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COAL PARTITIONING PROJECT

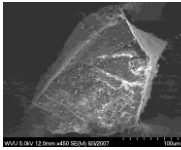
Mineral Transformations in High Temperature Gasification of Gravity and Size Separated Fractions of a High Volatile Bituminous Coal

Nari Soundarrajan and Sarma V. Pisupati
Pennsylvania State University

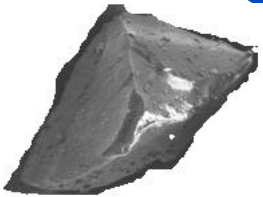


**U.S. DEPARTMENT OF
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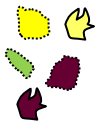
Background - Coal Conversion in Gasifier



Coal + included minerals



**Complex
mixture of
organic and
inorganic
materials**



Excluded minerals

Grinding

Motivation

Entrained flow slagging gasifiers are a high temperature, high throughput operation [1]...**BUT** they face....

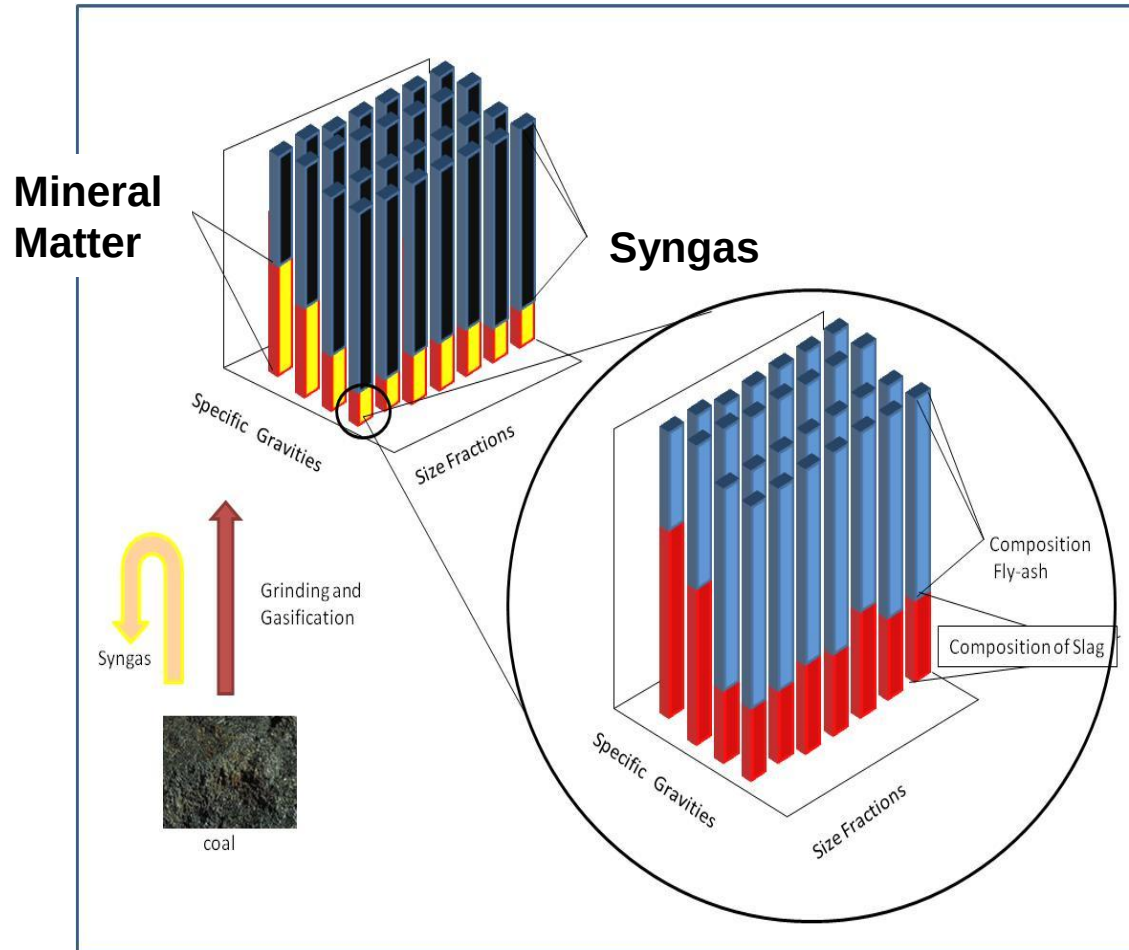
- Unburned carbon loss and reduction in efficiency [1]
- Flyash carryover to heat recovery units (syngas coolers) and downstream equipment [1,2]
 - Downtime/loss of reliability
- Existing models and tools do not adequately predict flyash formation/ash deposition [3]

[1] Tampa electric integrated gasification combined cycle project, Project Performane Summary. Tampa. Tampa Electric Co., C. (2004).

[2] "Wabash River Coal Gasification Repowering Project", Wabash River Energy Ltd. Final Technical Report, under DOE Cooperative Agreement DE-FC21-92MC29310, Aug. 2000

[3] Yamashita, T., Y. Fujii, et al. (2006). "Modeling of gasification and fragmentation behavior of char particles having complicated structures." Combustion and Flame 146(1-2): 85-94.

Particle Population Model for Lab Scale



Gravity Separation

Specific gravity ranges

SG1: $1.3 < \rho$

SG2: $1.3 < \rho < 1.6$

SG3: $1.6 < \rho < 2.6$

SG4: $\rho > 2.6$

Size Separation

Seven size ranges

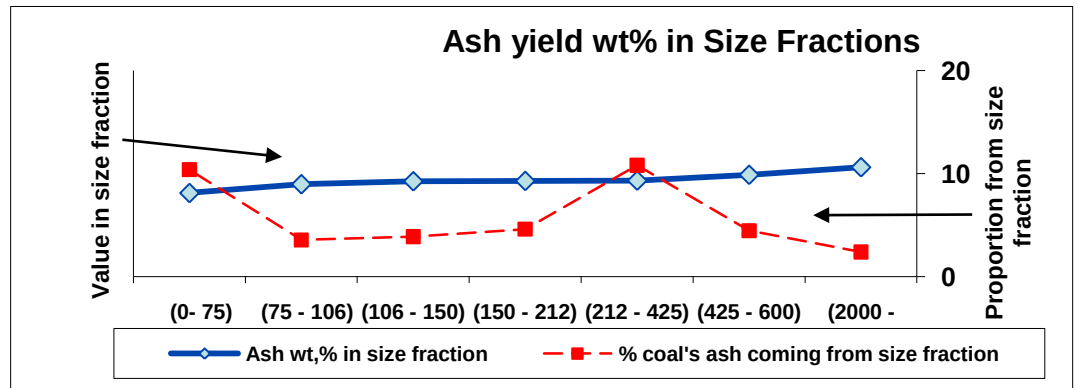
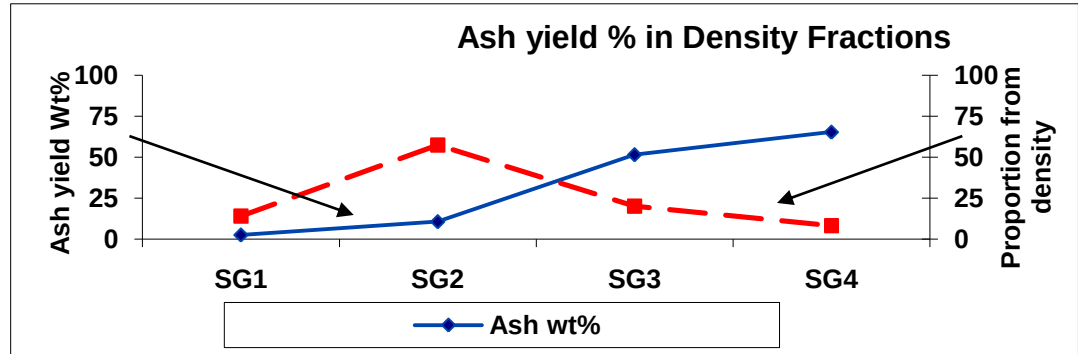
Largest cut: PS1 > 600 μm

Smallest cut: PS7 < 75 μm

Particle Partitioning

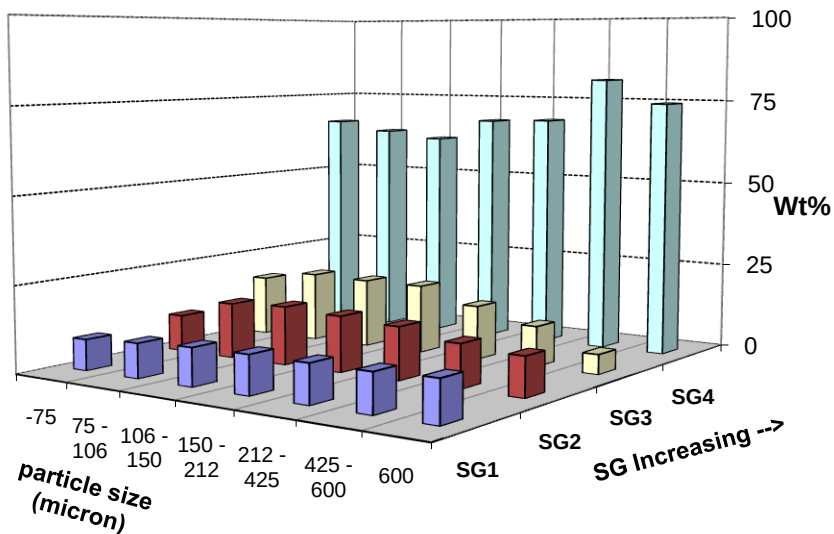
Coal: Ash Yield Heterogeneity

- Ash yield varies widely with density
 - Bulk of the ash is in SG3 and SG4
 - Single largest contribution to total ash yield of coal is from SG2 (included minerals)
-
- Size fractions 0-75 μm and 212-425 μm contribute max towards the whole coal ash yield
 - Ash yield variation with size fraction is not significant
 - Heterogeneity in ash yield (about)
- SG1 - 80 %, SG2 + 80 %
 SG3 + 570 % SG4 + 720 %

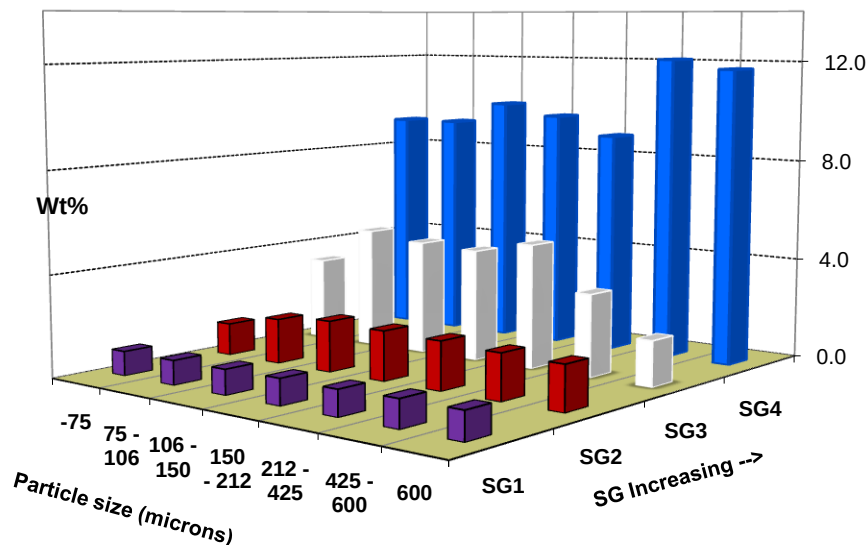


Iron and Sulfur Distribution in Coal

Fe_2O_3 Distribution (on ash basis)



Sulfur Distribution (coal)



XRD / CCSEM / Mossbauer

Samples	XRD	CCSEM	Mossbauer**
BSG4 (heaviest, density > 2.6 g/cc)	Pyrite, Marcasite, Quartz, Magnetite, Calcite, Kaolinite (tr) Potassium silicate,	Pyrite, Pyrrhotite, Oxidized pyrite, Iron-rich compounds and Si, Al containing unclassified compounds	Szomolnokite Pyrite Jarosite Magnetite - A Magnetite - B
BSG3 (heavy, density 1.6 - 2.6 g/cc)	Pyrite, Marcasite, Quartz, Calcite, Kaolinite, Illite, Sodium Aluminum silicate, Jarosite	Quartz, Calcite, Ankerite, Kaolinite, Montmorillonite, Mixed Aluminum silicates, Pyrite, Pyrrhotite, Gypsum and Si-rich, Ca-rich unclassified compounds	Jarosite, Fe ²⁺ in clay and pyrite

*** identified iron phases alone*

Particle Class Shortlist

	PS1 > 600 μm	PS2	PS3 212-425 μm	PS4	PS5	PS6	PS7 0-75 μm
BSG1 <1.3 g/cc							Py
							AL
BSG2 1.3- 1.6							Py
							AL
BSG3 1.6 – 2.6	Py	Py	Py				Fine Py/AL minerals
	AL	AL	AL				
BSG4 >2.6 g/cc	Py	Py	Py				Fine Py minerals

- *Agrees well with mineral liberation processes***
- *Substantial amount of included mineral matter in SG1, SG2*
- *Py = pyrite, AL: aluminosilicates*

** Austin, L. G., A. Kalligeris-Skentzos, et al. (1994). Powder Technology 80(2): 147-158,

Gasification Tests

Experimental Setup

- Ash yield of BSG3 (1.6-2.6 g/cc) and BSG4 (>2.6 g/cc) much higher than coal.

Samples

- BSG3 minerals composed of aluminosilicates and pyrites mostly in included form.
- BSG4 minerals composed of pyrites mainly and substantially as excluded form.

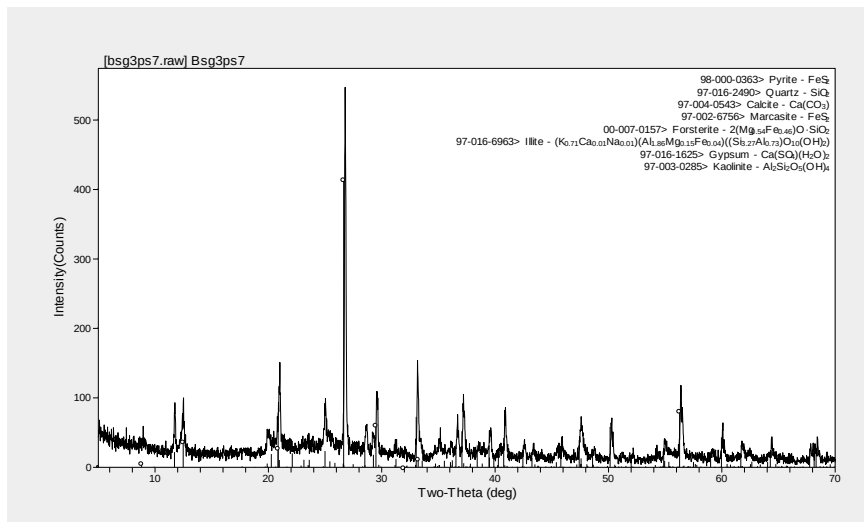
Conditions

- Coarse and fines size fractions from BSG3 & BSG4 gasified in CO₂+steam at 1400 C.

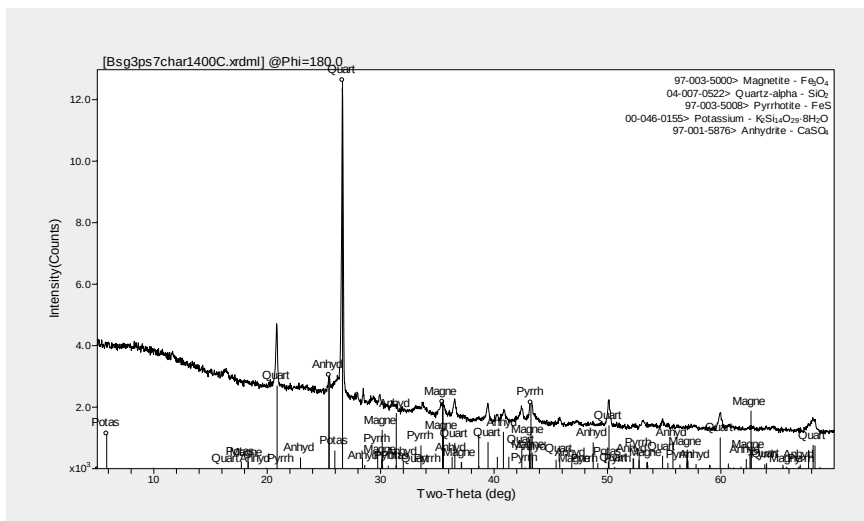
Chars

BSG3 showed much lower conversion (~56-60%) compared to BSG4 (as well as SG1 & SG2), all of which showed 77-82% at 1400C, 1.7 sec

XRD: BSG3 Fines

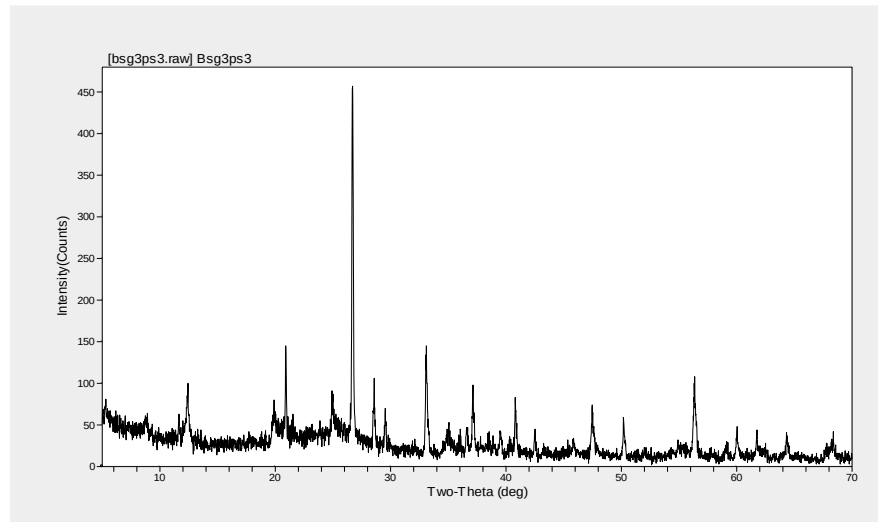


**BSG3PS7
COAL**

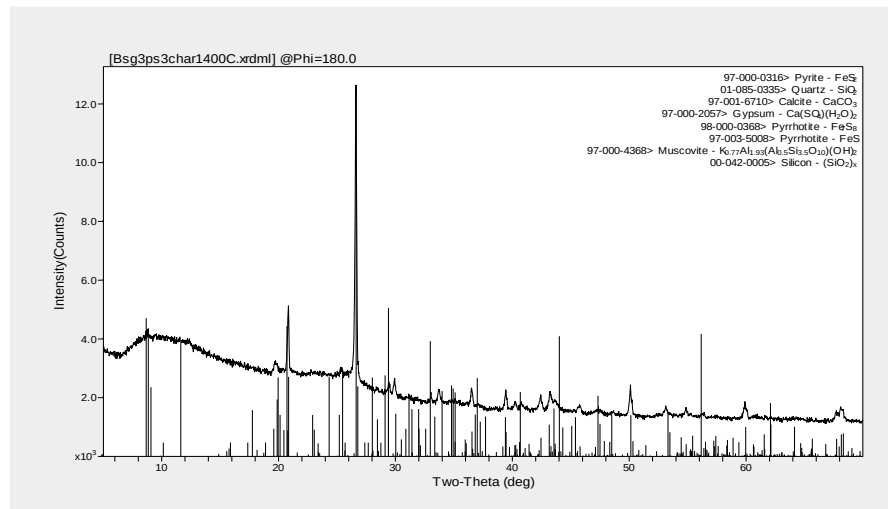


**CHAR 1400C
58% C
conversion**

XRD: BSG3 Coarse

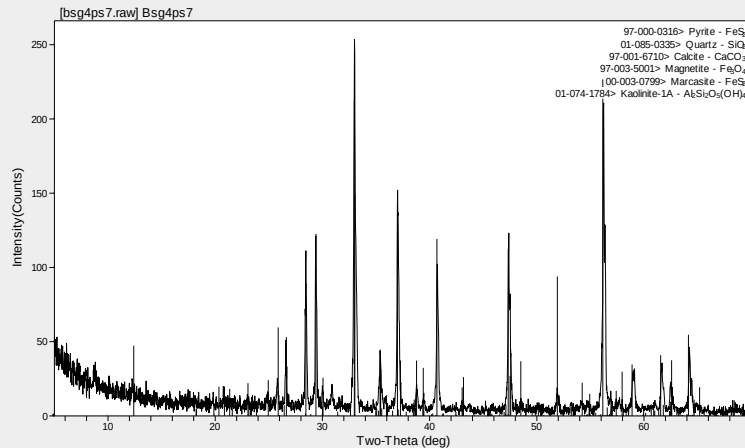


**BSG3PS3
COAL**

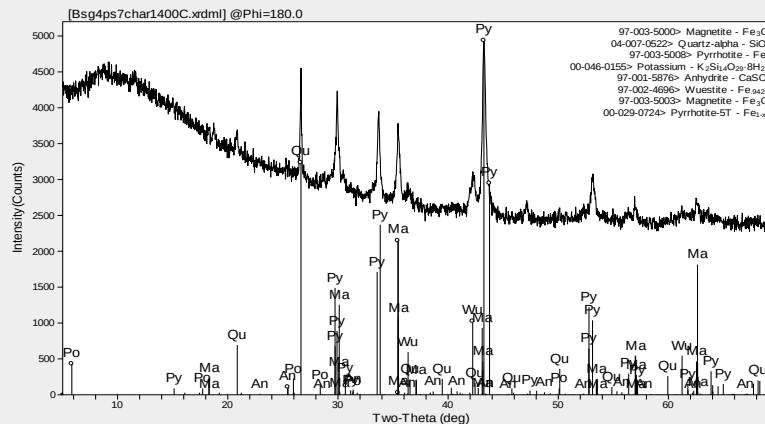


**CHAR 1400C
57% C
Conversion**

XRD: BSG4 Fines

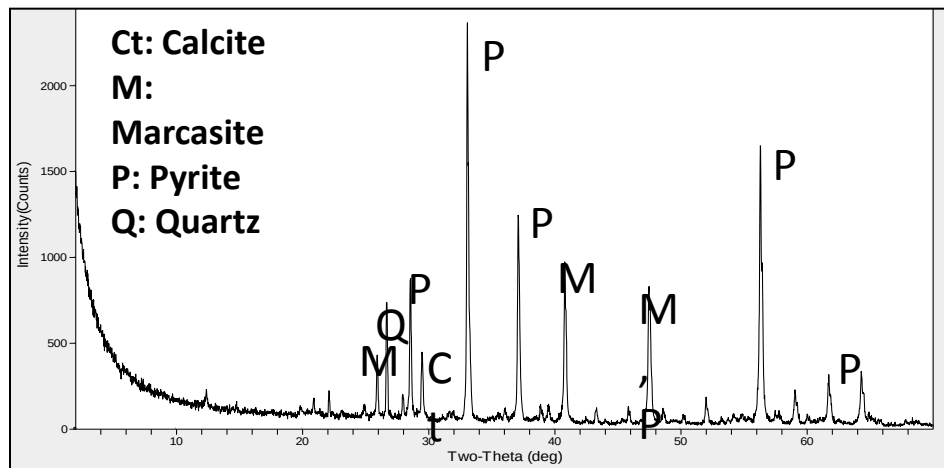


**BSG4PS7
COAL**

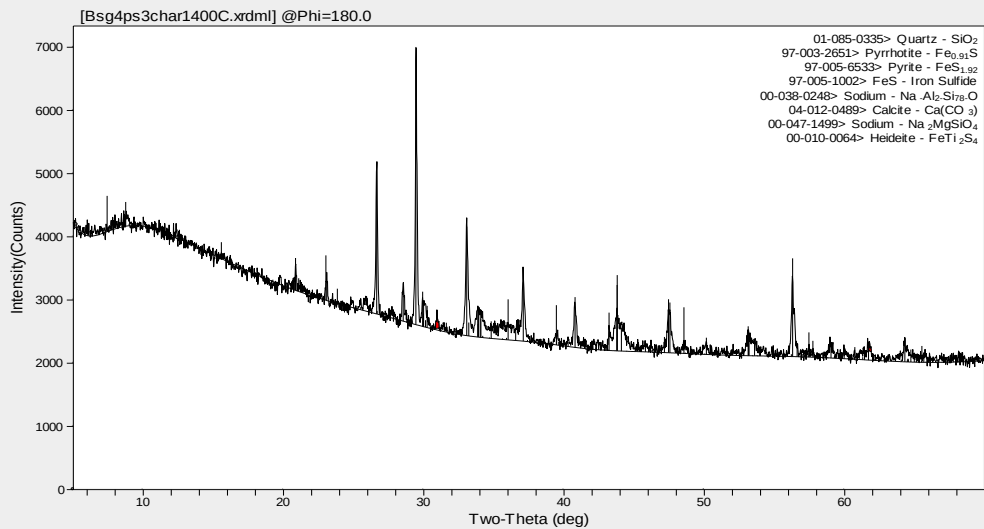


**CHAR 1400C
80% C
Conversion**

XRD: BSG4 Coarse

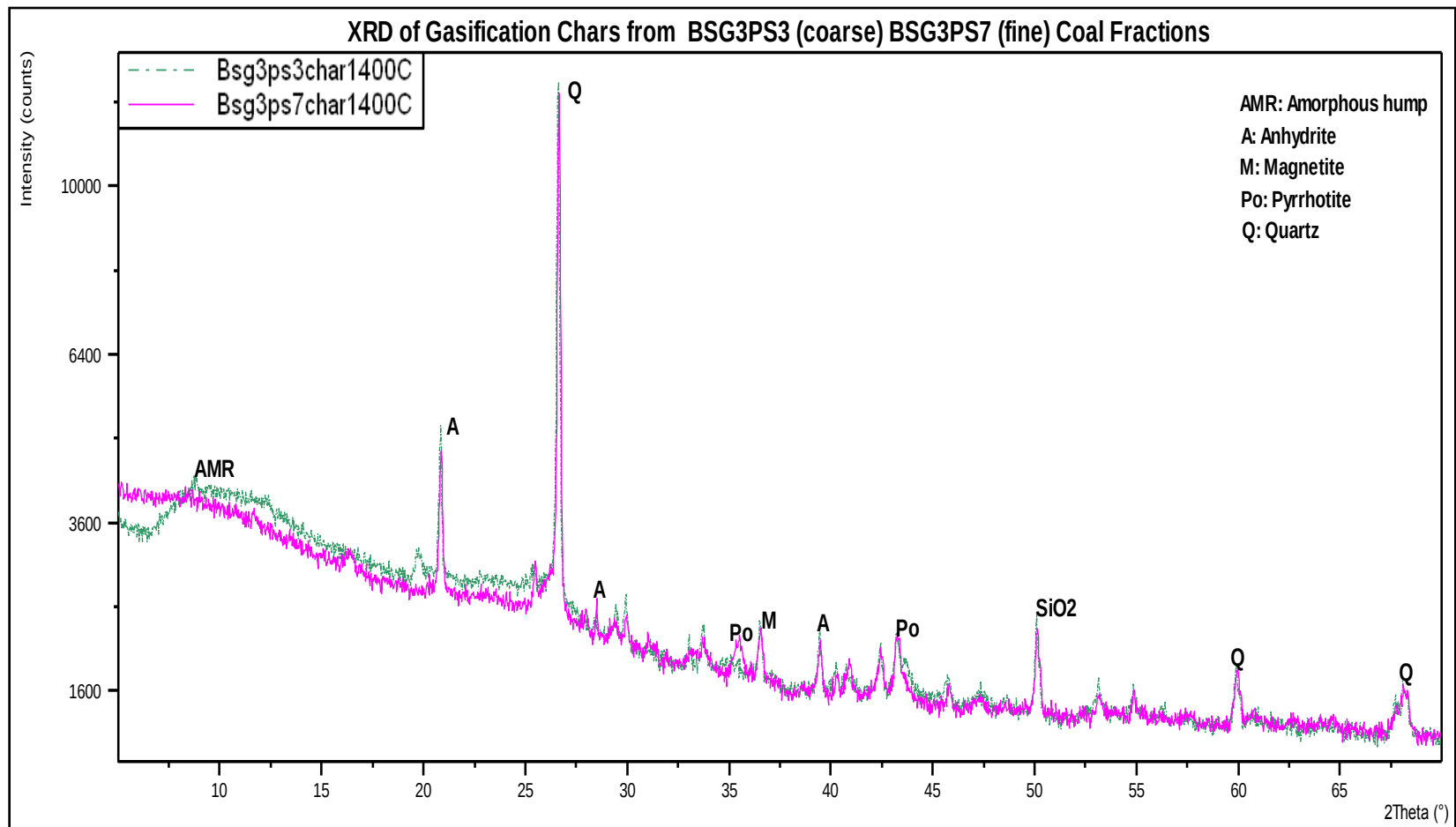


BSG4PS3
Coal

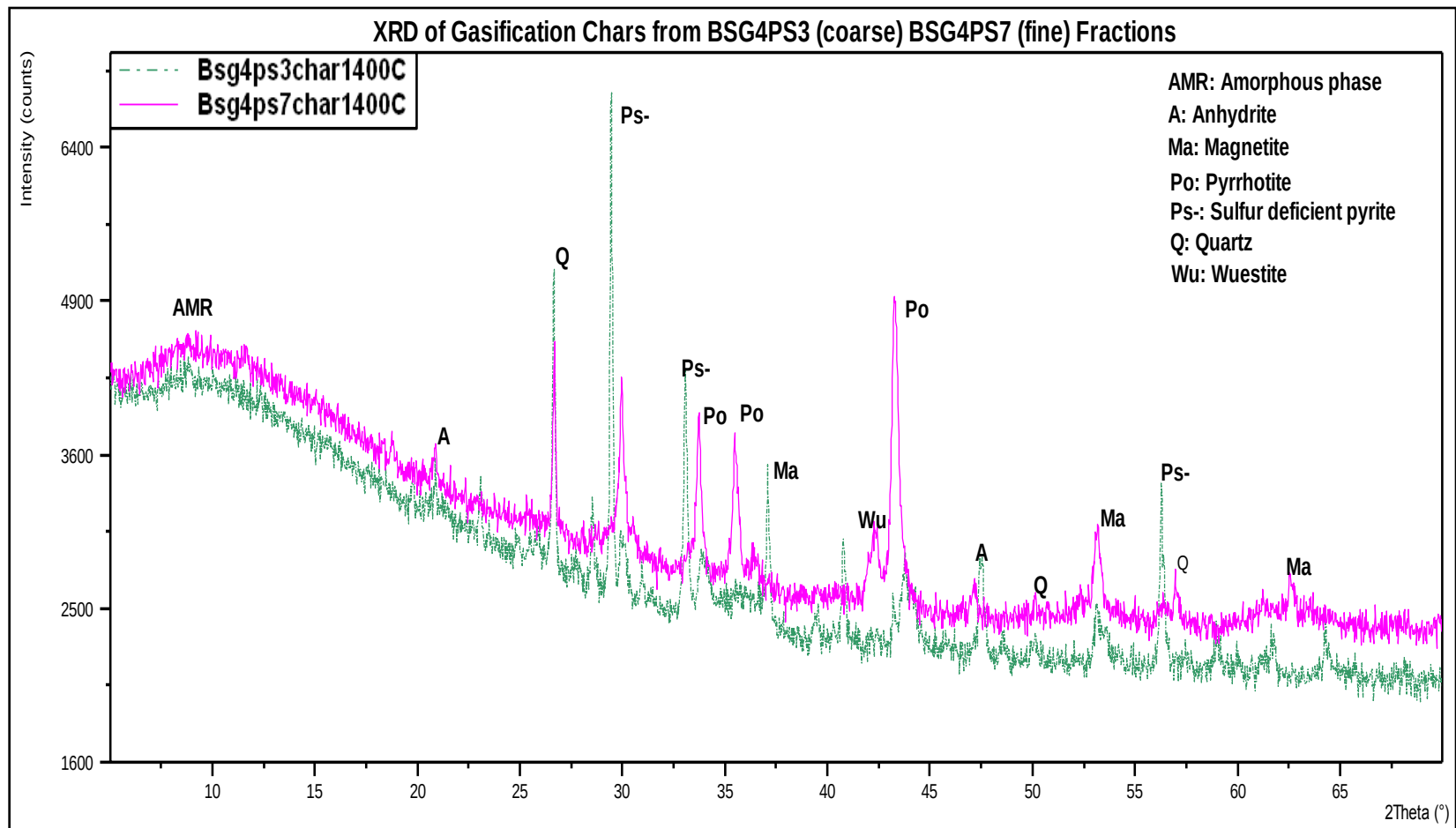


CHAR 1400C
77% C
Conversion

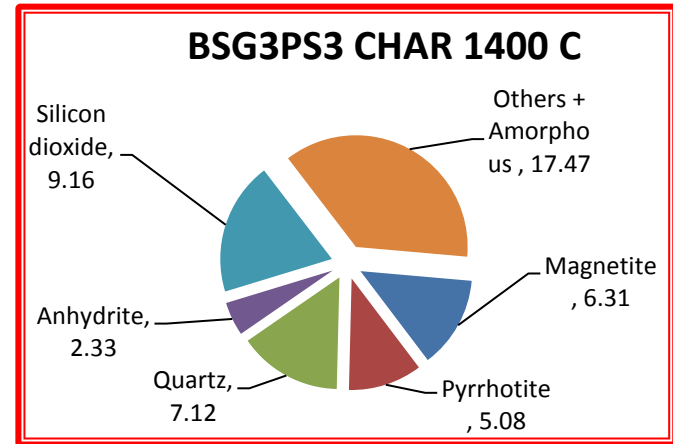
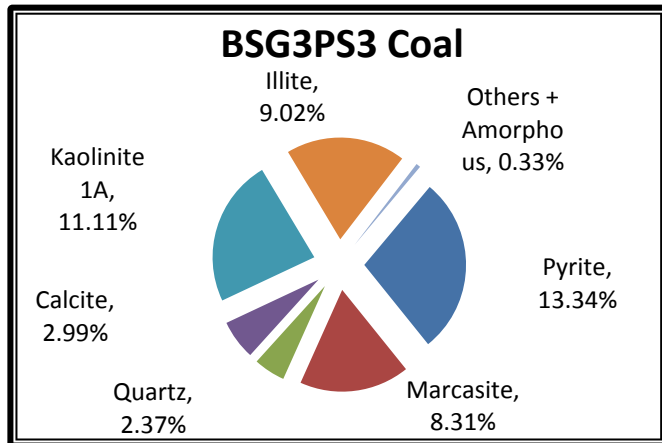
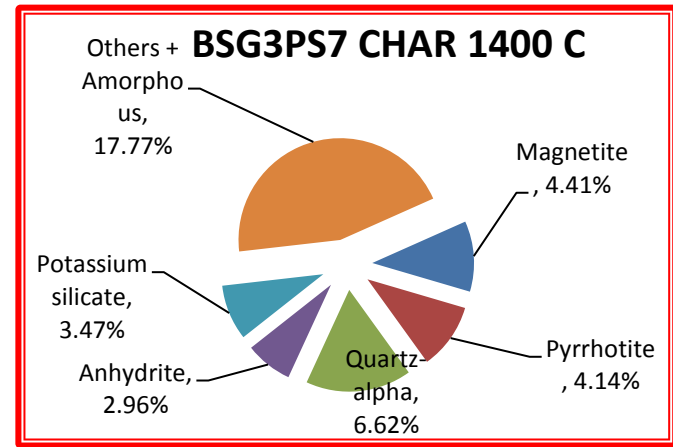
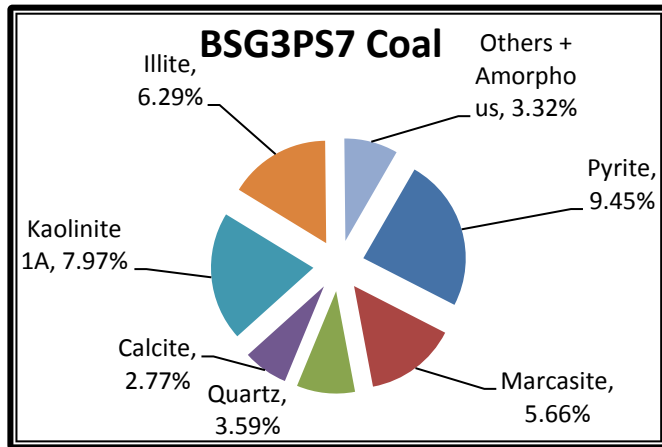
Transformations: Bsg3ps3 and ps7



Transformations: Bsg4ps3 and ps7

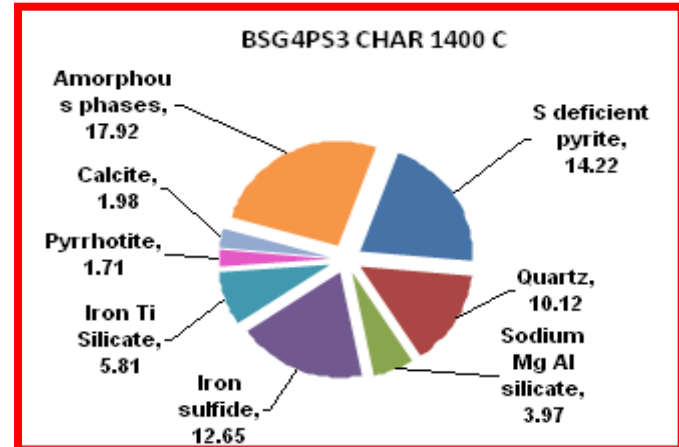
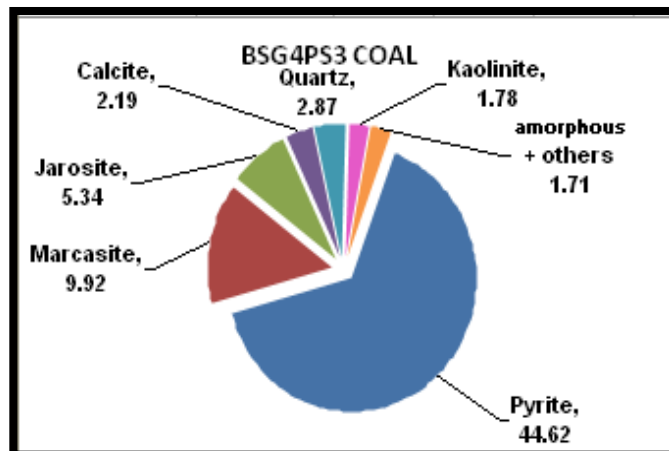
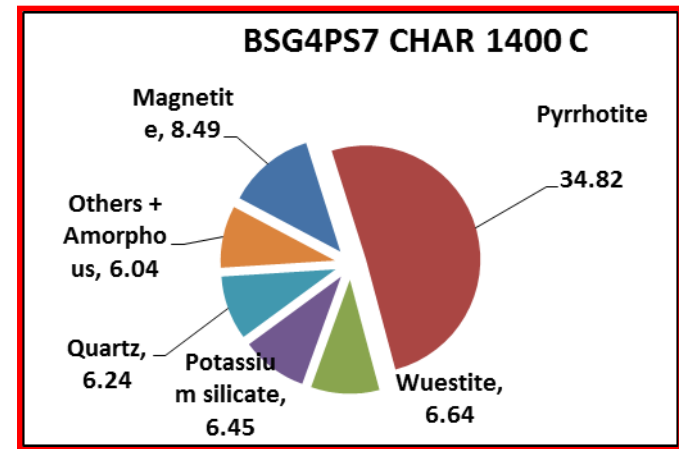
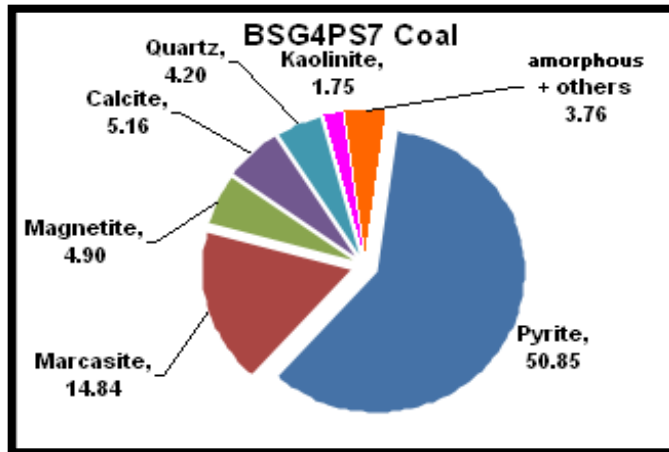


BSG3 Coal → Char



1 Bool, L. E., T. W. Peterson, et al. (1995). Combustion and Flame **100**(1-2): 262-270.

BSG4 Coal → Char



Crystalline → Amorphous

Changes in crystallinity of mineral phases during gasification in drop tube reactor

	Crystalline Phase	% in Coal on mm basis		% in Char on whole coal basis	% Crystallinity Lost
BSG4PS7 Fine Coal	Iron minerals	70.59	change to	49.95	29%
	Other minerals	11.12	change to	12.69	-14%
	Negative indicates increase in crystalline phases				
BSG4PS3 <u>Coarse</u> Coal				Char	
	Iron minerals	59.89	change to	22.43	63%
	Other minerals	6.84	change to	3.69	46%
BSG3PS7 Fine Coal				Char	
	Iron minerals	15.11	change to	11.04	27%
	Other minerals	20.62	change to	13.04	37%
BSG3PS3 <u>Coarse</u> Coal				Char	
	Iron minerals	21.64	change to	11.39	47%
	Other minerals	25.49	change to	18.61	27%

Summary

- Formation of Sulfur deficient pyrites in SG4 fractions.
- SG3 fractions (coal rich in aluminosilicates and associated iron minerals) form larger proportion of amorphous phases¹.
- SG4 fines show increase in crystalline phases of non-iron minerals.
- Coal fractions where iron minerals associate with aluminosilicates (SG3) show greater propensity to form amorphous phases.
- Chars from the coarse fractions of both heavier density fractions show more intermediate phase minerals and higher amorphous content.

Acknowledgments

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Thank you for your time

QUESTIONS?