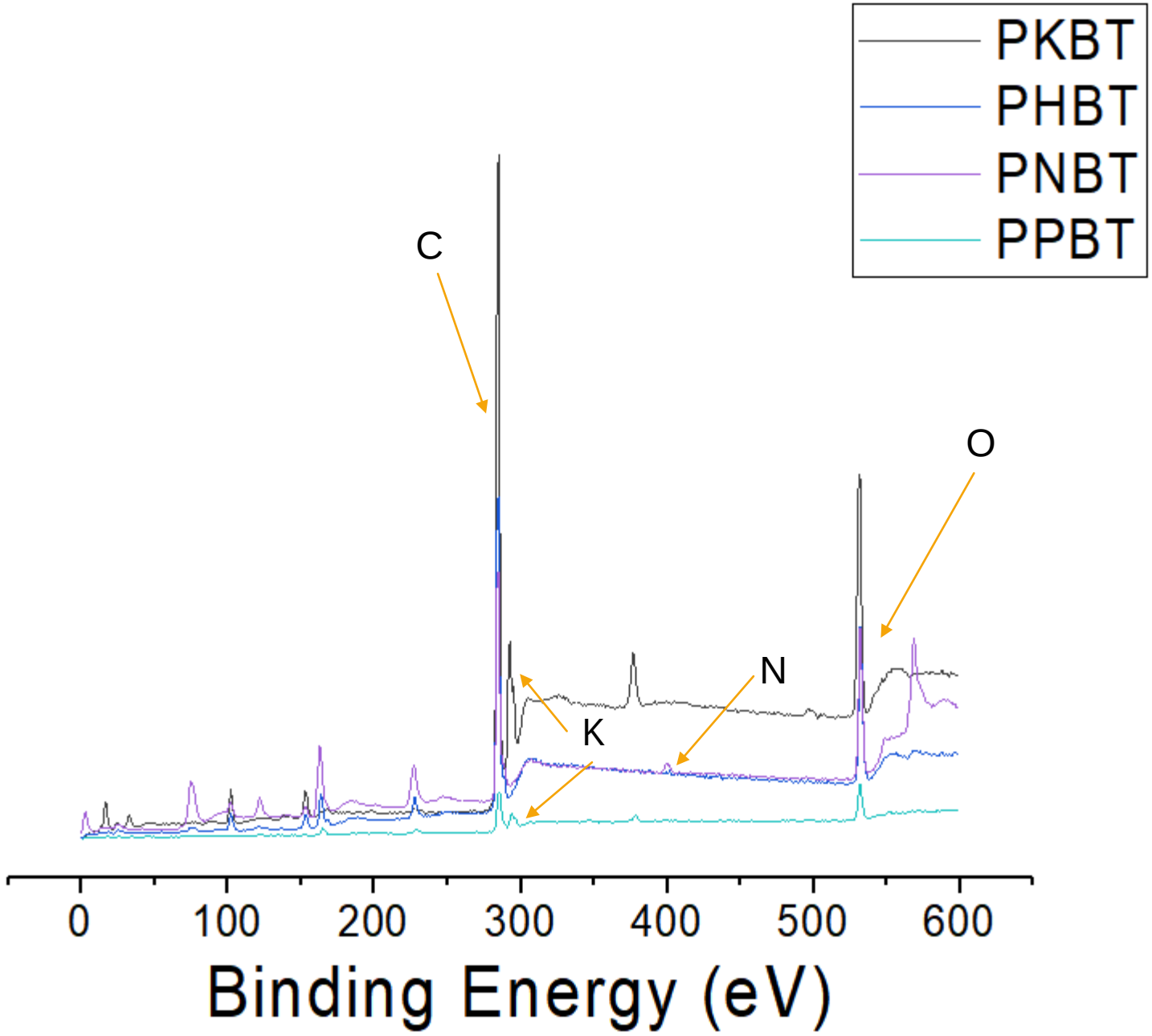

Survey Scan of Semi-conductive Polymers

- K is present in PKBT and PPBT
- N is present in P-NH_4-BT
- K is not present in PHBT

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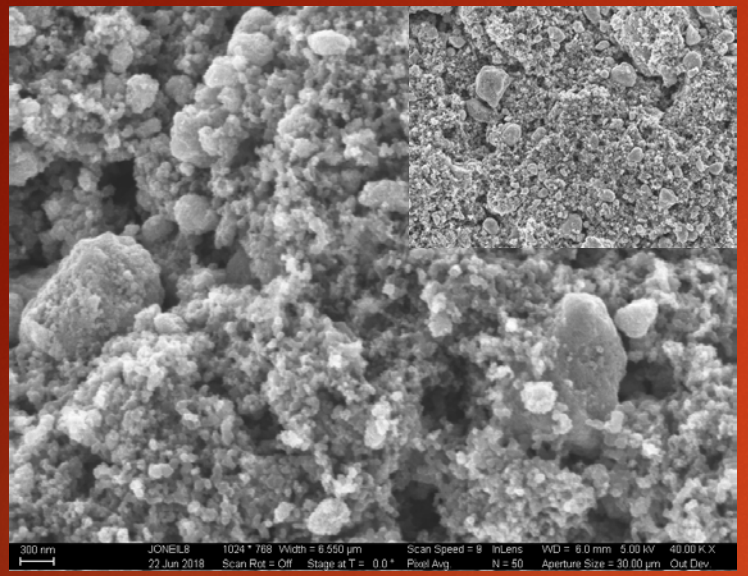
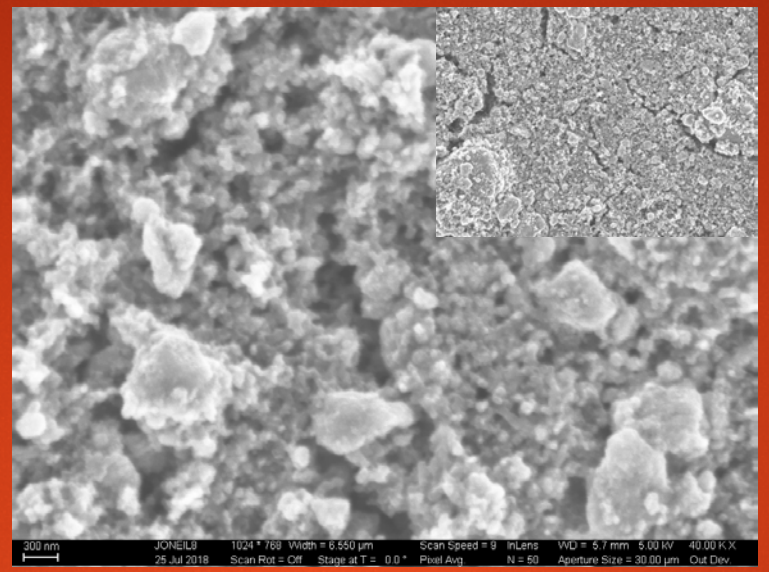
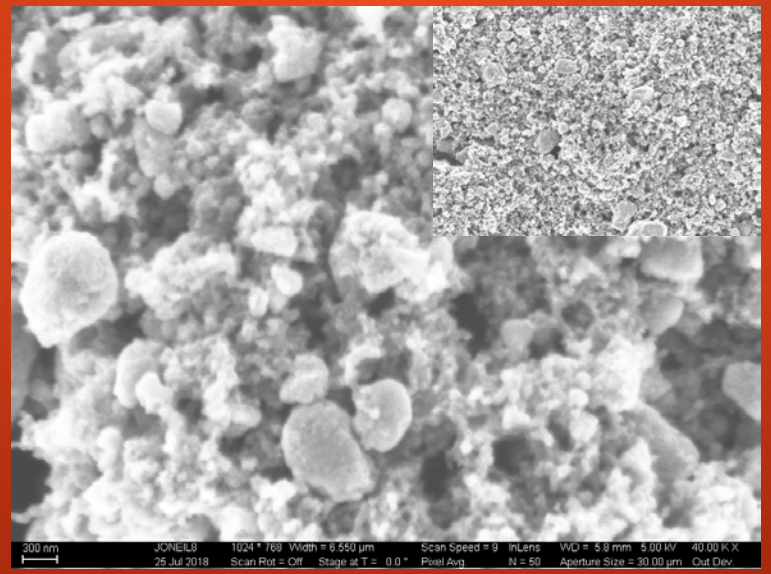
Morphology



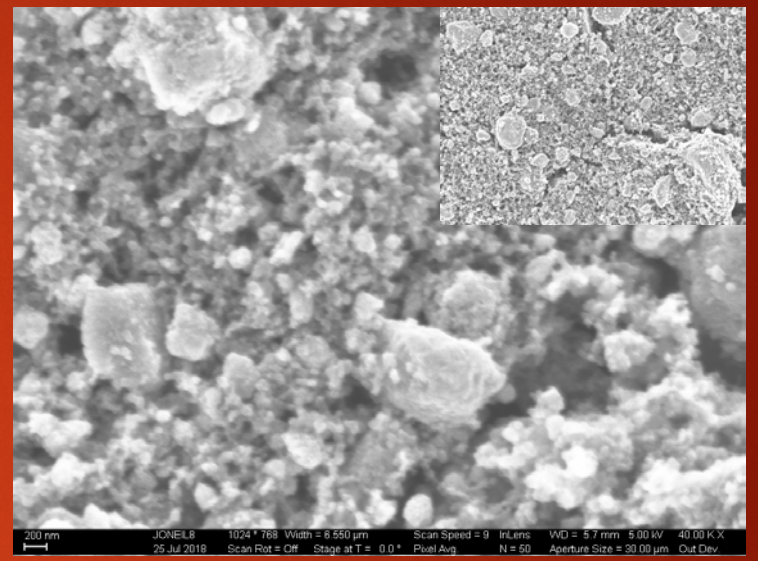
P-NH_4-BT



PPBT



P-H-BT



P-K-BT

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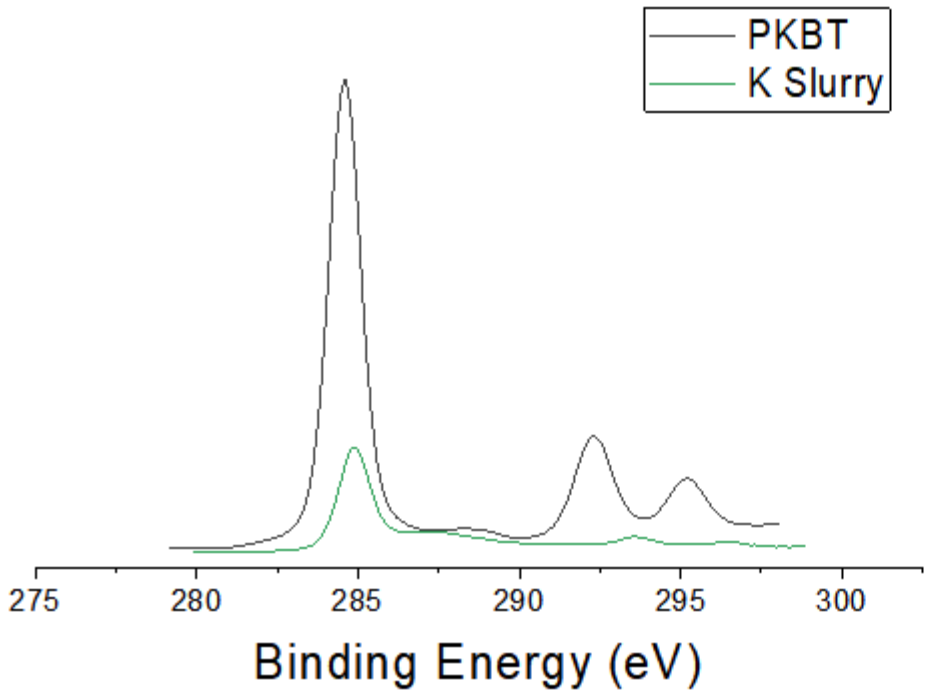
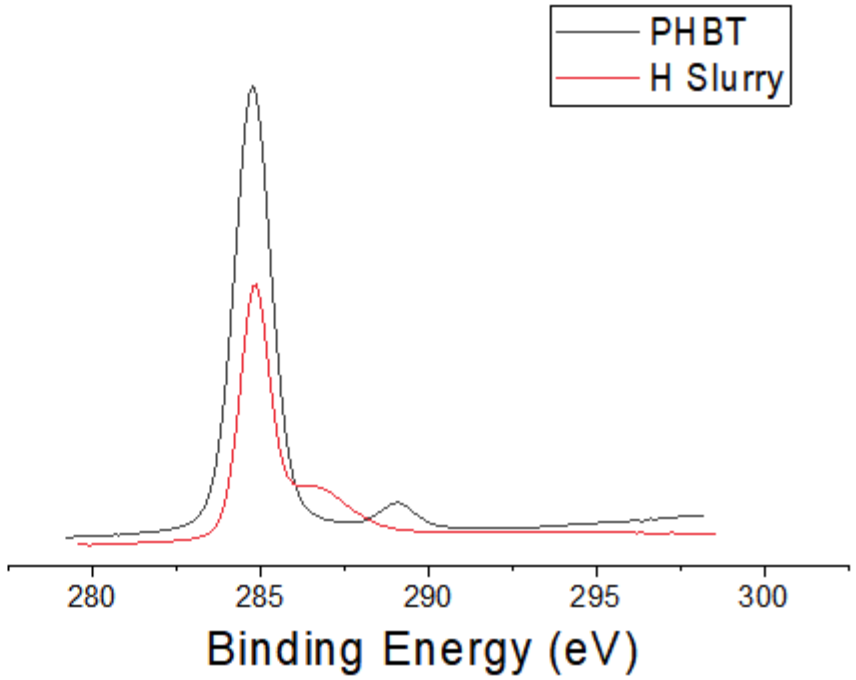
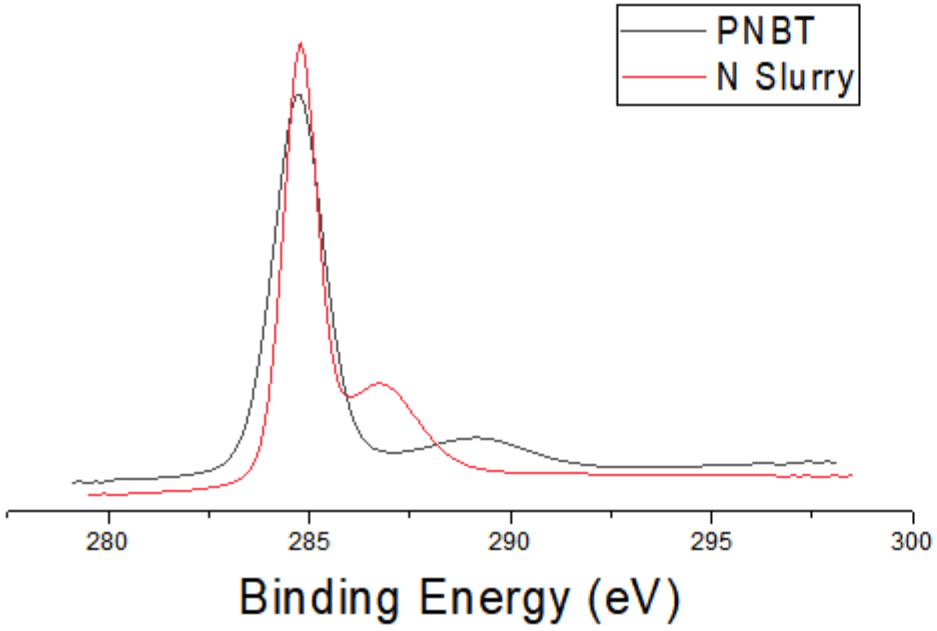
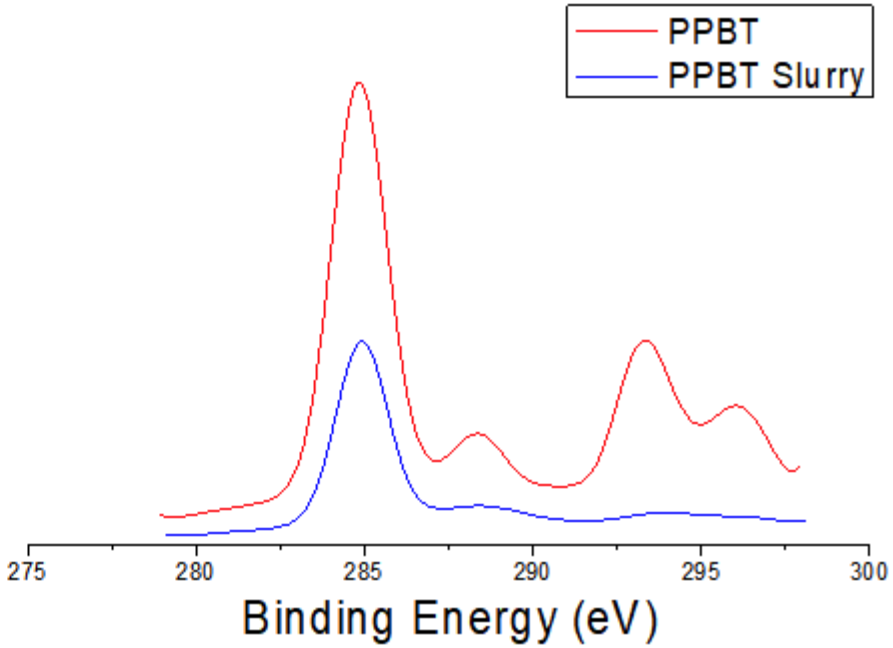
Carbon Peaks

- 1st peak: C-O
- 2nd peak: Carboxylate
- 3rd and 4th peak: pi-pi stacking satellite peaks









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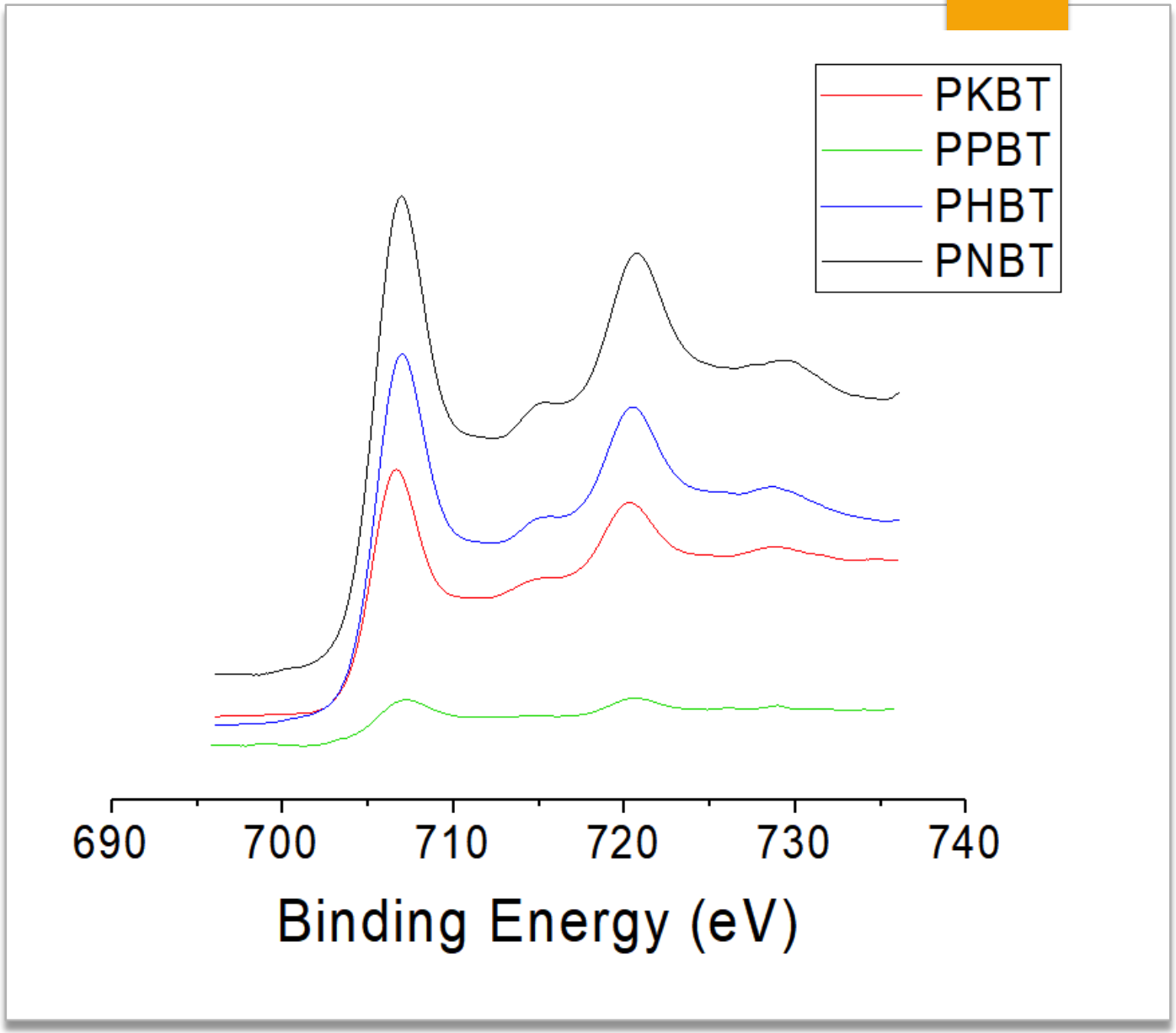
Iron Peaks

1st and 3rd peak: Fe^{+2}
2nd peak: Fe^{+3} shown due to interactions between Fe_3O_4 and polymer binder



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Conclusions

- Successful ion exchange
- Dispersion of ion-exchange electrodes are similar to that of the PPBT electrode
- Smaller polymer particle sizes may increase charge transport due to surface chemistry
- PPBT and PKBT induce more interactions as seen from pi-pi satellite peaks
- Iron peak at ~716 eV shows interactions between Magnetite and each polymer binder

Future Work

- Battery testing (cycle life and rate capability)
- Conductivity tests

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Questions?

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