Development of High Temperature Proton Exchange Membrane Electrolytes

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Planned Completion = December ‘06

Research Goals and Objectives

Develop proton-conducting solid electrolytes possessing the following characteristics:

- Proton conductivity in excess of 0.1 S/cm
- Temperature stability at T > 125 ^{o}C
- Reduced humidity dependence on water saturating conditions (< 25% relative humidity)

Relevance to Current State-of-the-Art

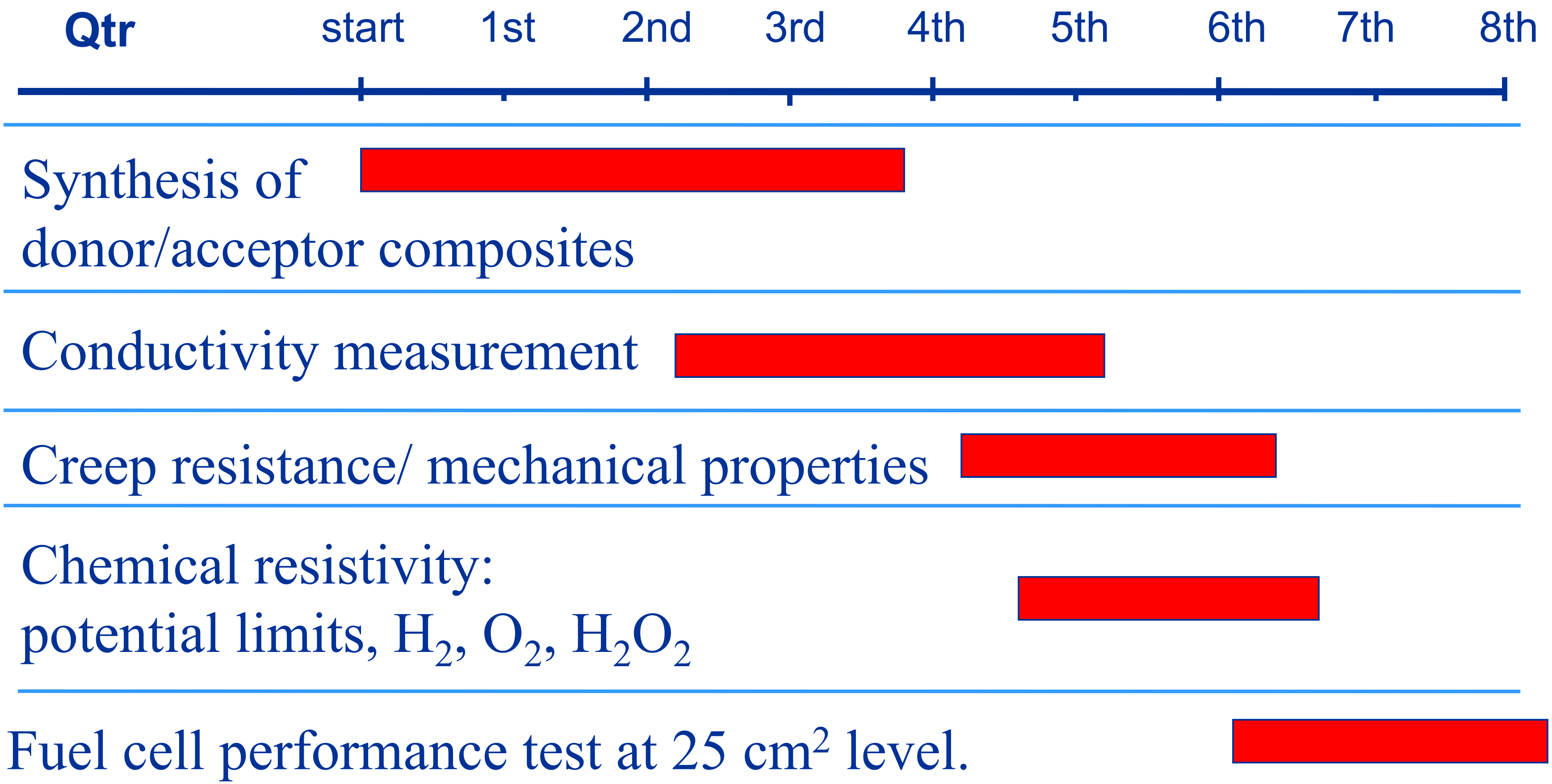
- Fuel Cell specific power ~ 100 W/kg
- Proton Exchange Membrane (PEM) conductivities ~ 0.1 Siemens/cm

Relevance to NASA

Task VII – Hydrogen Powered Aeropropulsion

- Improve power density of fuel cells
- Renewable power generation

Budget, Schedule and Deliverables



Anticipated Technology End Use

Vehicle Systems Program

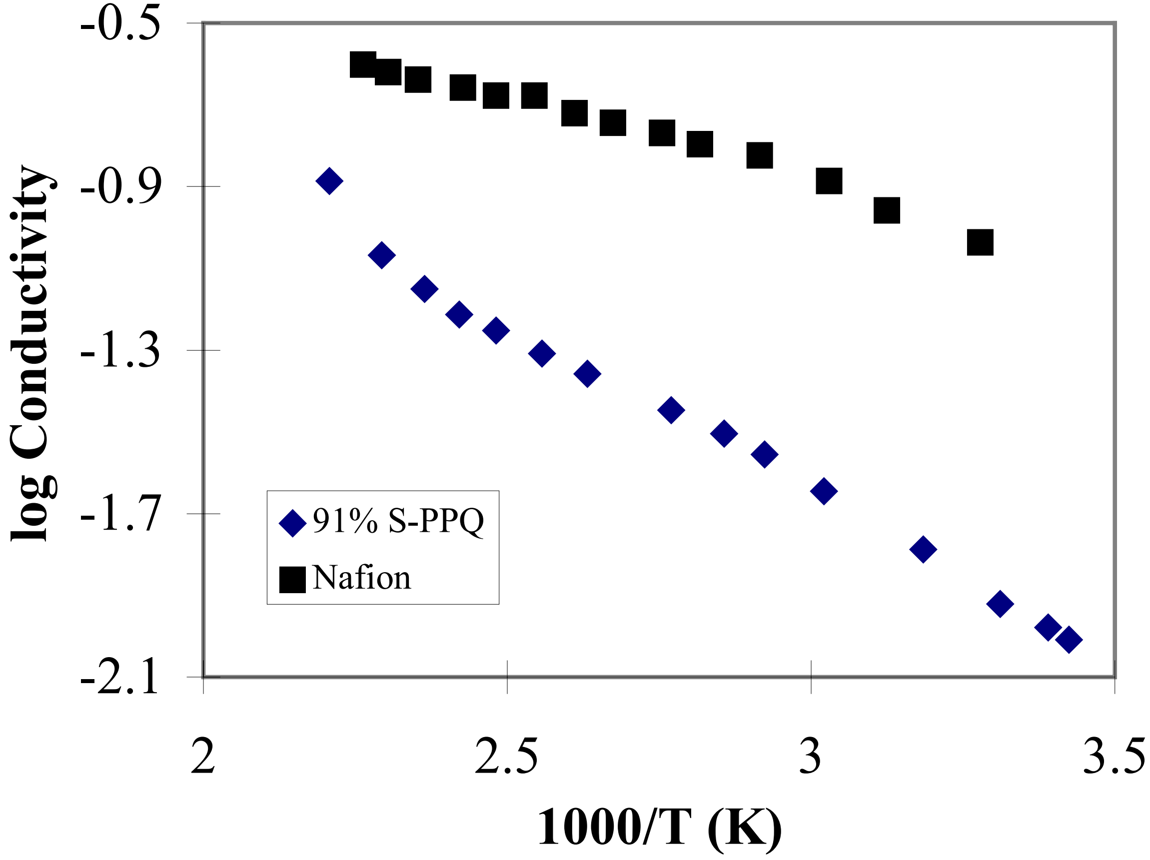
-New Aircraft Energy Sources and Management focus area

-LEAP (Low Emission Alternative Power) project

-AFCPS (Aircraft Fuel Cell Power System): "Develop and demonstrate fuel cell-based power system."

- focus: Regenerative PEM fuel cell development for HALE (High Altitude Long Endurance) solar electric aircraft
- longer-term: High temperature PEM materials (> 125 ^{o}C, 25% relative humidity), secondary and primary

Rationale: Effect of Temperature on Conductivity for Membrane Electrolytes



Structure of Hexagonal Boron Nitride

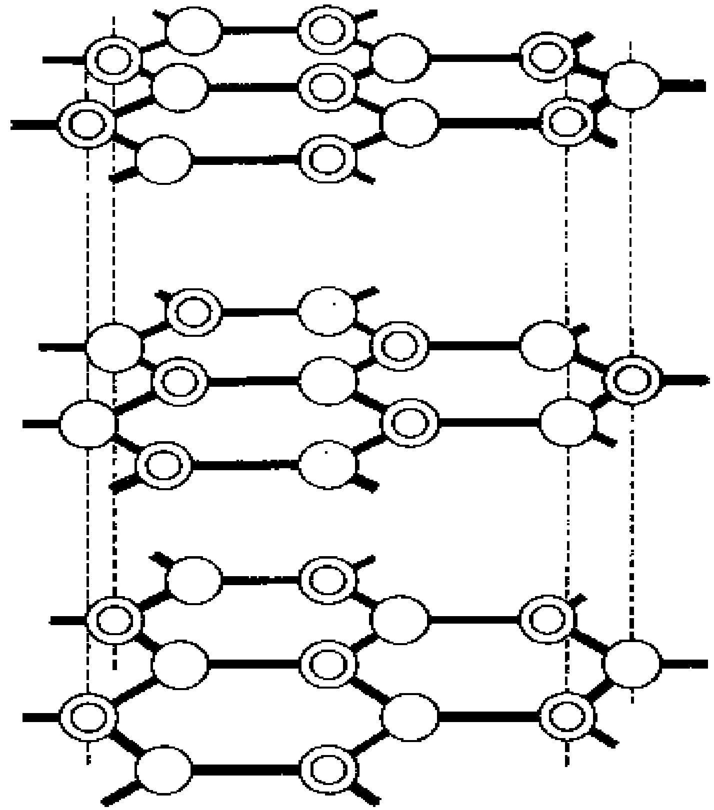


Fig. VI-1: *Layer Arrangement in hexagonal Boron Nitride*

K. Niedenzu and J.W. Dawson, Boron-Nitrogen Compounds, Academic Press, New York, 1965

Accomplishments and Results

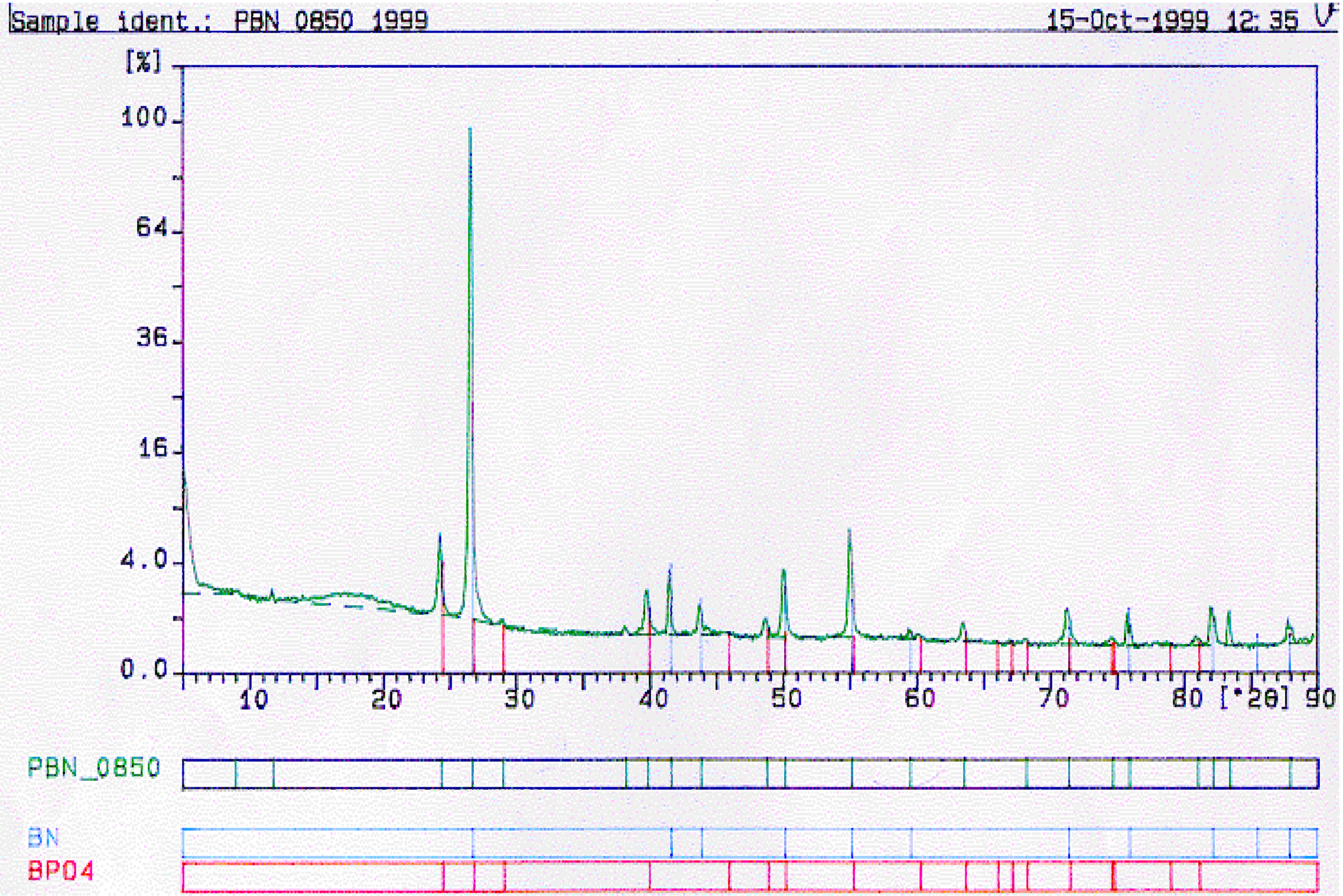
- hexagonal BN used a matrix for proton donors (Bronsted acids)
- No clear evidence of intercalation was detected
- h-BN found to be inert to H_3PO_4 and H_2SO_4; earlier mass gains due to capillary uptake
- Similar behavior found for BC and SiN
- Proton conductivity measurement of BN-H_3PO_4 composites in progress

Acid Stability of h-BN

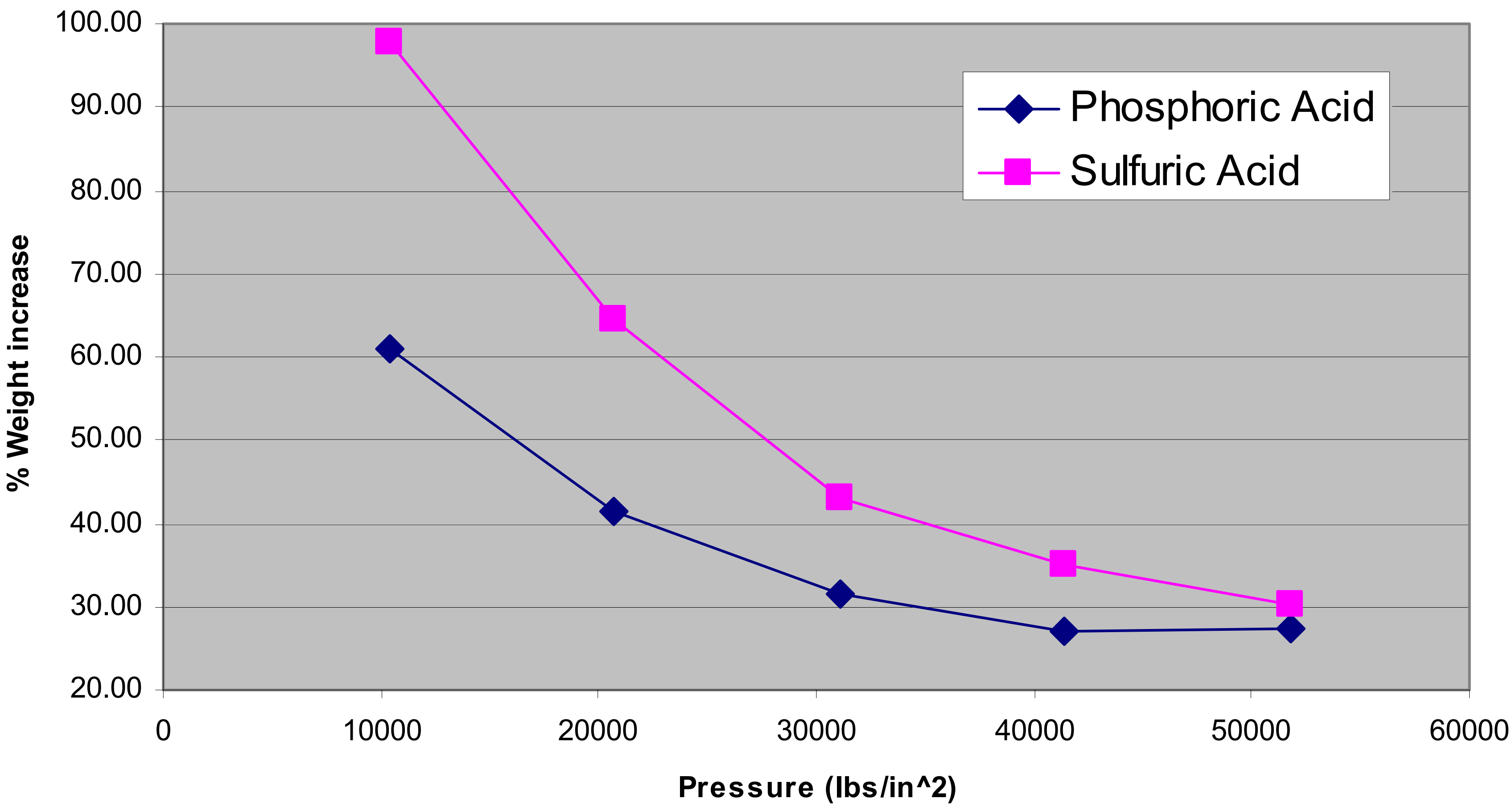
Acid	% weight change after 24 h exposure
HCl	-0.54
HCl (1 week)	-1.50
HCl (3 h, 80° C)	-2.51
HBr	-0.97
HI	-0.96
H_2SO_4	+42.0
H_2SO_4(30% SO_3)	+88.7
H_3PO_4	+36.1
$HClO_4$	-0.10

Acid	% weight change after 24 h exposure
HNO_3	-0.81
HNO_3(11% NO_2)	-0.763
CH_3SO_3H	-0.80
CF_3SO_3H	-0.40
CF_3COOH	-0.12
NH_4OH	+0.70
NaOH (8.0 M)	+5.5
H_2O	-0.57

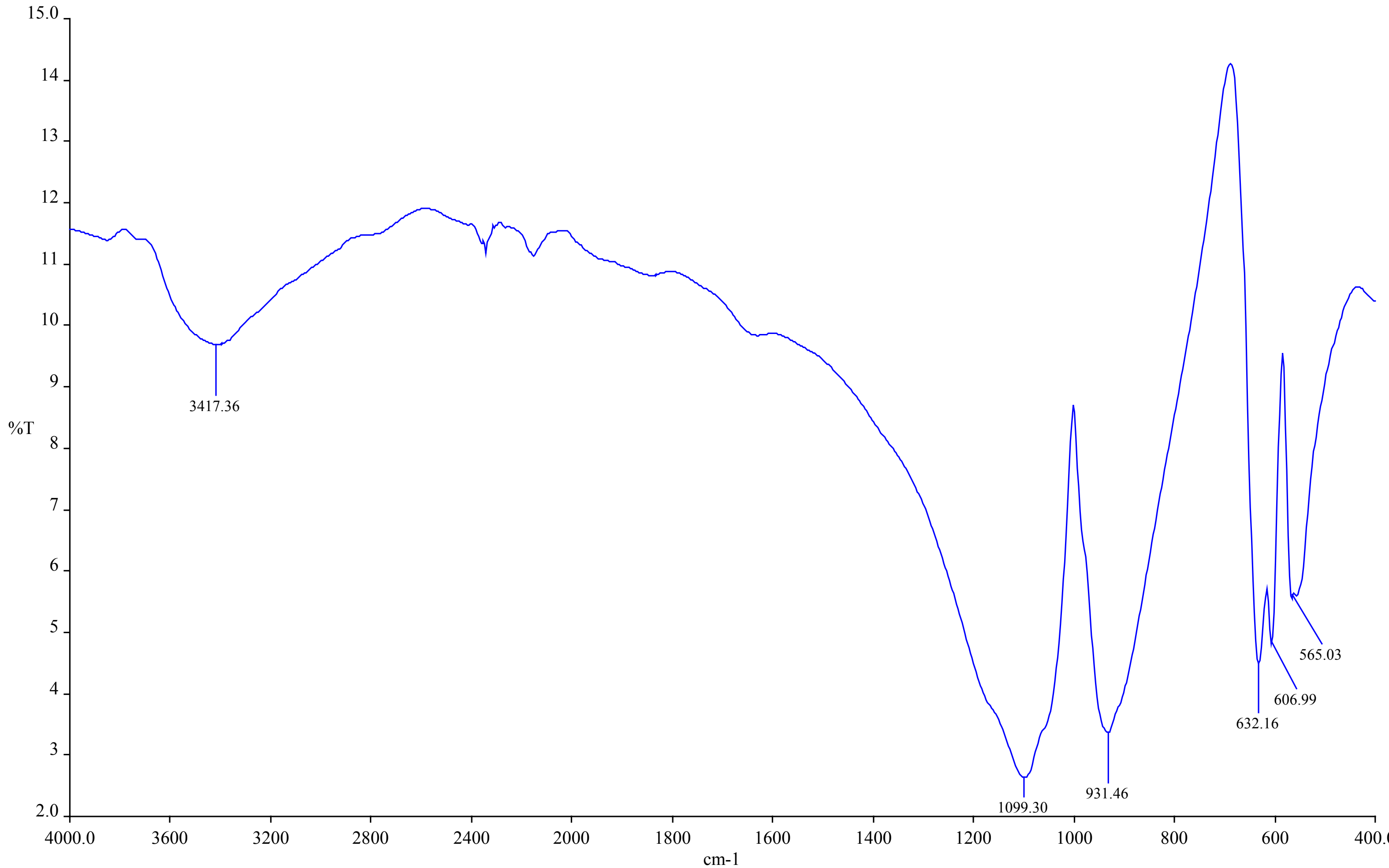
XRD Spectrum of H_3PO_4-treated h-BN



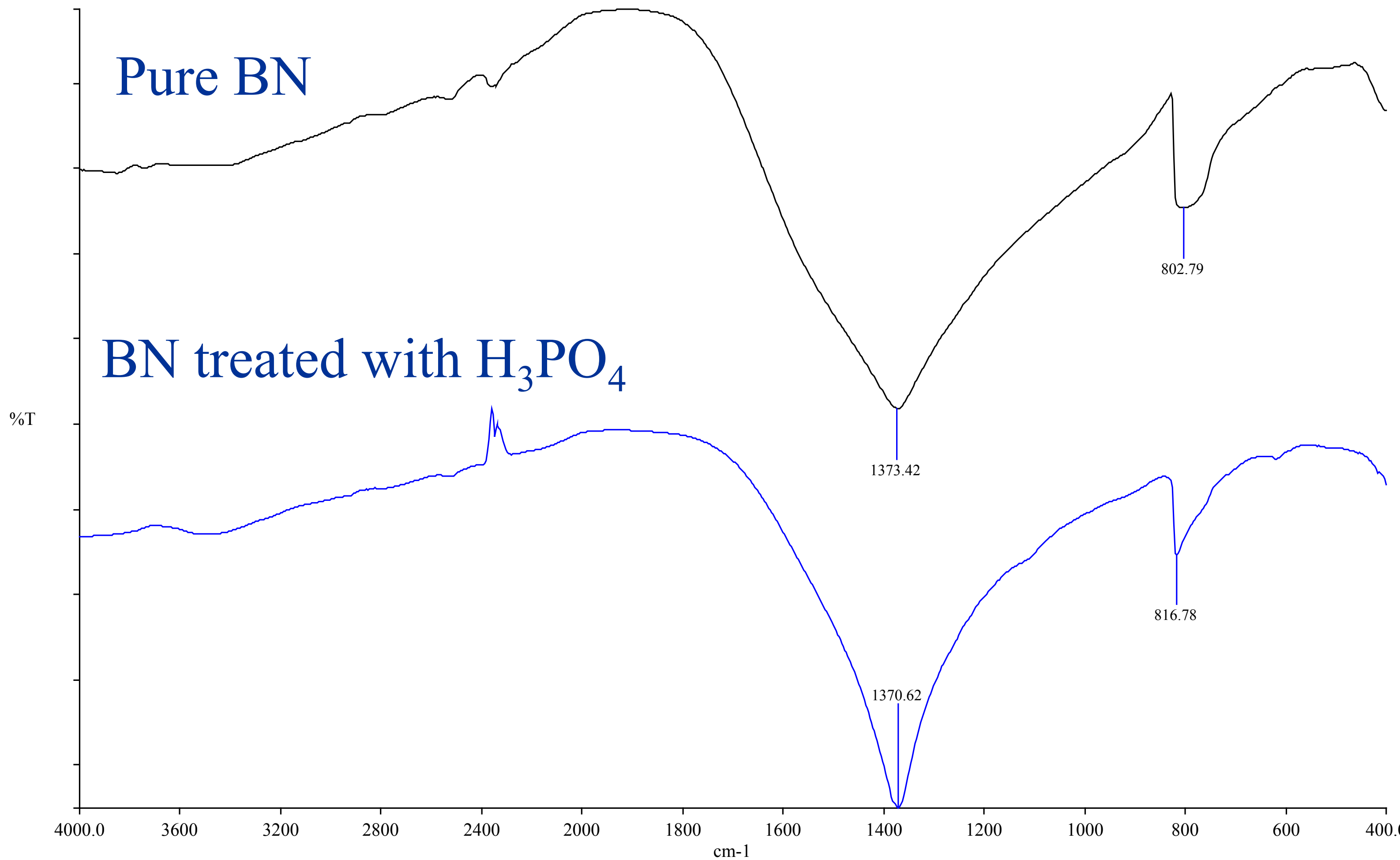
Effect of pressure (void volume) on acid uptake by BN



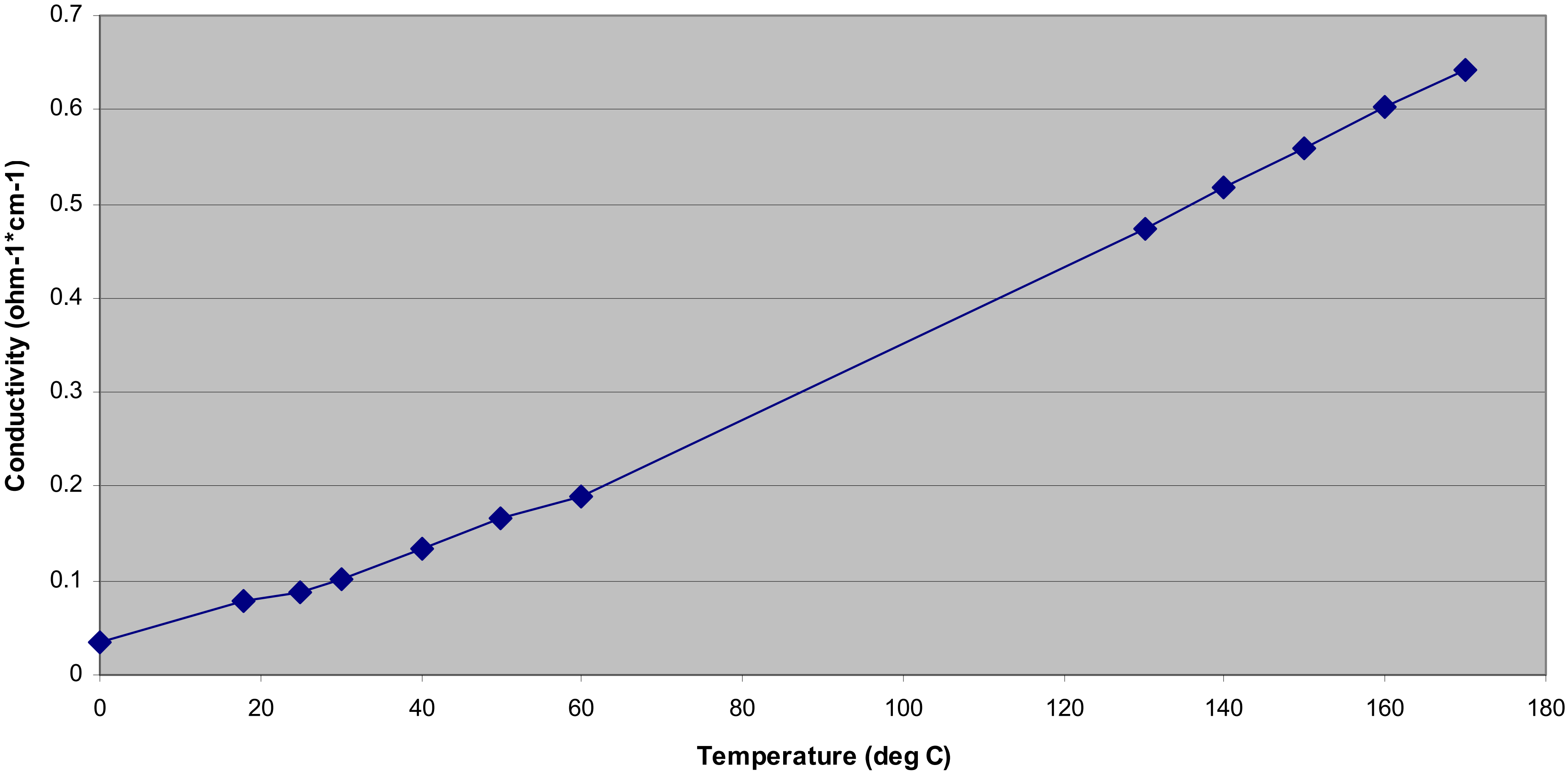
IR spectrum of BPO_4



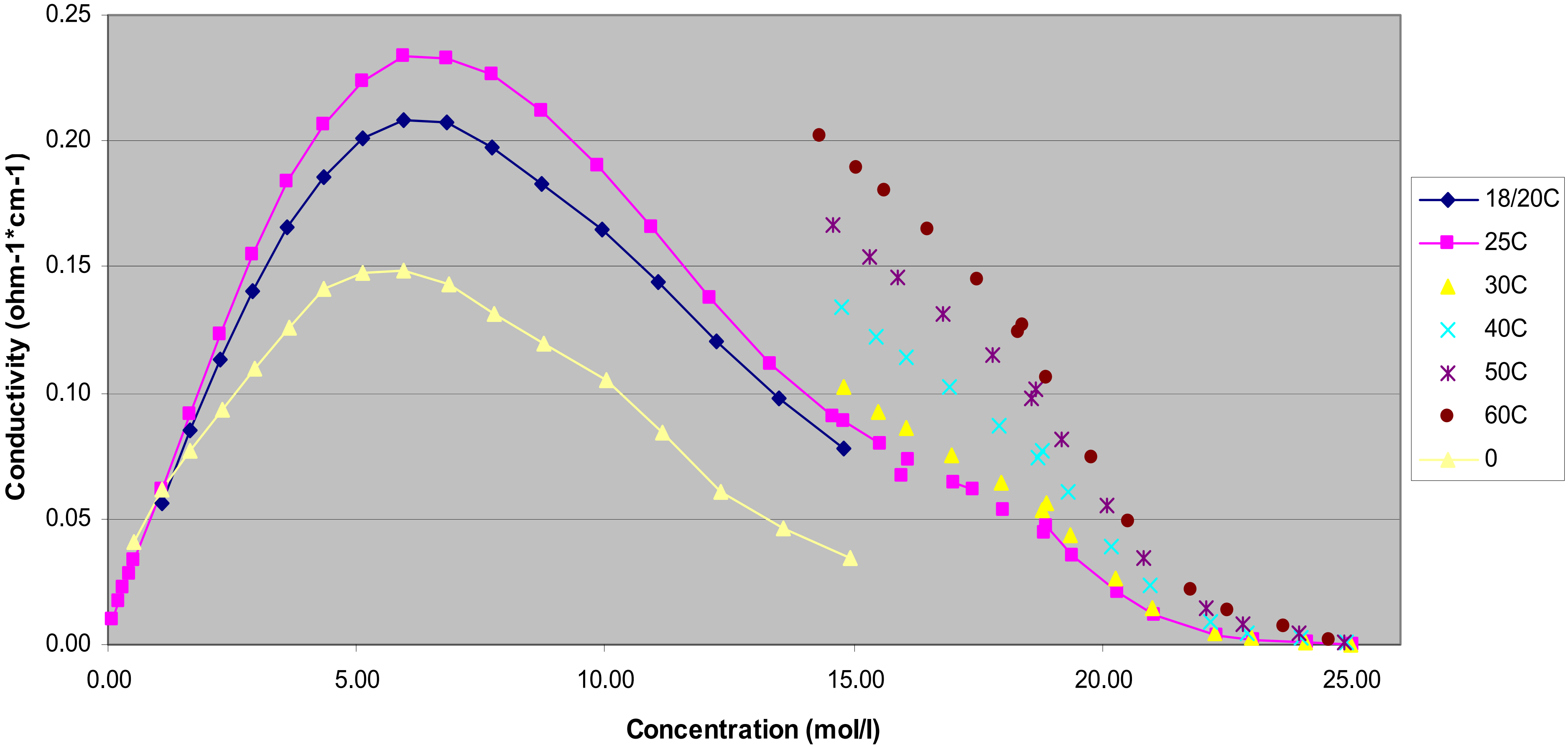
IR spectrum of BN before/after 120 °C H_3PO_4 exposure, rinsing, and drying



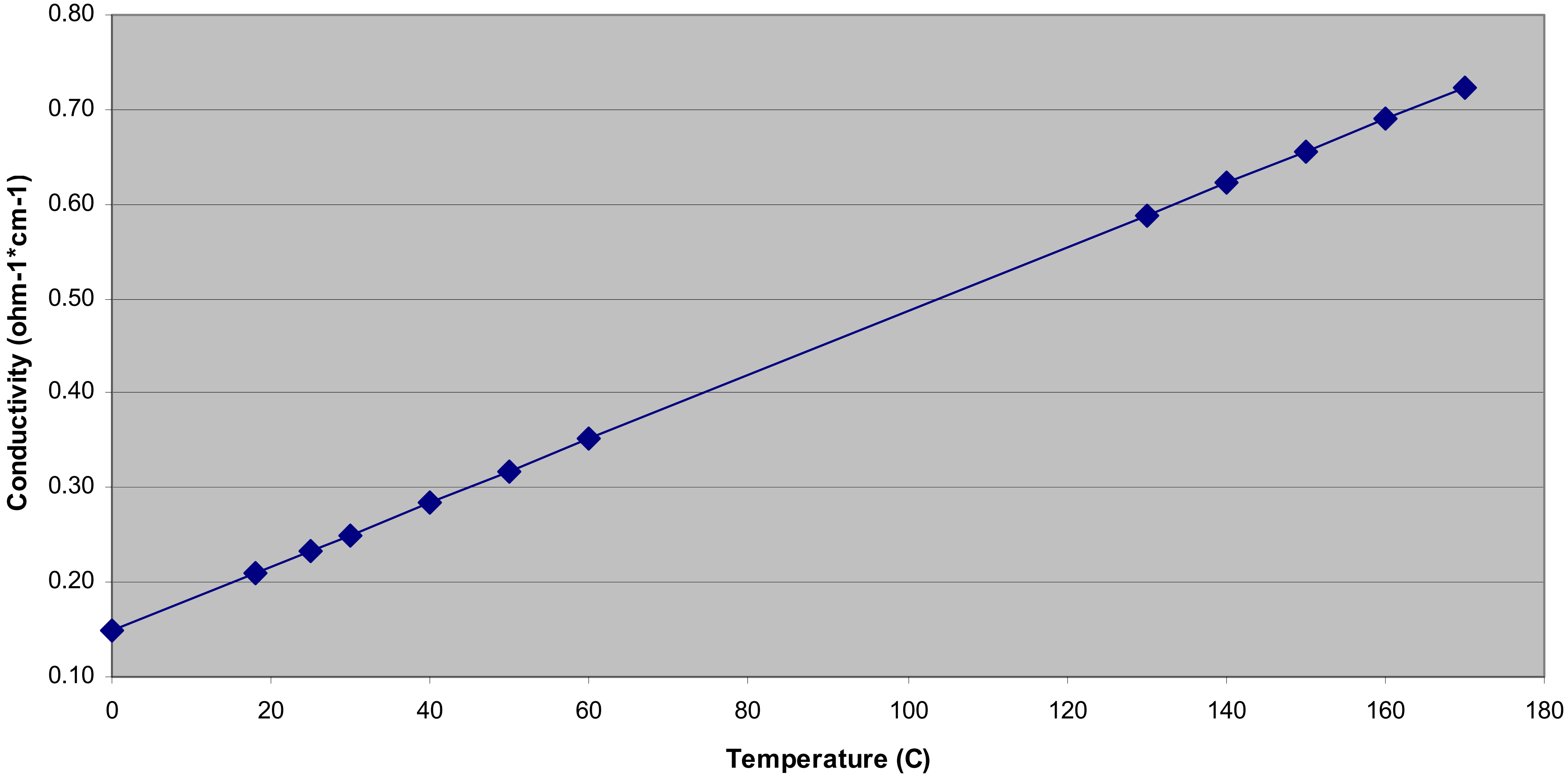
Phosphoric acid conductivity vs T (85% conc)



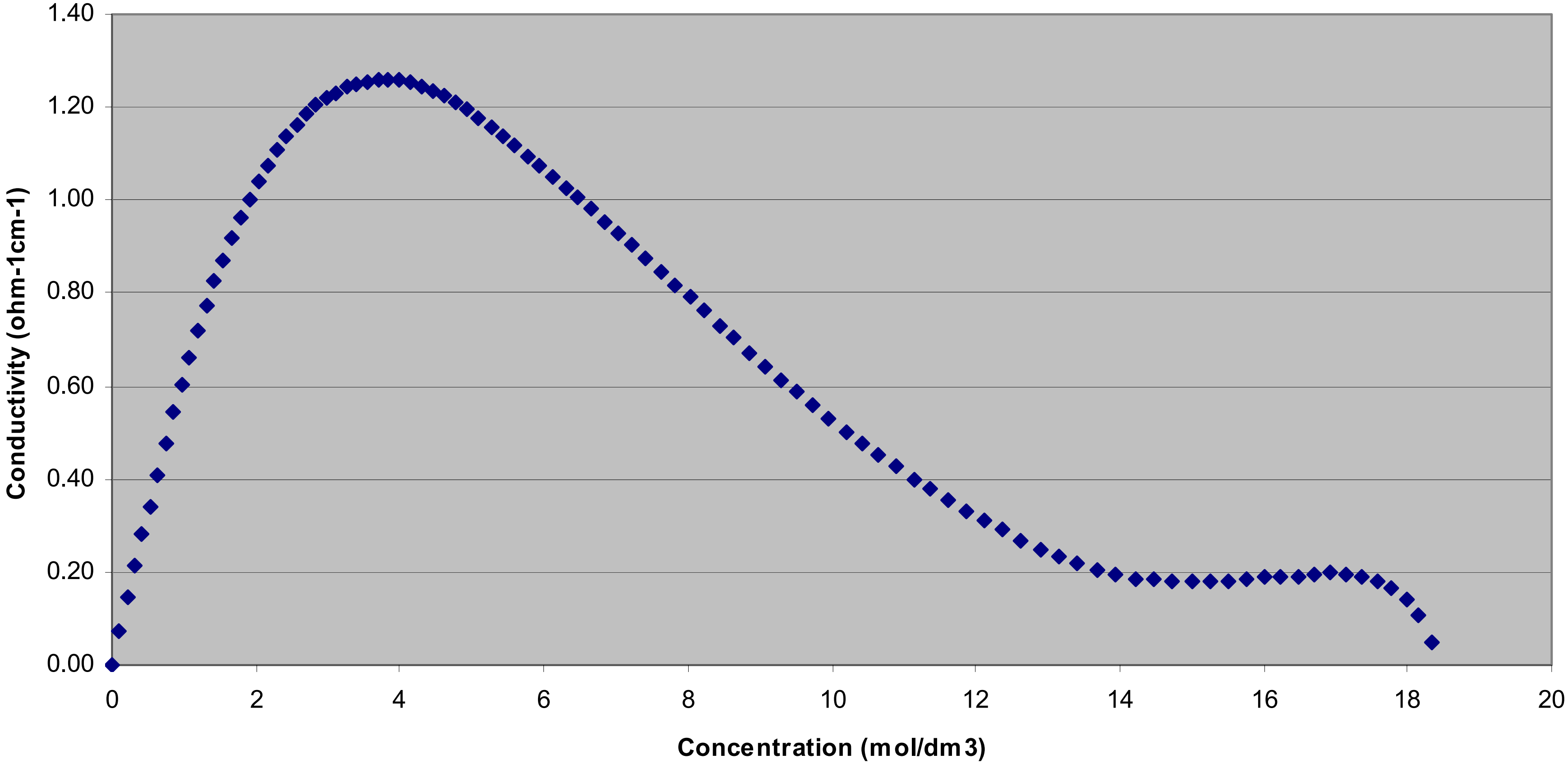
Phosphoric acid conductivity vs concentration at various temperatures



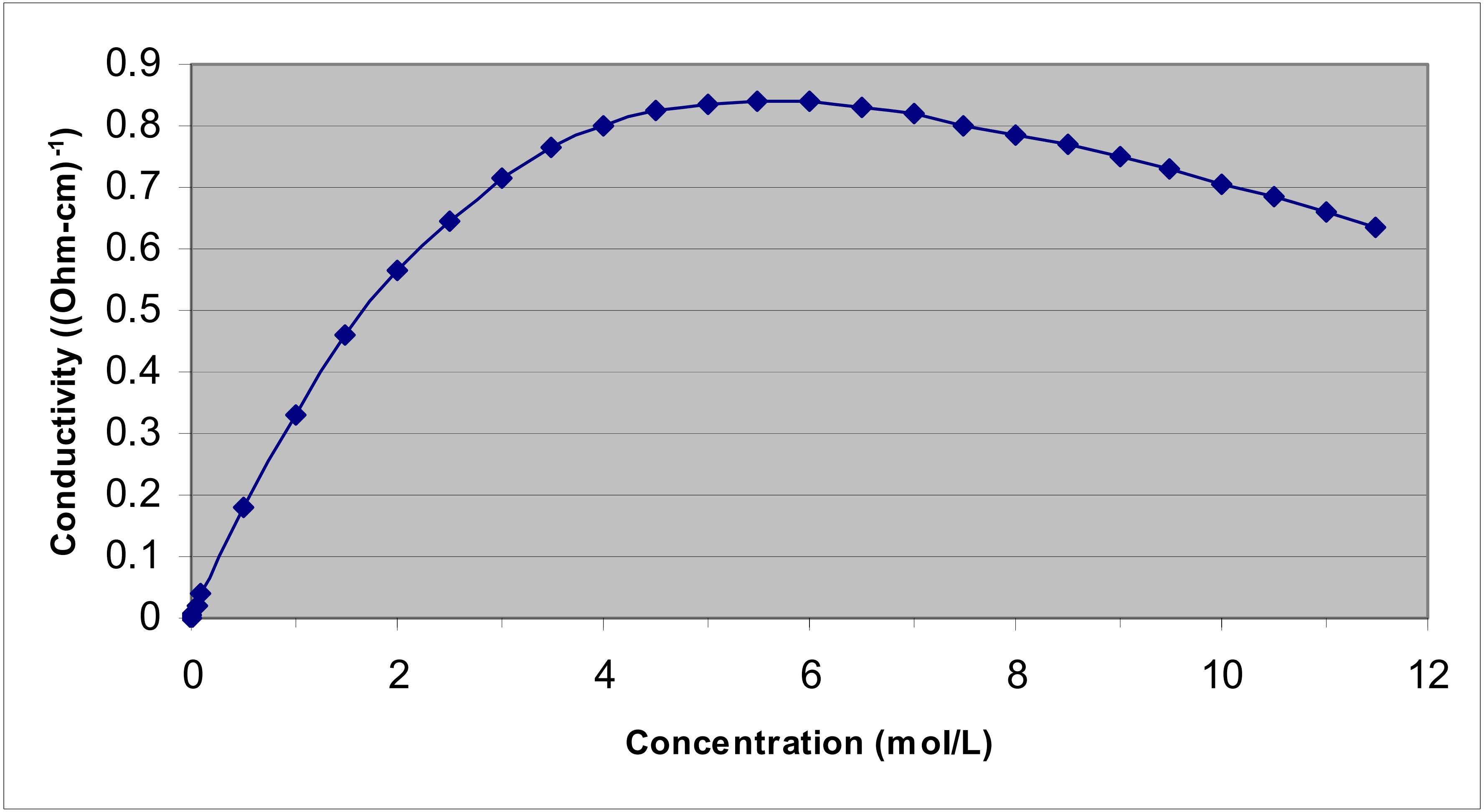
H_3PO_4 conductivity vs T at optimum conc (45%)
extrapolated data



Conductivity vs Concentration for H_2SO_4 at 21 ^oC



Conductivity vs Concentration for HCl (aq) at 25 °C



Future Plans

Include acid/water mixtures as liquid phase components of electrolyte composites to augment proton conductivities.

Substantiate water content vs conductivity relationships

Establish volatility vs temperature characteristic

Effect of dissolved phosphate salts in H_3PO_4

Estimate differential pressure limits of electrolyte composites

Compare results to BC and SiN analogous systems

Examine chemical/thermal stability of polymeric matrices:

- polyketones
- polysulfones
- polyphenylquinoxalines
- polybenzimidazoles, and
- polybenzoxazoles.