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Georgia Institute of Technology
Office of Contract Administration
PROJECT CLOSEOUT - NOTICE

28-AUG-1997 09:20

(1)

Closeout Notice Date 28-AUG-1997

Project Number E-21-R01 Doch Id 40649

Center Number 10/24-6-R0252-0A0

Project Director CHAMPION, THOMAS

Project Unit ECE

Sponsor SIERRA PACIFIC POWER COMPANY/RENO, NEVADA

Division Id 712

Contract Number AGREEMENT DTD 970103 Contract Entity GTRC

Prime Contract Number

Title CHANCE 5000 POUND CERAMIC 6" DISK (SUSPENSION) INSULATOR FAILURES

Effective Completion Date 10-MAY-1997 (Performance) 10-MAY-1997 (Reports)

Closeout Action:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory and Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

Distribution Required:

Project Director/Principal Investigator	Y
Research Administrative Network	Y
Accounting	Y
Research Security Department	N
Reports Coordinator	Y
Research Property Team	Y
Supply Services Department	Y
Georgia Tech Research Corporation	Y
Project File	Y

E-21-R01
#1

6 Inch Ceramic Disk Insulator Evaluation
Project No. 96-399

Final Close-out Report

March 6, 1997

Problem Description: Ceramic disk insulators from a single manufacturer were exhibiting longitudinal cracks in the porcelain sheds and separation of the cap from the main body of the insulator. Some insulators were also exhibiting arcing burns in the side of the cap. These failures were resulting in dropping of the overhead conductor. There were also occasions when voltage was detected on the steel cross-arm.

Test Procedure: The insulators were subjected to a number of tests as defined in ANSI Standards C29.1 and C29.2, several custom tests, and microphysical examination. Testing included:

1) Visual Inspection
2) Free Fall Pin Impact
3) Mechanical and Electrical (ANSI C29.2, Section 8.3.4)
4) Pendulum Impact to Shed (ANSI C29.2, Section 8.2.8)
5) Thermal Shock Test (ANSI C29.2, Section 8.2.6)
6) Porosity Test (ANSI C29.2, Section 8.3.2)
7) Ceramic Puncture Under Oil (ANSI C29.2, Section 8.3.5)
8) Failure Analysis
9) Microphysical Testing (X-ray Diffraction & SEM)

Equipment:

Polaroid Photographic Copy Stand
Bausch and Lomb Stereozoom 7 Microscope
160K Tensile Machine
Drop Weight Tester
Pendulum Impact Tester
100kV Power Supply
350kV Series Resonant Test Set
High Pressure Test Bomb
Thermal Shock Tanks

Number of Samples: A total of 80 ceramic disk insulators were received for evaluation.

Test Results: A number of manufacturing defects were identified involving both the ceramic and the grout used to attach the cap and pin.

(new) E-21-R01
N/a

MICROSTRUCTURE OF INSULATOR CEMENT AND PORCELAIN

W. Jack Lackey, Giancarlo Giannetti and Elliot Pickering

1. APPROACH

Materials analysis was conducted on five porcelain insulators. Four were manufactured by Chance and one by Victor. The cement and porcelain shell of each was examined. Each cement sample was ground into a powder for the x-ray diffraction (XRD) scans using a mortar and pestle. During this operation it was clear that the victor cement was much stronger than the Chance cement samples. XRD was performed on the cement samples using a Philips Automated Powder Diffractometer, Series PW 1800. It was determined that no significant peaks would be present below 20 degrees 2Θ. The analysis program used on the samples was a gonio scan from 25 - 90 degrees 2Θ using Cu Kα radiation. The porcelain shells were broken using a hammer. A fracture surface from each sample was examined under low voltage using a Hitachi S-800 Scanning Electron Microscope and optical microscope.

	Sample ID	XRD Cement	Optical Microscopy Cement
PI1	Chance, R36b	**X**	**X**
PI2	Victor, R11a	**X**	**X**
PI3	Chance, new sample	**X**	
PI4	Chance, 1985	**X**	
PI5	Chance, R24b		

	Optical Microscopy Porcelain	SEM of Cement	SEM of Porcelain	Cement Strength
PI1	**X**	**X**	**X**	**W**
PI2	**X**	**X**	**X**	**S**
PI3	**X**		**X**	**W**
PI4	**X**		**X**	**W**
PI5	**X**			**W**

Fig.1 Showing which samples were analyzed via different methods. X indicates sample examined. W and S denote weak and strong, respectively.

2. RESULTS

The portland cement used in the insulator bonds the iron pin into position in the pin hole of the porcelain shell. According to Cherney (1) the porcelain shell does not tolerate volume expansion of the cement. There are three mechanisms which contribute to the volume expansion of portland cement.

The first possible failure mechanism is the result of uncombined, free CaO hydrating to $Ca(OH)_2$. The second is the result of MgO hydrating to $Mg(OH)_2$. Magnesium is an impurity in the raw materials used to make portland cement. The third mechanism is the reaction of excess gypsum.

2.1 XRD Results

Portland cement contains multiple phases of several different calcium, magnesium, aluminum and iron oxides called clinker components. Also present are products of cement hydration. XRD will show only those phases diffracting the greatest intensities. Because there are multiple phases in the cement there is a high degree of chance that lines having similar d-spacings will overlap and will not be distinguishable. Using x-ray diffraction data from Bogue (2), the plot/ re-plot method was used to subtract out the known phases in portland cement from the data in the .DI scan files. The following data tabulated below show the results of scans PI1a, PI2a, PI2b and PI3a. Four strong phases were observed.

The 100% peak is approximately the same for all the samples (d-space = 2.61). Plot /re-plot and computer analysis both concluded that $Ca(OH)_2$ was a primary phase in the samples. Also CaO, Fe_2O_3 and $4CaO.Al_2O_3.Fe_2O_3$ phases were present. The data do not provide evidence of free MgO in the samples.

2.2 SEM Results

SEM showed evidence of greater crystallinity in the Victor cement than the in Chance. (Figure 2, PI1) That is, the crystals were larger in the Victor cement. Darker spherical regions about 80 microns in diameter were observed in the Victor cement sample. Cracks typically extended from the dark regions. (Figure 2) Voids containing large crystals (Figure 4) were observed via SEM in the Victor cement sample. The micrograph shown in Figure 3 is typical of the Chance cement.

Under SEM and optical microscopy there was no evidence of cracks or inclusions in the fracture surface of the porcelain samples.

3. CONCLUSIONS

The following conclusion are based on the examination of the cement and porcelain.

1. The Victor cement sample was much stronger than the Chance cement as evidenced by the ease with which the Chance sample were ground into a powder in a mortar and pestle.

2. XRD showed Ca(OH)2, (Calcium Hydroxide) as a major phase in all the cement samples (Victor and Chance). That is to say similar intensities were observed for the d-spacing's that identify it as a major phase. Possible hydration of free CaO.

3. Some variability in the XRD patterns of the Chance cement samples was observed, i.e. phases present varied from sample to sample (compare patterns around 32 degrees 2Θ). This Bragg angle implies variability in the concentration of the 4CaO.Al2O3.Fe2O3 phase.

4. There is no XRD evidence of Mg(OH)2, (Magnesium Hydroxide).

5. Duplicate XRD patterns were very similar in appearance giving evidence of good reproducibility.

6. The porcelain samples were similar in appearance when examined by optical and electron microscopy. It should be noted that the differences in porosity or composition are difficult to detect by these techniques.

Figure 2.
Victor cement
Sample PI2

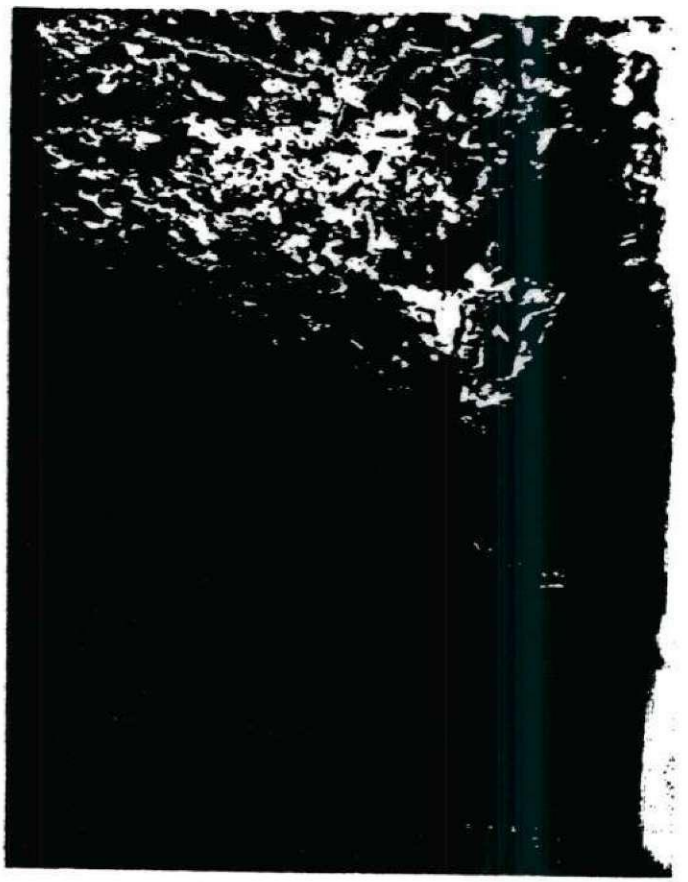


Figure 3.
Chance cement
Sample PI1

Figure 4.
Victor cement
Sample PI2

REFERENCES

1. Cherney, E.A., "Important Aspects of Ceramic Insulator Design"
2. Bogue, Robert Herman, "The Chemistry of Portland Cement" Reinhold Publishing Corporation, New York, 1947

Materials analysis

Possible phases in sample

pl1a

peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.1027	22.03				3.11 m	
2	3.0223	30.36					
3	2.7497	10.66	2.77 s				
4	2.6192	100				2.62 ss	2.63 ss
5	2.1843	10.66					
6	1.9201	52.49				1.93 s	1.921 ss
7	1.792	41.33				1.795 ss	1.801 s
8	1.6803	19.25	1.7 ss		1.69 ss	1.685 m	
9	1.4802	11.34		1.483 ss	1.482 ss		
10	1.4463	15.84	1.45 s		1.448 s	1.455 m	1.448 m
11	1.3137	12.76			1.307 s	1.312 m	
12	1.1419	18.37				1.144 m	

pl2a

peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.116	23.45				**3.11 m**	
2	2.7771	12.81	2.77 s				2.77 s
3	2.629	100				2.62 ss	2.63 ss
4	1.9265	51.24				1.93 s	1.921 ss
5	1.7947	29.96				1.795 ss	1.801 s
6	1.6863	16.85	1.7 ss		1.69 ss	1.685 m	
7	1.5716	11.35					1.572 s
8	1.4842	20.49		1.483 ss	1.482 s	1.48 m	
9	1.4488	17.73	1.45 s		1.448 s	1.455 m	1.448 m
10	1.3172	11.35			1.307 m	1.312 m	1.317 s
11	1.1768	11.35					
12	1.1435	12.81				**1.144 m**	

pi2b

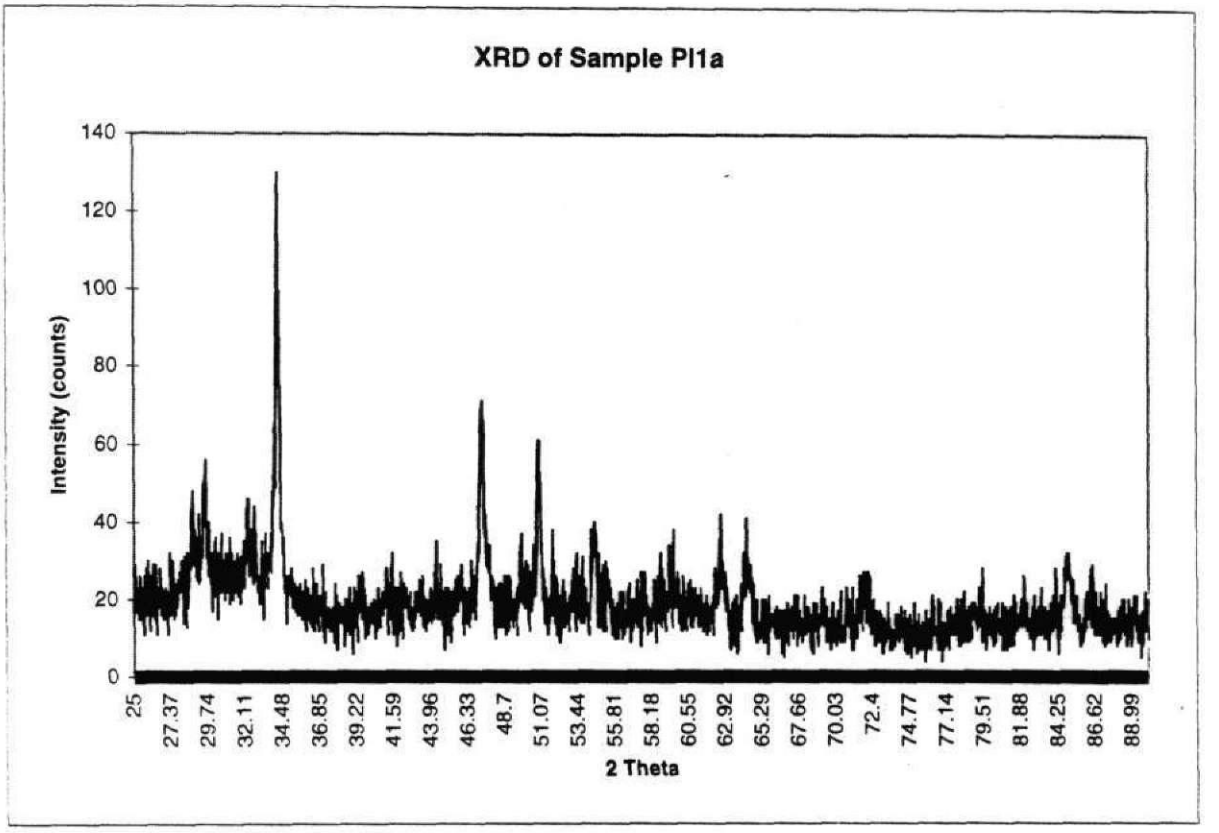
peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.0877	20.01				3.11 s	
2	2.7587	11.11	2.77 s				2.77 s
3	2.613	100				2.62 ss	2.63 ss
4	2.4155	7.88					
5	1.9209	56.91				1.93 s	1.921 ss
6	1.8171	11.7					1.801 s
7	1.7881	42.14				1.795 ss	
8	1.7592	7.88					
9	1.6801	20.81	1.7 ss		1.69 ss	1.685 m	
10	1.5665	7.88					1.572 s
11	1.4774	14.23		1.483 ss	1.482 s	1.48 m	
12	1.4454	14.9	1.45 s		1.448 s		1.448 m
13	1.3107	9.9			1.307 m		1.317 s
14	1.1715	7.88					
15	1.1401	12.93				1.144 m	
16	1.0578	12.31					

pi3a

peak no.	d spacing	I/Imax	Ca(OH)2	C4AF
1	3.363	10.05		
2	3.0833	19.75	3.11 m	
3	3.0071	19.75		
4	2.9389	14.41		
5	2.7606	44.44		2.77 s
6	2.723	49.52		
7	2.6075	100	2.62 ss	
8	2.274	8.78		
9	2.1775	15.85		
10	2.0902	8.78		
11	2.0449	9.34		
12	1.9696	12.38		
13	1.917	50.83	1.93 s	1.921 ss

pi3a

			Ca(OH)2	C4AF
14	1.813	12.38		
15	1.7858	38.49	1.795 ss	1.808 s
16	1.7544	8.78		
17	1.6807	22.3	1.685 m	
18	1.4801	15.85	1.48 m	
19	1.445	11.74	1.455 m	1.448 m
20	1.3092	10.5		1.317 s
21	1.1407	13.72	1.144 m	


XRD of Sample PI1a
Intensity (counts)
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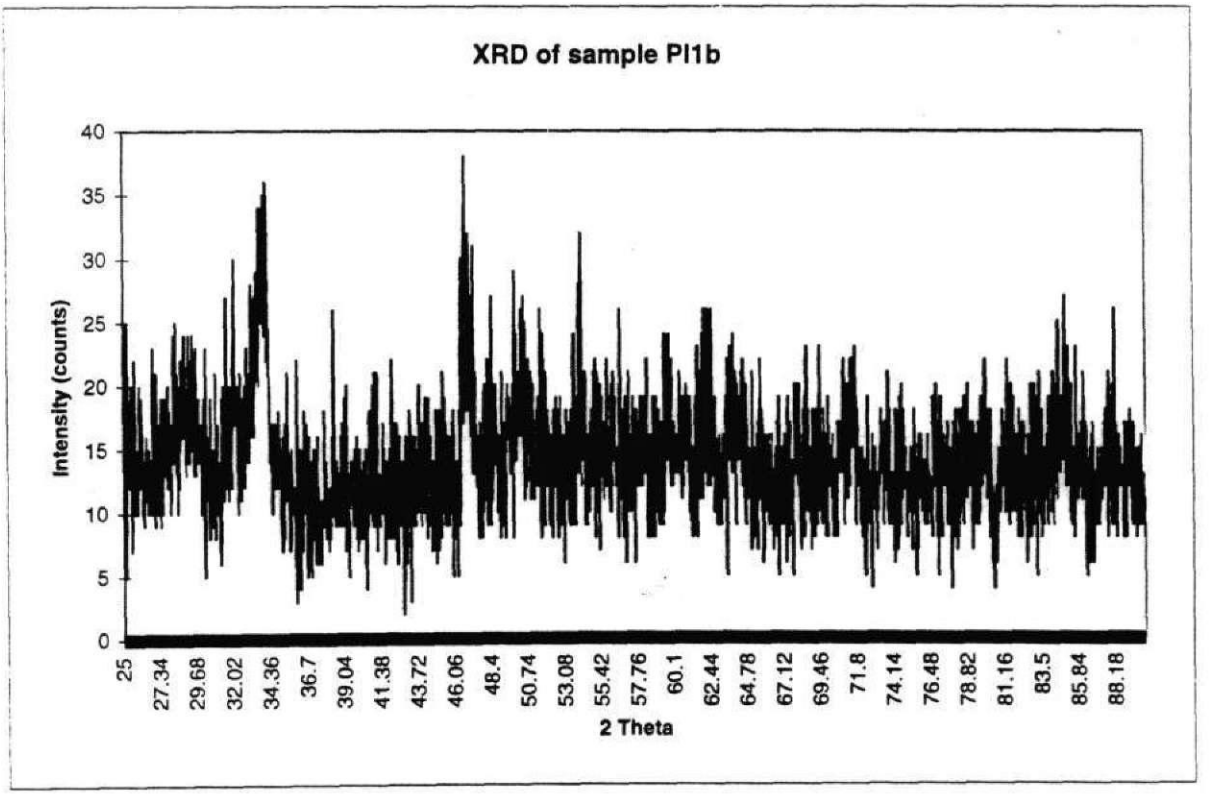
120
100
80
60
40
20
0
25
27.37
29.74
32.11
34.48
36.85
39.22
41.59
43.96
46.33
48.7
51.07
53.44
55.81
58.18
60.55
62.92
65.29
67.66
70.03
72.4
74.77
77.14
79.51
81.88
84.25
86.62
88.99
2 Theta


XRD of sample PI1b
Intensity (counts)
40
35
30
25
20
15
10
5
0
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
62.44
64.78
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71.8
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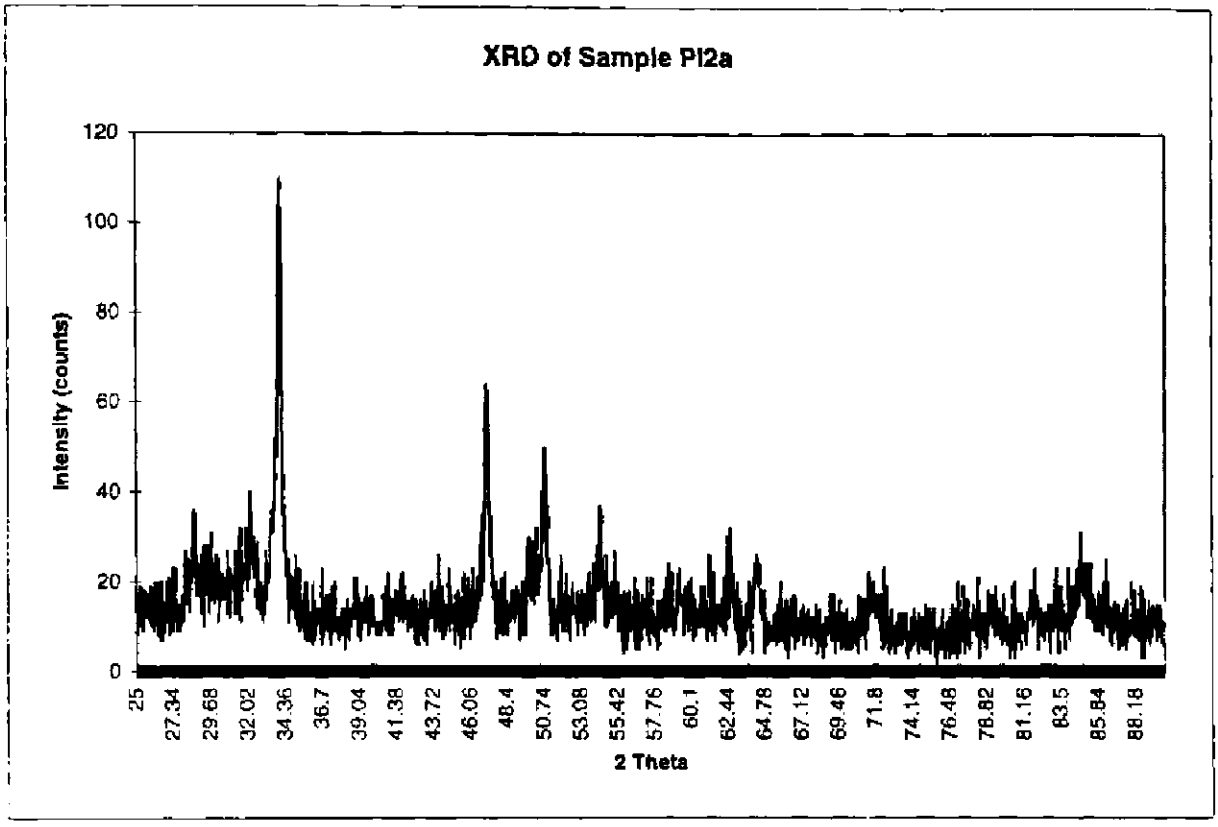
78.82
81.16
83.5
85.84
88.18
2 Theta


XRD of Sample PI2a
Intensity (counts)
2 Theta
120
100
80
60
40
20
0
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
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81.16
83.5
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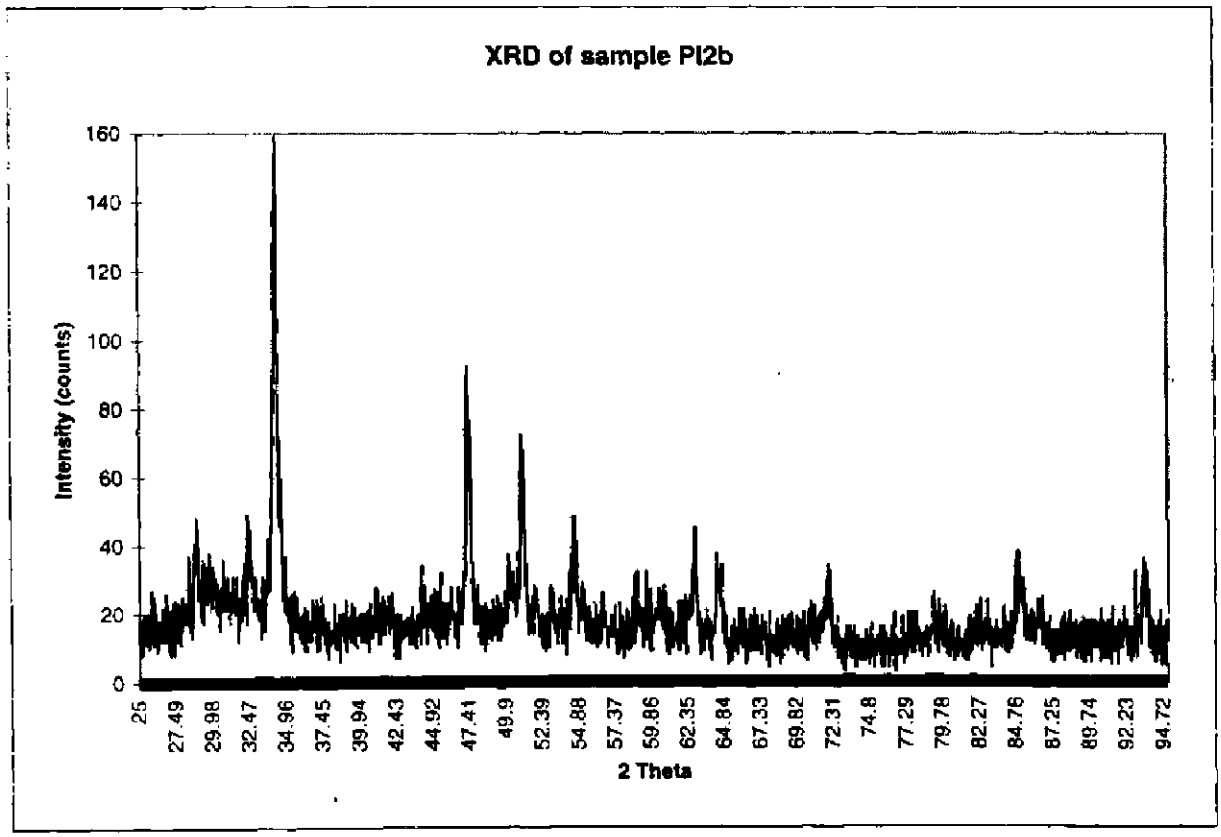
88.18


XRD of sample PI2b
Intensity (counts)
2 Theta
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140
120
100
80
60
40
20
0
25
27.49
29.98
32.47
34.96
37.45
39.94
42.43
44.92
47.41
49.9
52.39
54.88
57.37
59.86
62.35
64.84
67.33
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72.31
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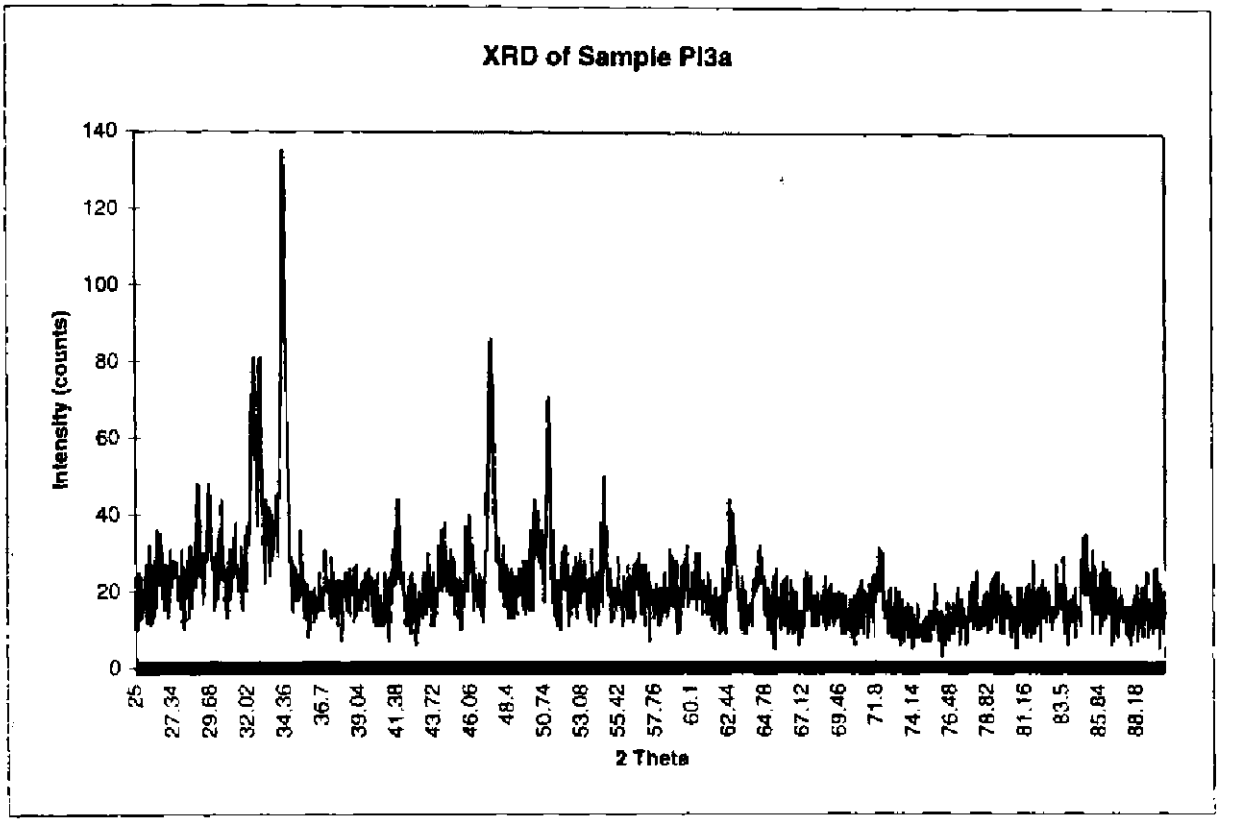
84.76
87.25
89.74
92.23
94.72


XRD of Sample Pl3a
Intensity (counts)
0
20
40
60
80
100
120
140
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
62.44
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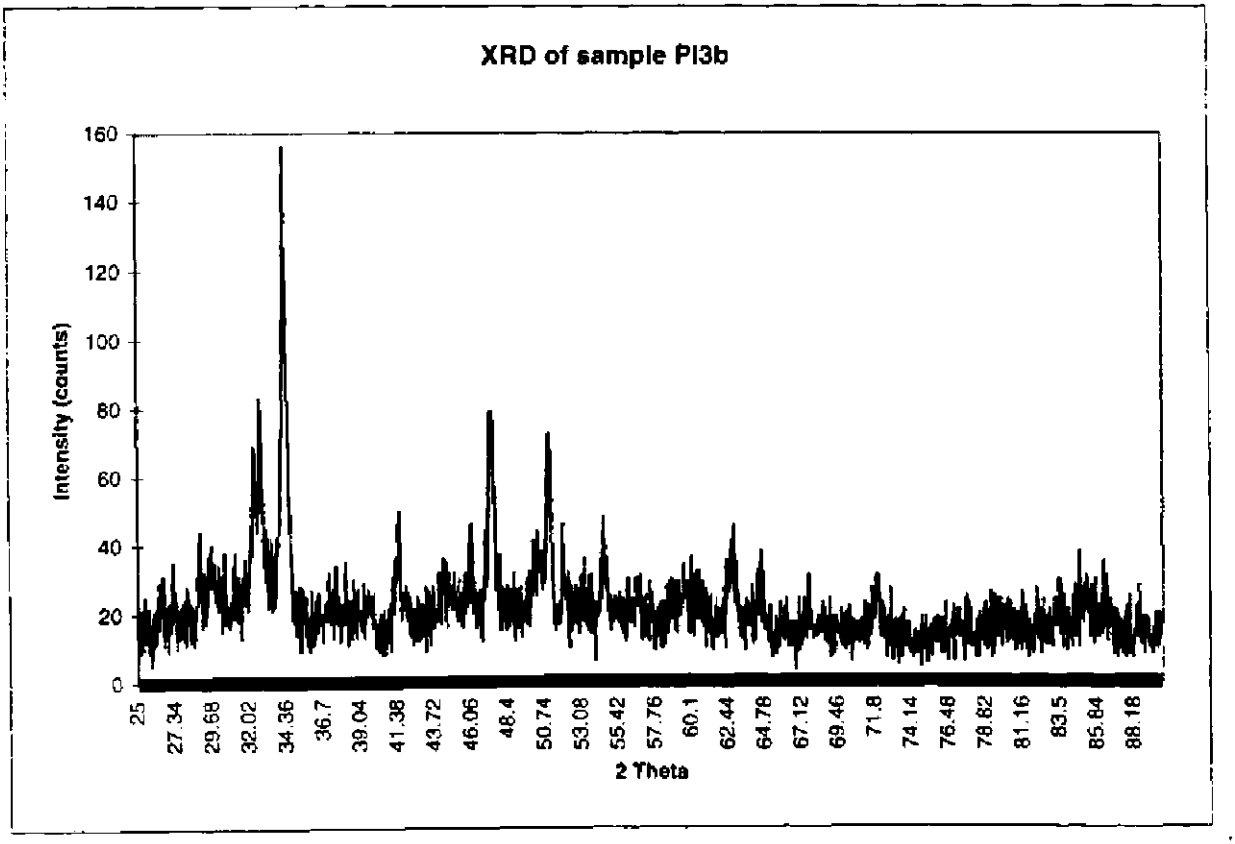
78.82
81.16
83.5
85.84
88.18
2 Theta


XRD of sample Pl3b
Intensity (counts)
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20
40
60
80
100
120
140
160
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
62.44
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81.16
83.5
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88.18
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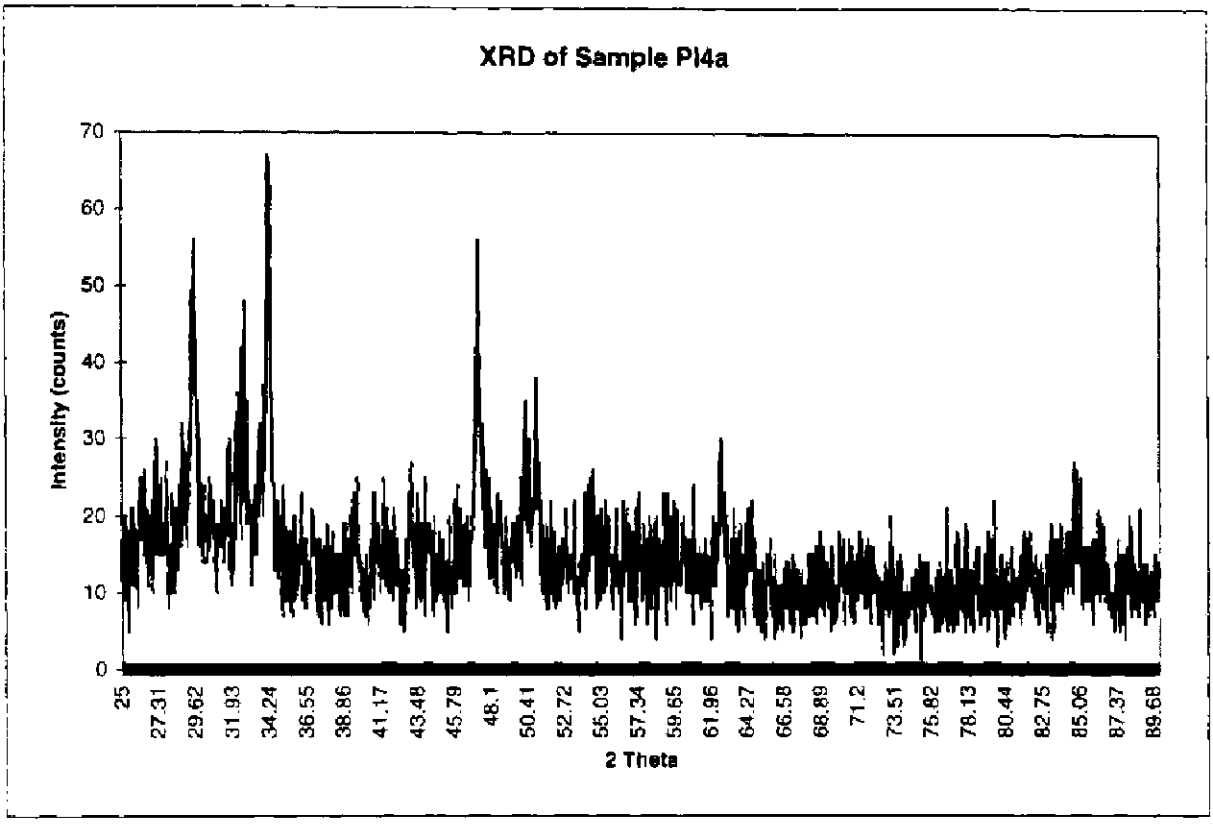
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Intensity (counts)
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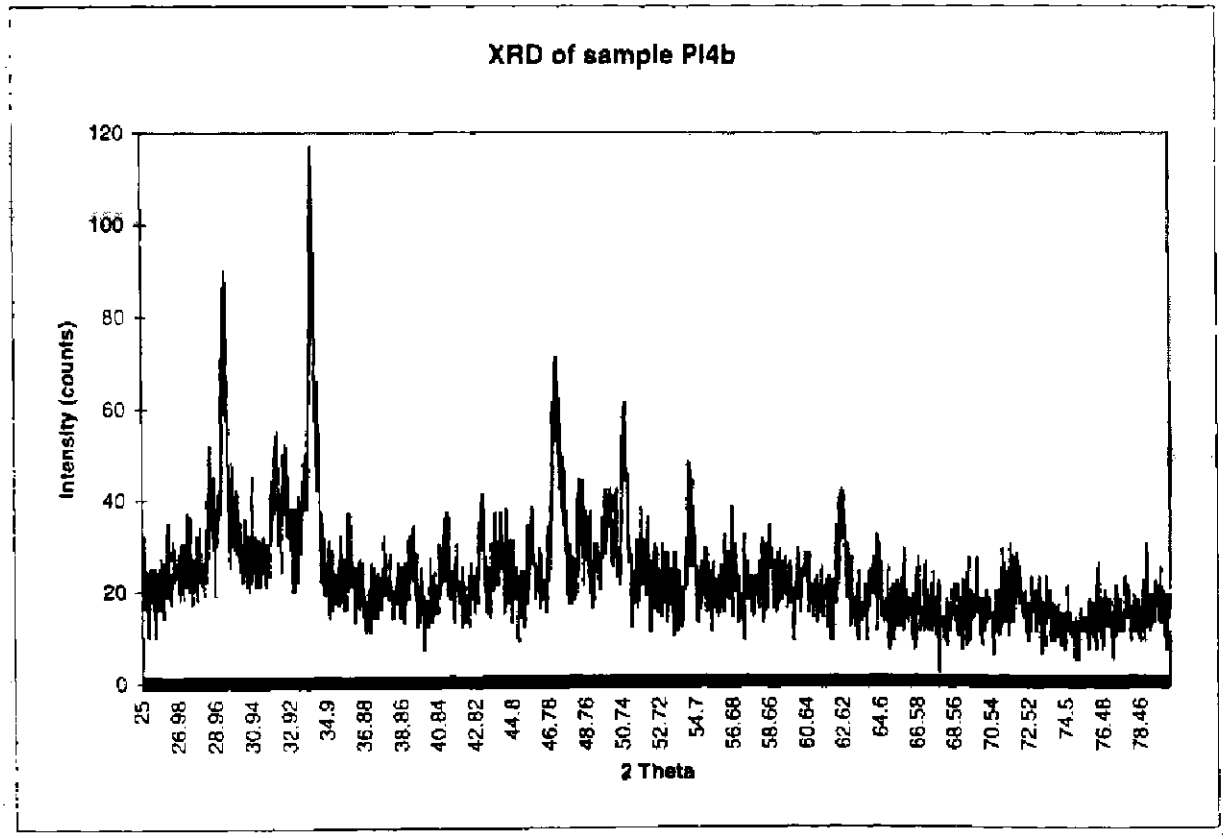
20
30
40
50
60
70
25
27.31
29.62
31.93
34.24
36.55
38.86
41.17
43.48
45.79
48.1
50.41
52.72
55.03
57.34
59.65
61.96
64.27
66.58
68.89
71.2
73.51
75.82
78.13
80.44
82.75
85.06
87.37
89.68
2 Theta


XRD of sample PI4b
Intensity (counts)
0
20
40
60
80
100
120
25
26.98
28.96
30.94
32.92
34.9
36.88
38.86
40.84
42.82
44.8
46.78
48.76
50.74
52.72
54.7
56.68
58.66
60.64
62.62
64.6
66.58
68.56
70.54
72.52
74.5
76.48
78.46
2 Theta

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Victor cement
Sample PI2

Figure 3.
Chance cement
Sample PI1

Figure 4.
Victor cement
Sample PI2

REFERENCES

1. Cherney, E.A., "Important Aspects of Ceramic Insulator Design"
2. Bogue, Robert Herman, "The Chemistry of Portland Cement" Reinhold Publishing Corporation, New York, 1947

Materials analysis

Possible phases in sample

pi1a

peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.1027	22.03				3.11 m	
2	3.0223	30.36					
3	2.7497	10.66	2.77 s				
4	2.6192	100				2.62 ss	2.63 ss
5	2.1843	10.66					
6	1.9201	52.49				1.93 s	1.921 ss
7	1.792	41.33				1.795 ss	1.801 s
8	1.6803	19.25	1.7 ss		1.69 ss	1.685 m	
9	1.4802	11.34		1.483 ss	1.482 ss		
10	1.4463	15.84	1.45 s		1.448 s	1.455 m	1.448 m
11	1.3137	12.76			1.307 s	1.312 m	
12	1.1419	18.37				1.144 m	

pi2a

peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.116	23.45				3.11 m	
2	2.7771	12.81	2.77 s				2.77 s
3	2.629	100				2.62 ss	2.63 ss
4	1.9265	51.24				1.93 s	1.921 ss
5	1.7947	29.96				1.795 ss	1.801 s
6	1.6863	16.85	1.7 ss		1.69 ss	1.685 m	
7	1.5716	11.35					1.572 s
8	1.4842	20.49		1.483 ss	1.482 s	1.48 m	
9	1.4488	17.73	1.45 s		1.448 s	1.455 m	1.448 m
10	1.3172	11.35			1.307 m	1.312 m	1.317 s
11	1.1768	11.35					
12	1.1435	12.81				1.144 m	

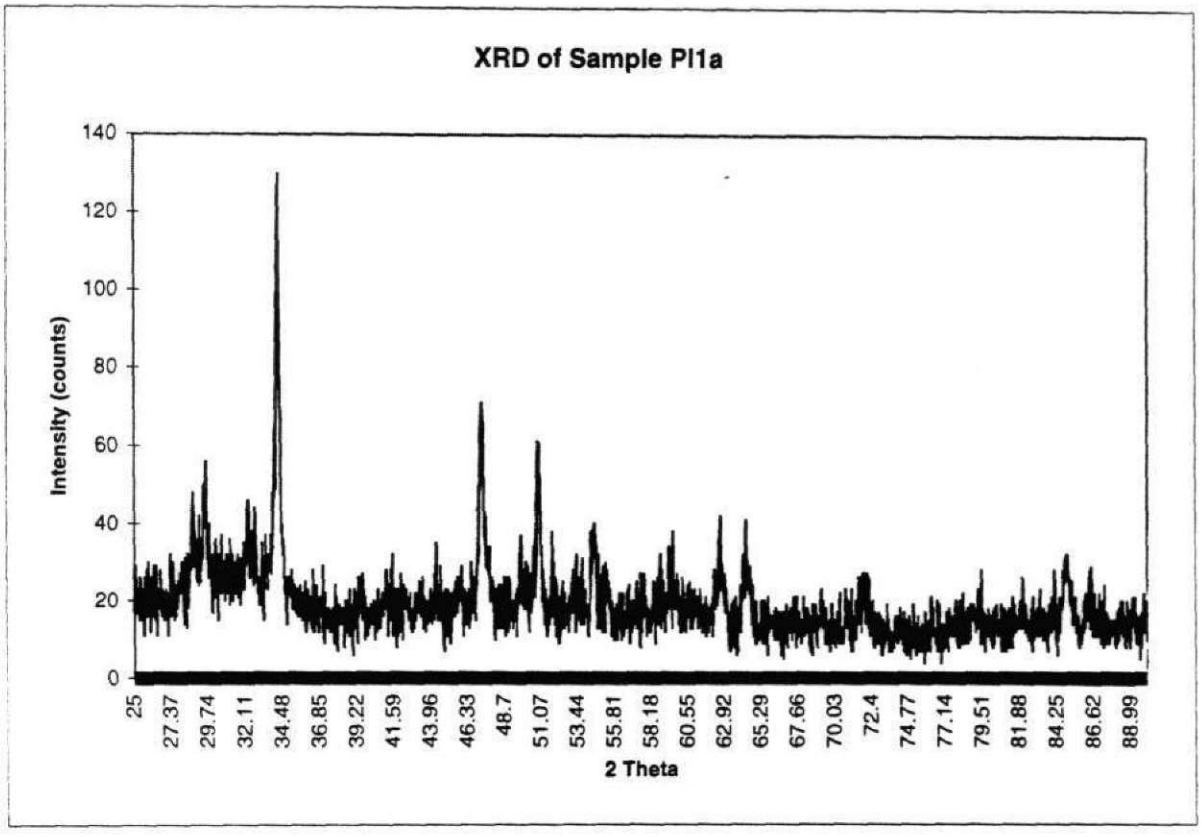
pi2b

peak no.	d spacing	I/Imax	CaO2	MgO	Fe2O3	Ca(OH)2	C4AF
1	3.0877	20.01				3.11 s	
2	2.7587	11.11	2.77 s				2.77 s
3	2.613	100				2.62 ss	2.63 ss
4	2.4155	7.88					
5	1.9209	56.91				1.93 s	1.921 ss
6	1.8171	11.7					1.801 s
7	1.7881	42.14				1.795 ss	
8	1.7592	7.88					
9	1.6801	20.81	1.7 ss		1.69 ss	1.685 m	
10	1.5665	7.88					1.572 s
11	1.4774	14.23		1.483 ss	1.482 s	1.48 m	
12	1.4454	14.9	1.45 s		1.448 s		1.448 m
13	1.3107	9.9			1.307 m		1.317 s
14	1.1715	7.88					
15	1.1401	12.93				1.144 m	
16	1.0578	12.31					

pi3a

peak no.	d spacing	I/Imax	Ca(OH)2	C4AF
1	3.363	10.05		
2	3.0833	19.75	3.11 m	
3	3.0071	19.75		
4	2.9389	14.41		
5	2.7606	44.44		2.77 s
6	2.723	49.52		
7	2.6075	100	2.62 ss	
8	2.274	8.78		
9	2.1775	15.85		
10	2.0902	8.78		
11	2.0449	9.34		
12	1.9696	12.38		
13	1.917	50.83	1.93 s	1.921 ss

	pi3a			
			Ca(OH)2	C4AF
14	1.813	12.38		
15	1.7858	38.49	1.795 ss	1.808 s
16	1.7544	8.78		
17	1.6807	22.3	1.685 m	
18	1.4801	15.85	1.48 m	
19	1.445	11.74	1.455 m	1.448 m
20	1.3092	10.5		1.317 s
21	1.1407	13.72	1.144 m	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62.92
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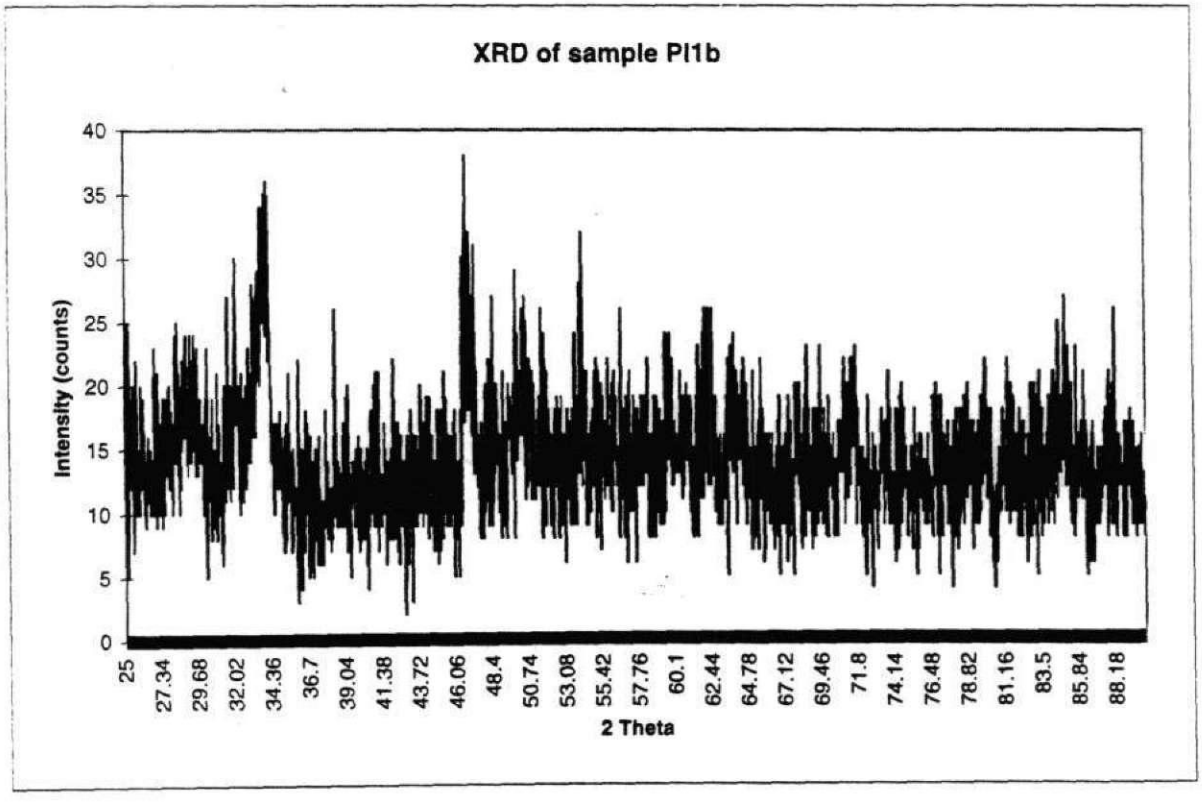
2 Theta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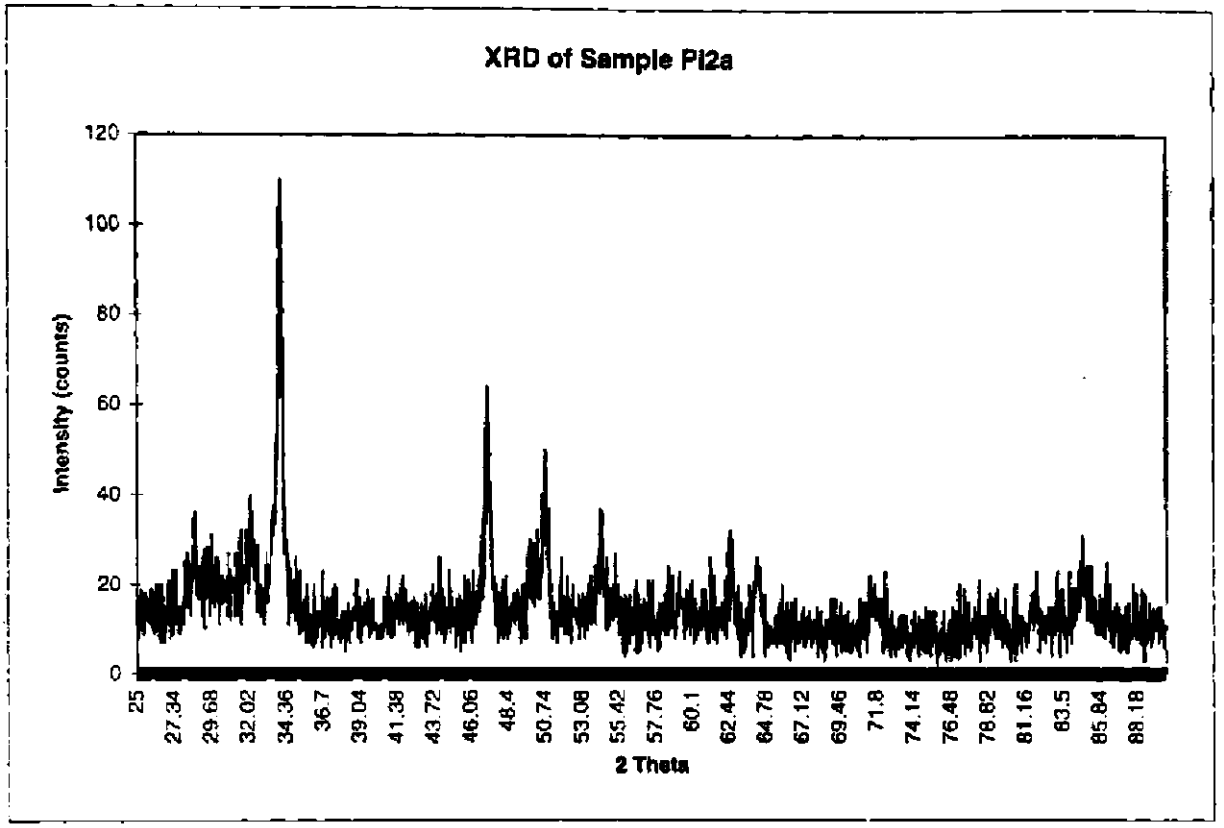
88.18
2 Theta


XRD of Sample PI2a
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46.06
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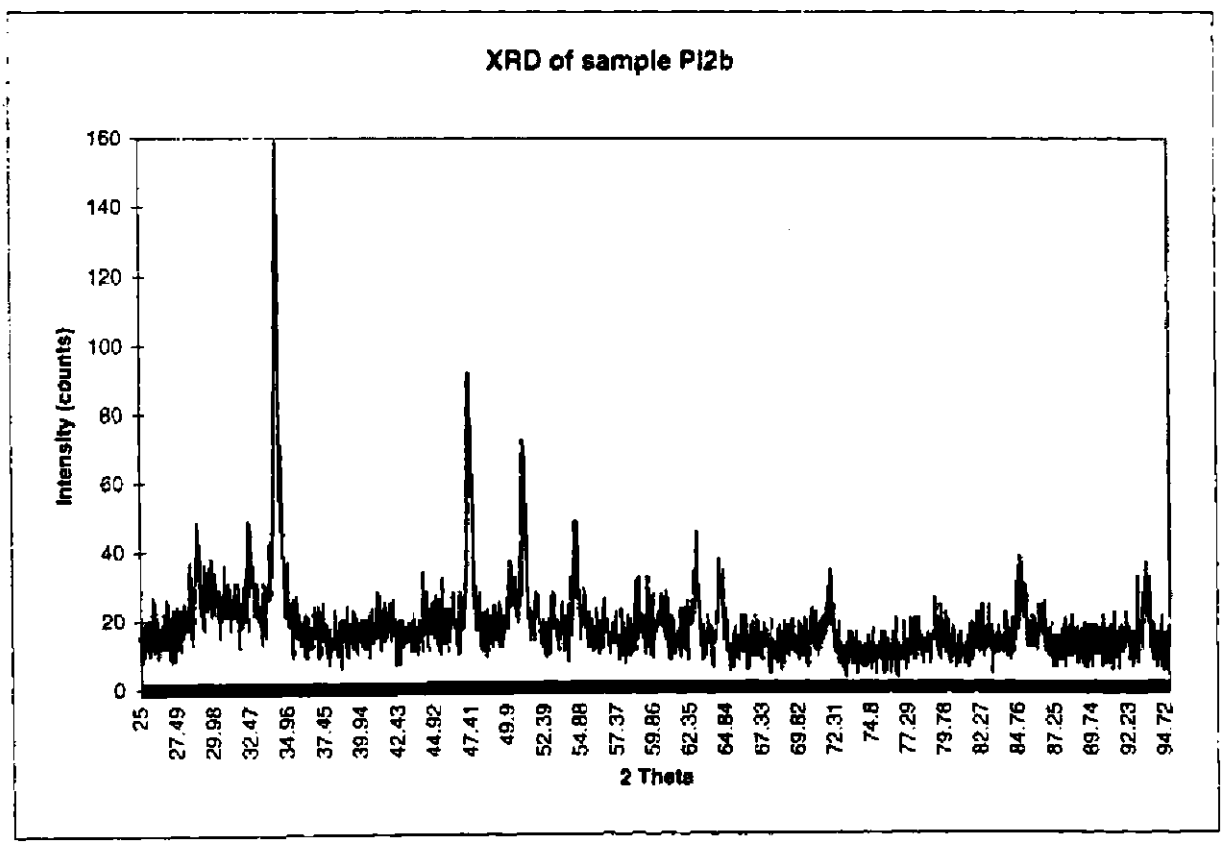
2 Theta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62.35
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67.33
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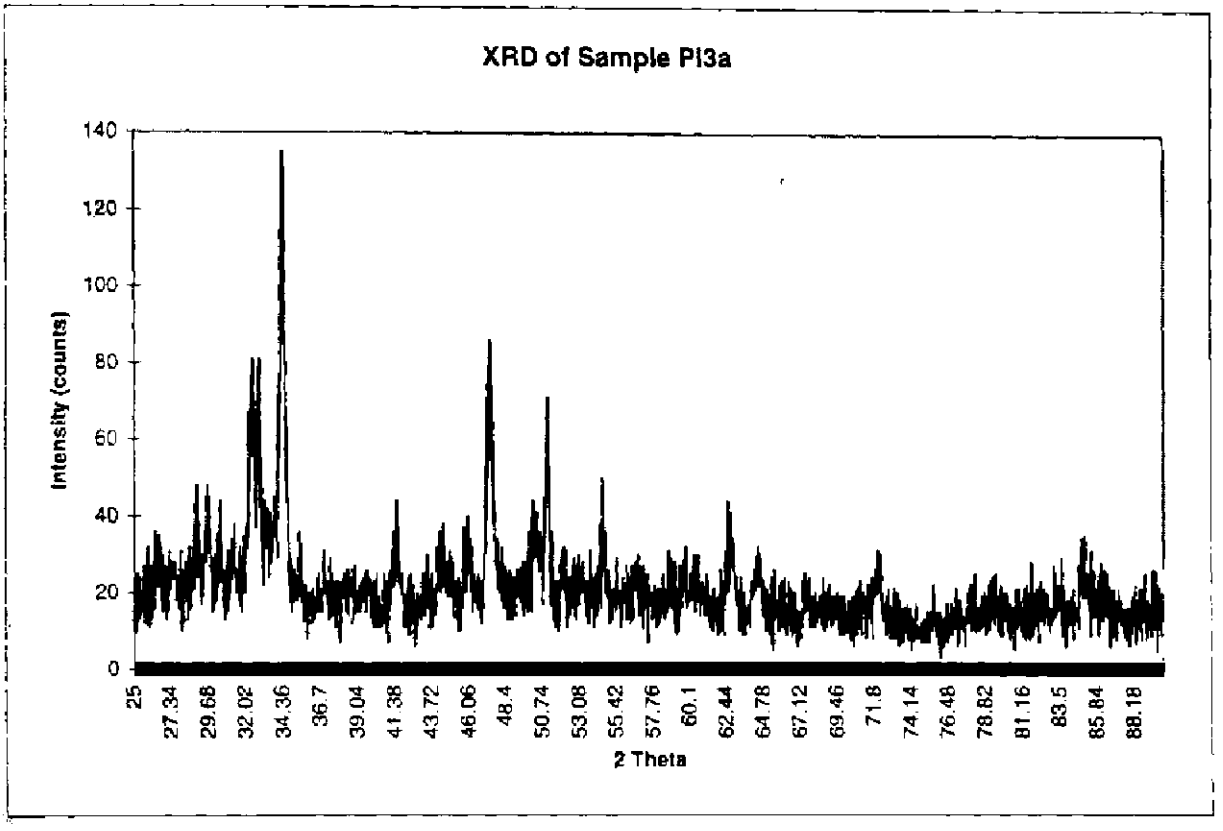
2 Theta


XRD of Sample Pl3a
Intensity (counts)
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60
80
100
120
140
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29.68
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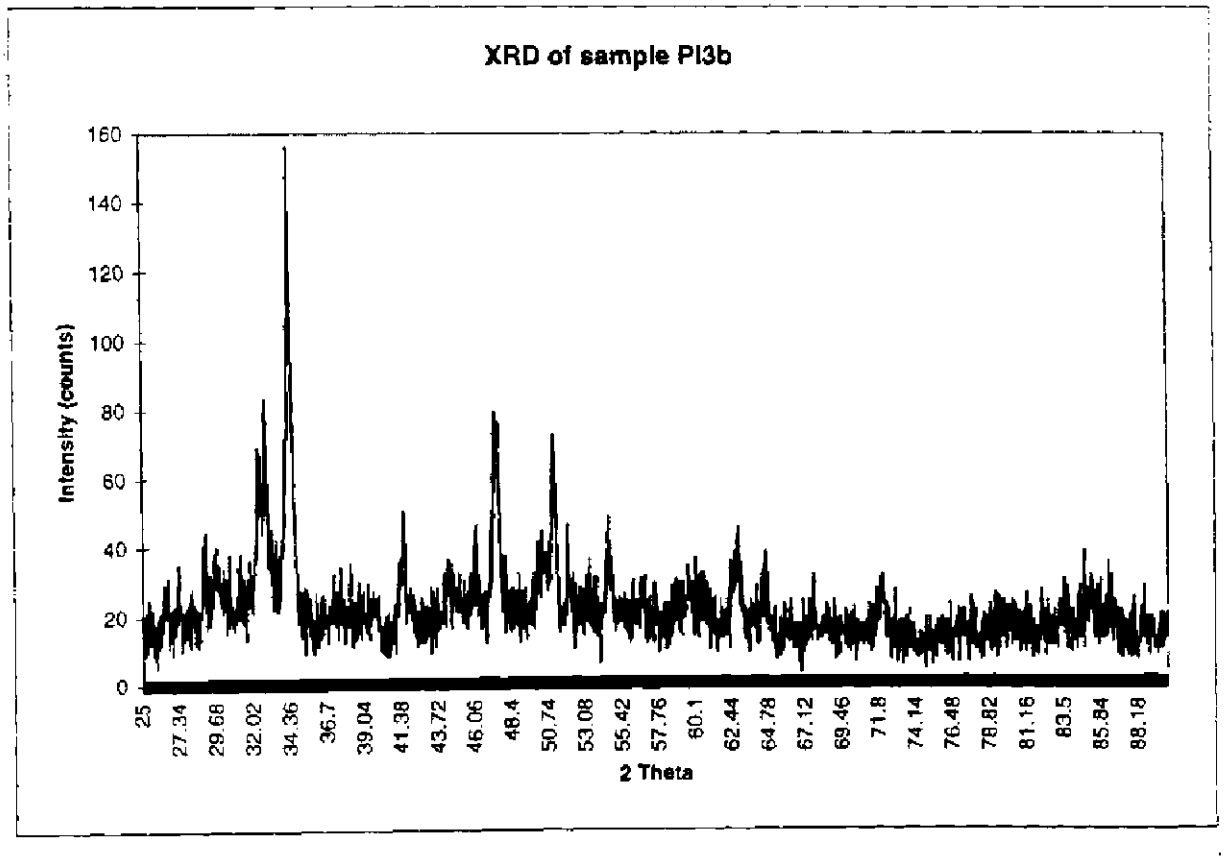
XRD of sample Pl3b
Intensity (counts)
2 Theta
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40
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100
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140
160
25
27.34
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32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
62.44
64.78
67.12
69.46
71.8
74.14
76.48
78.82
81.16
83.5
85.84
88.18

MICROSTRUCTURE OF INSULATOR CEMENT AND PORCELAIN

W. Jack Lackey, Giancarlo Giannetti and Elliot Pickering

1. APPROACH

Materials analysis was conducted on five porcelain insulators. Four were manufactured by Chance and one by Victor. The cement and porcelain shell of each was examined. Each cement sample was ground into a powder for the x-ray diffraction (XRD) scans using a mortar and pestle. During this operation it was clear that the victor cement was much stronger than the Chance cement samples. XRD was performed on the cement samples using a Philips Automated Powder Diffractometer, Series PW 1800. It was determined that no significant peaks would be present below 20 degrees 2Θ. The analysis program used on the samples was a gonio scan from 25 - 90 degrees 2Θ using Cu Kα radiation. The porcelain shells were broken using a hammer. A fracture surface from each sample was examined under low voltage using a Hitachi S-800 Scanning Electron Microscope and optical microscope.

	Sample ID	XRD Cement	Optical Microscopy Cement
PI1	Chance, R36b	X	X
PI2	Victor, R11a	X	X
PI3	Chance, new sample	X	
PI4	Chance, 1985	X	
PI5	Chance, R24b		

	Optical Microscopy Porcelain	SEM of Cement	SEM of Porcelain	Cement Strength
PI1	X	X	X	W
PI2	X	X	X	S
PI3	X		X	W
PI4	X		X	W
PI5	X			W

Fig.1 Showing which samples were analyzed via different methods. X indicates sample examined. W and S denote weak and strong, respectively.

2. RESULTS

The portland cement used in the insulator bonds the iron pin into position in the pin hole of the porcelain shell. According to Cherney (1) the porcelain shell does not tolerate volume expansion of the cement. There are three mechanisms which contribute to the volume expansion of portland cement.

The first possible failure mechanism is the result of uncombined, free CaO hydrating to $Ca(OH)_2$. The second is the result of MgO hydrating to $Mg(OH)_2$. Magnesium is an impurity in the raw materials used to make portland cement. The third mechanism is the reaction of excess gypsum.

2.1 XRD Results

Portland cement contains multiple phases of several different calcium, magnesium, aluminum and iron oxides called clinker components. Also present are products of cement hydration. XRD will show only those phases diffracting the greatest intensities. Because there are multiple phases in the cement there is a high degree of chance that lines having similar d-spacings will overlap and will not be distinguishable. Using x-ray diffraction data from Bogue (2), the plot/ re-plot method was used to subtract out the known phases in portland cement from the data in the .DI scan files. The following data tabulated below show the results of scans PI1a, PI2a, PI2b and PI3a. Four strong phases were observed.

The 100% peak is approximately the same for all the samples (d-space = 2.61). Plot /re-plot and computer analysis both concluded that $Ca(OH)_2$ was a primary phase in the samples. Also CaO, Fe_2O_3 and $4CaO.Al_2O_3.Fe_2O_3$ phases were present. The data do not provide evidence of free MgO in the samples.

2.2 SEM Results

SEM showed evidence of greater crystallinity in the Victor cement than the in Chance. (Figure 2, PI1) That is, the crystals were larger in the Victor cement. Darker spherical regions about 80 microns in diameter were observed in the Victor cement sample. Cracks typically extended from the dark regions. (Figure 2) Voids containing large crystals (Figure 4) were observed via SEM in the Victor cement sample. The micrograph shown in Figure 3 is typical of the Chance cement.

Under SEM and optical microscopy there was no evidence of cracks or inclusions in the fracture surface of the porcelain samples.

3. CONCLUSIONS

The following conclusion are based on the examination of the cement and porcelain.

1. The Victor cement sample was much stronger than the Chance cement as evidenced by the ease with which the Chance sample were ground into a powder in a mortar and pestle.

2. XRD showed Ca(OH)2, (Calcium Hydroxide) as a major phase in all the cement samples (Victor and Chance). That is to say similar intensities were observed for the d-spacing's that identify it as a major phase. Possible hydration of free CaO.

3. Some variability in the XRD patterns of the Chance cement samples was observed, i.e. phases present varied from sample to sample (compare patterns around 32 degrees 2Θ). This Bragg angle implies variability in the concentration of the 4CaO.Al2O3.Fe2O3 phase.

4. There is no XRD evidence of Mg(OH)2, (Magnesium Hydroxide).

5. Duplicate XRD patterns were very similar in appearance giving evidence of good reproducibility.

6. The porcelain samples were similar in appearance when examined by optical and electron microscopy. It should be noted that the differences in porosity or composition are difficult to detect by these techniques.

Figure 2.
Victor cement
Sample PI2

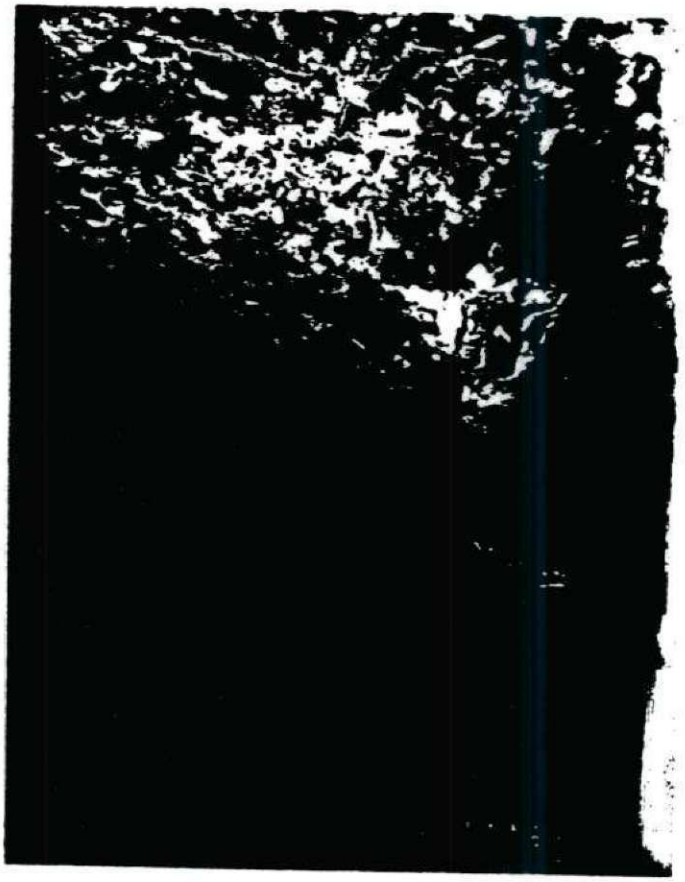

Figure 3.
Chance cement
Sample PI1

Figure 4.
Victor cement
Sample PI2

REFERENCES

1. Cherney, E.A., "Important Aspects of Ceramic Insulator Design"
2. Bogue, Robert Herman, "The Chemistry of Portland Cement" Reinhold Publishing Corporation, New York, 1947

Materials analysis

Possible phases in sample

pi1a

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pi2a

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pi2b

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8	1.7592	7.88					
9	1.6801	20.81	1.7 ss		1.69 ss	1.685 m	
10	1.5665	7.88					1.572 s
11	1.4774	14.23		1.483 ss	1.482 s	1.48 m	
12	1.4454	14.9	1.45 s		1.448 s		1.448 m
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pi3a

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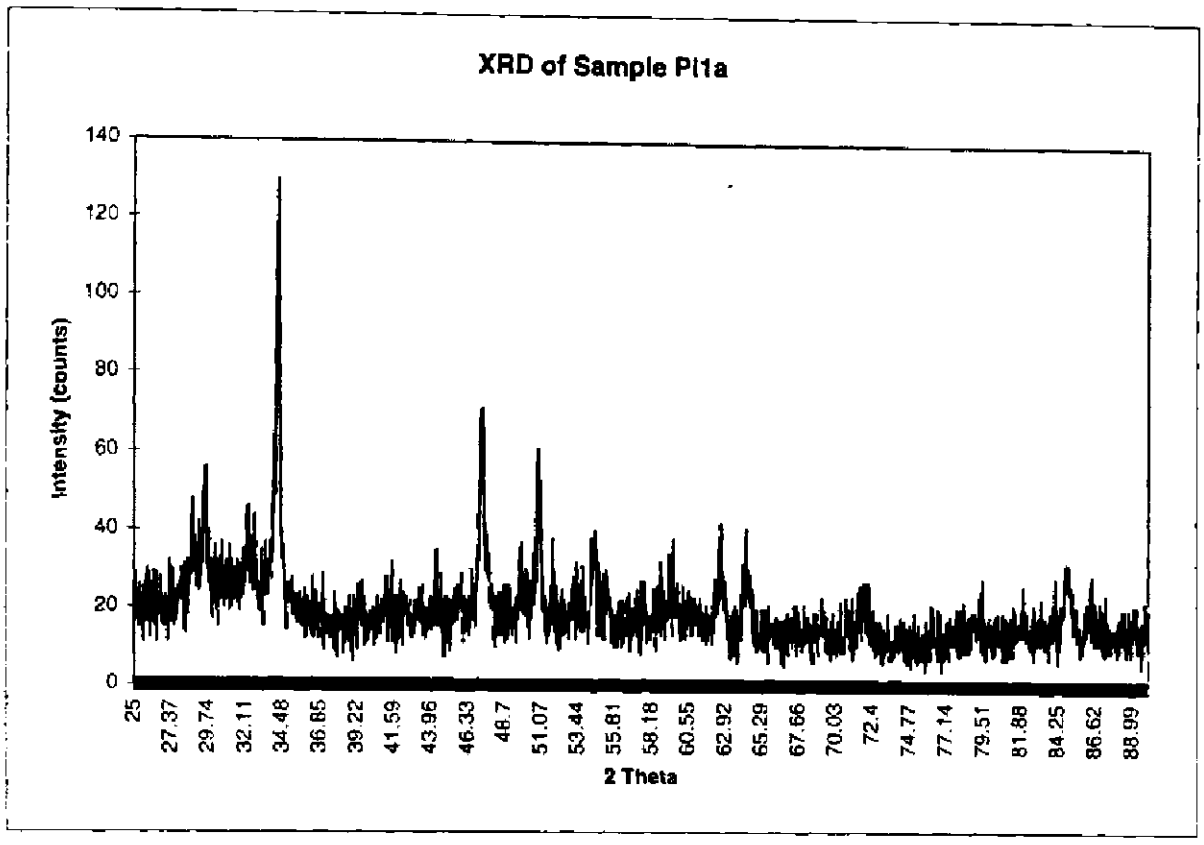
6	2.723	49.52		
7	2.6075	100	2.62 ss	
8	2.274	8.78		
9	2.1775	15.85		
10	2.0902	8.78		
11	2.0449	9.34		
12	1.9696	12.38		
13	1.917	50.83	1.93 s	1.921 ss

pi3a

			Ca(OH)2	C4AF
14	1.813	12.38		
15	1.7858	38.49	1.795 ss	1.808 s
16	1.7544	8.78		
17	1.6807	22.3	1.685 m	
18	1.4801	15.85	1.48 m	
19	1.445	11.74	1.455 m	1.448 m
20	1.3092	10.5		1.317 s
21	1.1407	13.72	1.144 m	


XRD of Sample Pl1a
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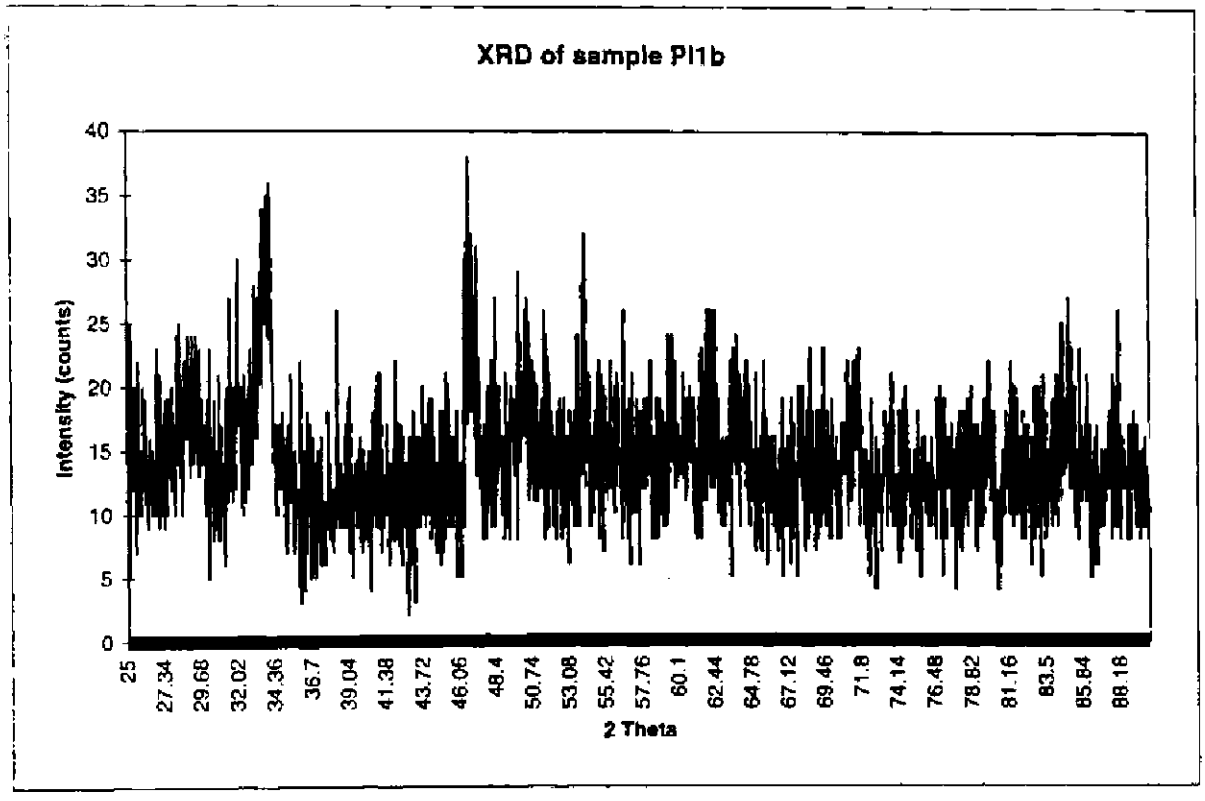
2 Theta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Intensity (counts)
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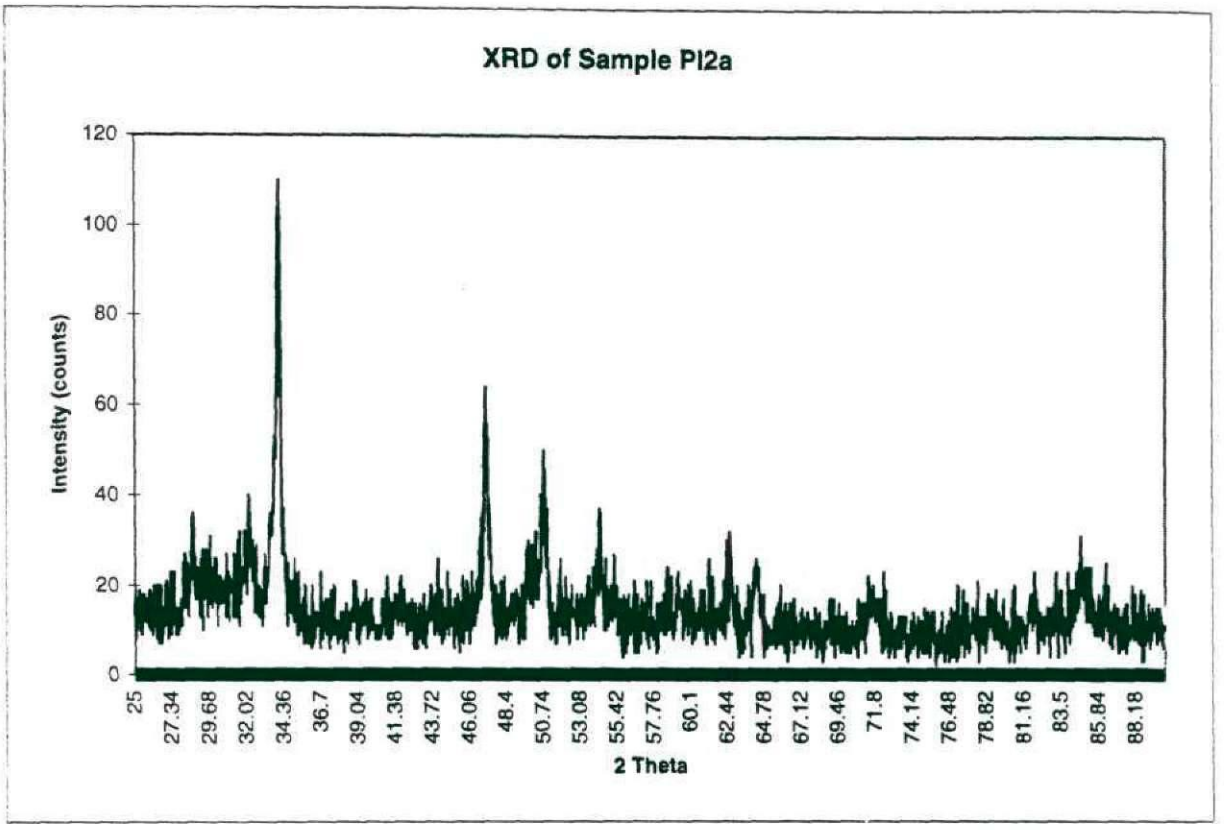
2 Theta


XRD of Sample Pl2a
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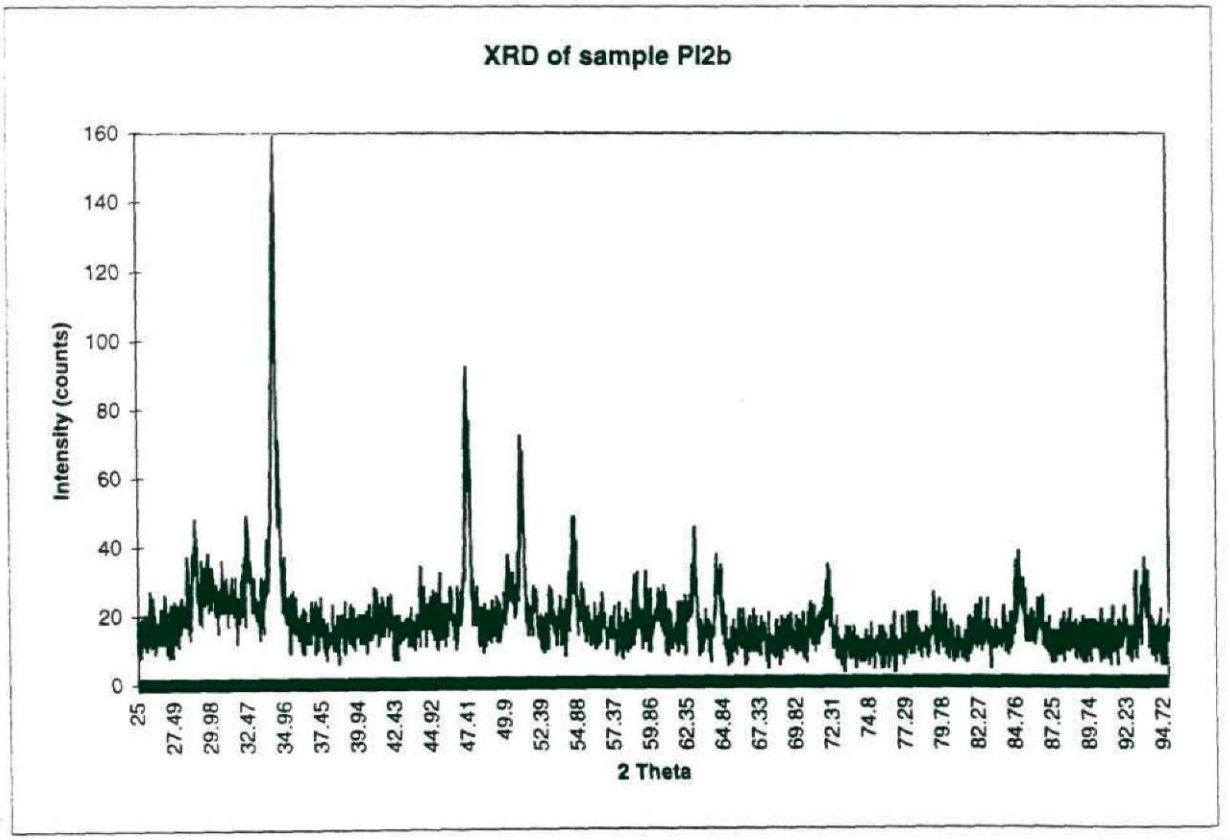
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39.94
42.43
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64.84
67.33
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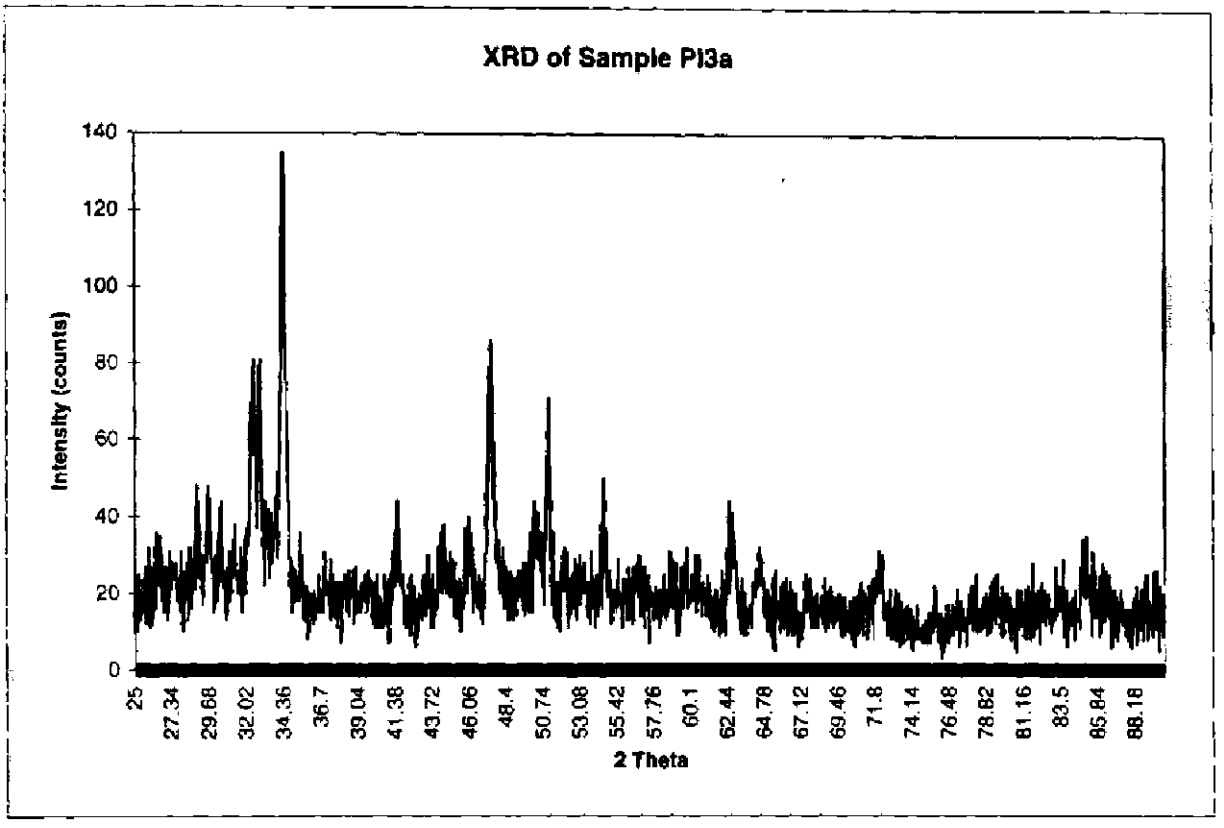
2 Theta


XRD of Sample PI3a
Intensity (counts)
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20
40
60
80
100
120
140
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
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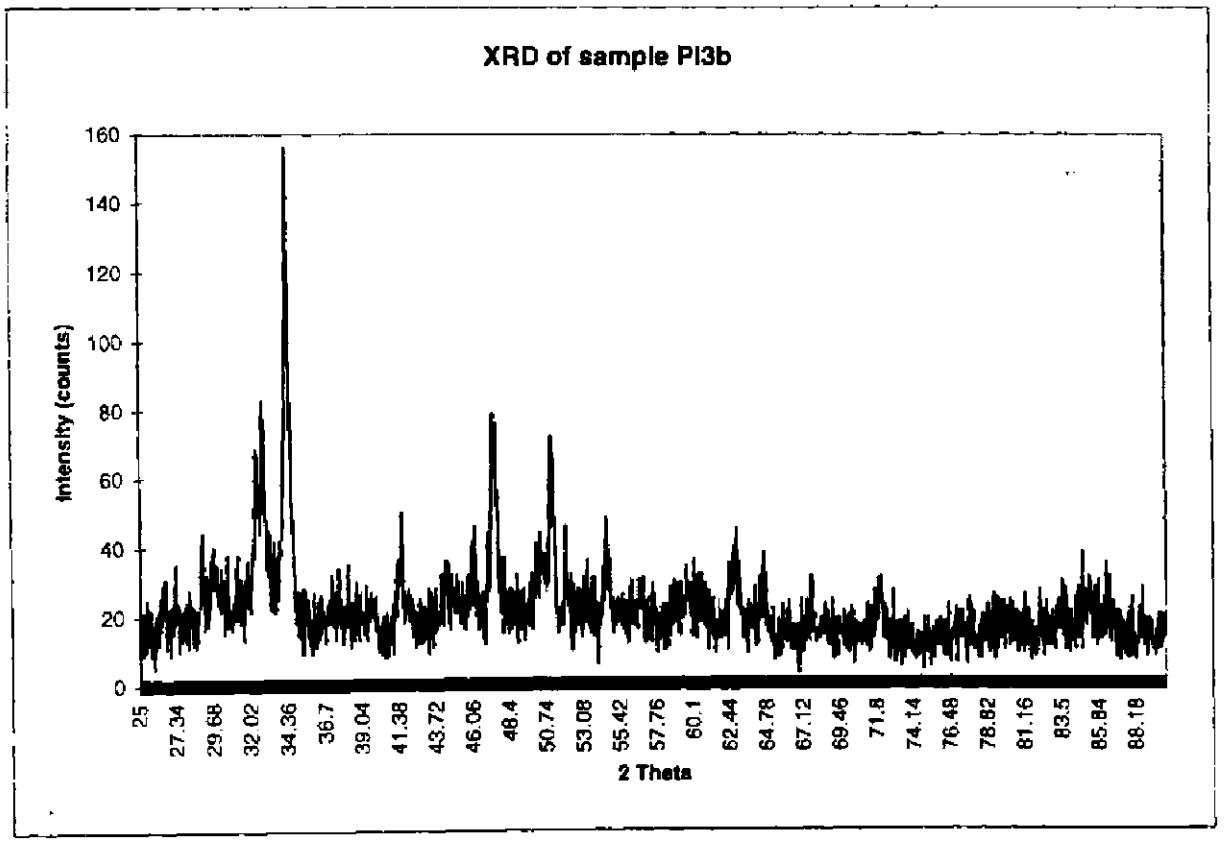
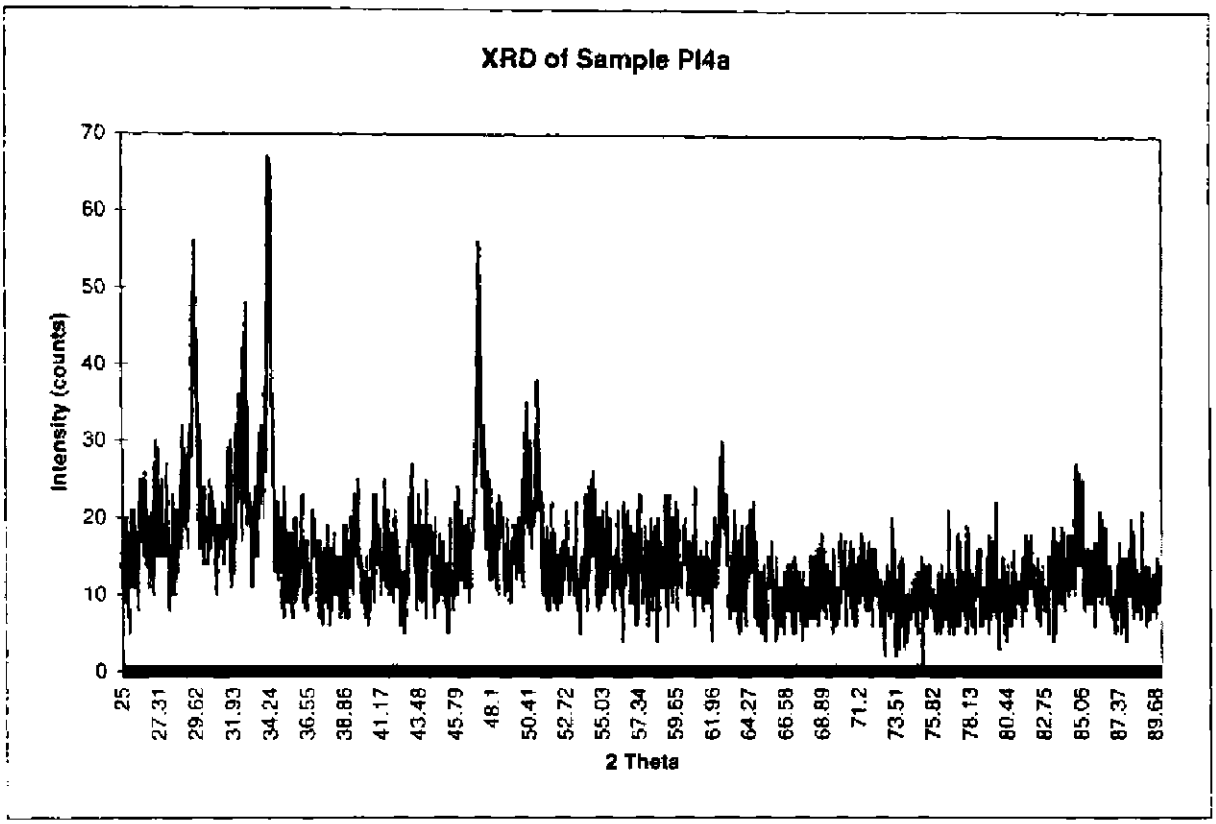
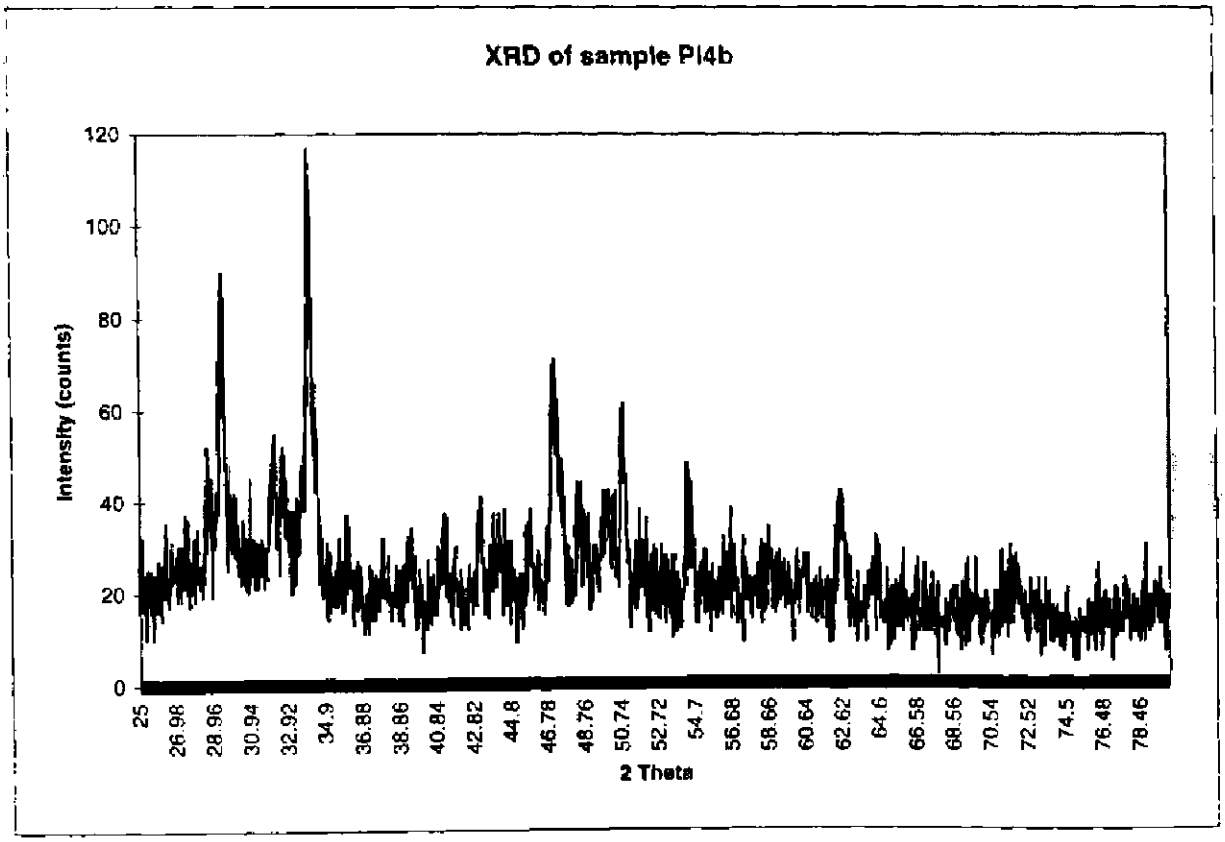

XRD of sample PI3b
Intensity (counts)
2 Theta
0
20
40
60
80
100
120
140
160
25
27.34
29.68
32.02
34.36
36.7
39.04
41.38
43.72
46.06
48.4
50.74
53.08
55.42
57.76
60.1
62.44
64.78
67.12
69.46
71.8
74.14
76.48
78.82
81.16
83.5
85.84
88.18


XRD of Sample PI4a
Intensity (counts)
0
10
20
30
40
50
60
70
25
27.31
29.62
31.93
34.24
36.55
38.86
41.17
43.48
45.79
48.1
50.41
52.72
55.03
57.34
59.65
61.96
64.27
66.58
68.89
71.2
73.51
75.82
78.13
80.44
82.75
85.06
87.37
89.68
2 Theta


XRD of sample PI4b
Intensity (counts)
0
20
40
60
80
100
120
25
26.98
28.96
30.94
32.92
34.9
36.88
38.86
40.84
42.82
44.8
46.78
48.76
50.74
52.72
54.7
56.68
58.66
60.64
62.62
64.6
66.58
68.56
70.54
72.52
74.5
76.48
78.46
2 Theta