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Characterization of Bangladesh sand for possible high-tech applications

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ABSTRACT

Sand samples from 5 deposits in Bangladesh was characterised on the basis of parameters that include composition, size, density, sphericity, moisture content, material composition and crystallinity for possible use in the production of silicon for high-tech applications. The results have been presented and discussed.

INTRODUCTION

Bangladesh is undertaking ambitious programmes to increase the use of off-grid, renewable energy technologies[1]. A photovoltaic system probably represents the shortest route to an affordable electricity option for remote and difficult to access villages. The dominant material used in PV cells is silicon[2]. About 95% of the current solar cell module market is based on silicon as raw material[3]. Silicon, the main constituent of silica does not occur in free state, but silicon compounds are abundantly available and constitute about 28% of the earth's crust.

In nature, silica occurs in different forms such as quartz, sandstone, quartzite and silica sand[4]. High purity silica sand for high-tech applications is currently sourced from a few locations situated in USA, UK, Germany, Belgium, France, and Brazil[4-6]. In Bangladesh 94773 tons of glass sand has been exploited during 1975-93[7]. Geological Survey Bangladesh has identified new deposits of silica sand. However, systematic characterization of sands of these deposits is yet to be undertaken. This work aims at evaluating silica of some deposits in Bangladesh for possible high-tech applications including the production of solar grade silicon.

MATERIALS AND METHODS

Study area

Samples of silica sand were collected from 5 different locations in Bangladesh (TABLE 1).

TABLE 1 : Location of the study area

Sample	Location		Latitude (°N)	Longitude (°E)
	Sub-district	District		
Dalia	Jaldhaka	Nilphamari	26.15	89.03
Kuakata	Kalapara	Patuakhali	21.82	90.12
Patgram	Patgram	Lalmonirhat	26.35	89.02
Bipinganj	Durgapur	Netrokona	25.11	90.67
Sylhet	Jaintiapur	Sylhet	25.13	92.12

Experimental

The samples were characterised on the basis of parameters that include composition, size, density, sphericity, moisture content, material composition and crystallinity. The mineralogical composition of the samples was determined by x-ray fluorescence analysis. Particle size distribution was analysed by Taylor sieve analysis. The bulk density was determined by a calibrated pycnometer. The sphericity of the particles in the samples was determined by using the following formula

Sphericity= (a+ b+ c)/ 3: a

where the longest diameter is a, diameter perpendicular to the longest diameter is b and diameter intersecting the other two at 45° is c (Figure 1).

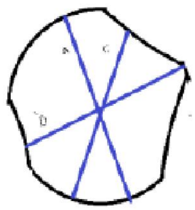

Figure 1: Sphericity Measurement

To determine the organic matter content, a certain quantity of oven dried sample was placed on an empty, clean and dry porcelain dish and the weight of the dish and sand specimen was determined. The dish was then placed in a muffle furnace and the temperature of the furnace was gradually increased to 440°C and the specimen was left there over-night. Then the dish was removed, allowed to cool to room temperature and the mass of the dish containing burned sand was determined. The difference in weight gave the organic matter content[8]. The phases present in the samples were identified by x-ray diffraction analysis. The samples were finely ground in an agate mortar before the x-ray diffraction patterns were recorded. Thermogavitimetric analysis (TGA) was performed to determine the thermal effects - to trace the loss of combined water and/or to observe if any polymorphic transformation took place. The samples were heated to 1000°C at a rate of 20°C/ min. Thermogravimetric analysis was performed again on the same sand samples heated for one hour at 580°C.

RESULT AND DISCUSSION

Optical microscopy

The colour, size and shape of the samples were observed under a stereo-microscope (Figure 2 (a-e)). Then the prepared grain slides were observed under a polarizing microscope (Figure 2(f-j)).

Polarizing microscopic images indicated high silica content in the Bipinganj sand. An analysis was performed on all samples with the Michel-Levy interference colour chart[9,10]. The presence of feldspar, iron oxide etc. could also be found in the samples. The results of analysis for $Si0_2$ are given in TABLE 2.

Material composition

X-ray fluorescence analysis of the samples is shown in TABLE 3.

It can be seen that the SiO_2 content are in the range 65-97%. Results obtained through Michel-Levy inter-

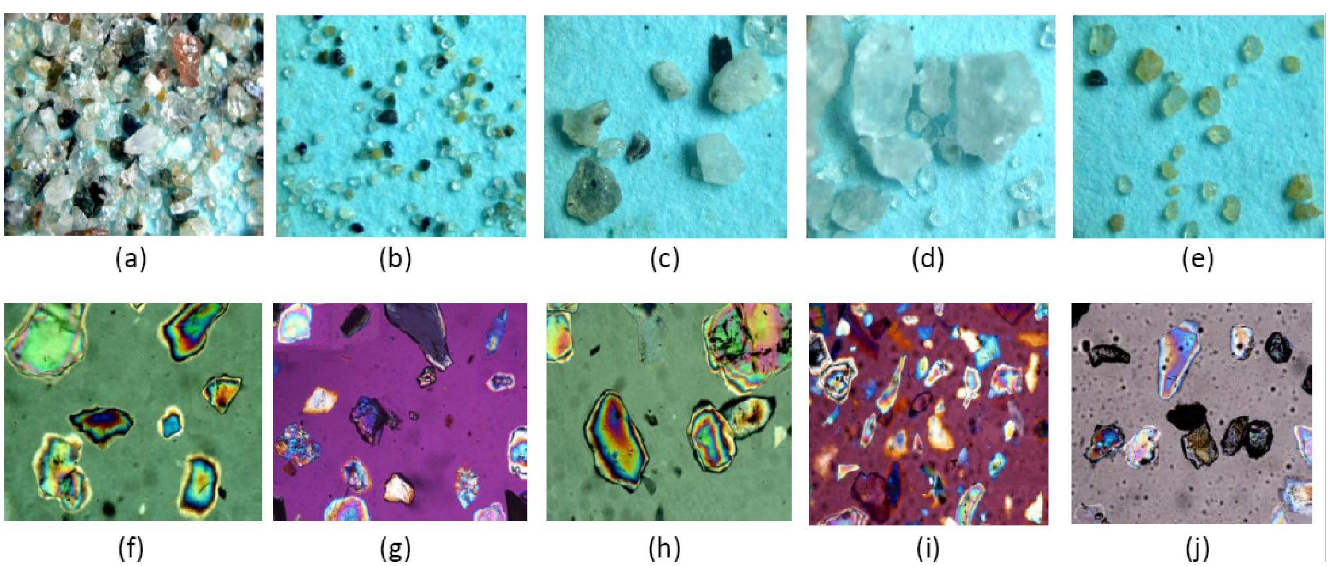

Figure 2 : Stereo-microscopic view of (a) Dalia, (b) Kuakata, (c) Patgram, (d) Bipinganj and (e) Sylhet sand and Polarizing microscopic view of (f) Dalia, (g) Kuakata (crossed polarized), (h) Patgram, (i) Bipinganj (crossed polarized) and (j) Sylhet (plane-polarized)

TABLE 2 : Polarizing Microscope data

Sample location	% of SiO_2
Dalia	74.82
Kuakata	60.5
Patgram	81.18
Bipinganj	94.10
Sylhet	85.49

TABLE 3 : Sand Sample Composition (XRF Analysis)

Content (Weight %)	Dalia	Kuakata	Patgram	Bipinganj	Sylhet
SiO_2	75.06	65.23	75.52	97.04	86.85
Na_2O	1.74	1.56	1.80	0.05	0.41
MgO	1.16	2.42	1.21	0.05	0.31
Al_2O_3	11.94	11.55	12.05	0.90	5.62
P_2O_5	0.08	0.57	0.06	0.01	0.05
K_2O	3.15	1.95	3.26	0.04	2.07
CaO	1.13	6.20	0.99	0.06	0.38
TiO_2	0.29	1.13	0.27	0.19	0.26
Cr_2O_3	0.58	0.43	0.49	0.43	0.69
MnO	0.08	0.20	0.07	0.01	0.04
Fe_2O_3	4.62	8.52	4.12	1.12	3.17

ference colour chart (TABLE 2) are in good agreement with the results of x-ray fluorescence analysis (TABLE 3).

The analyses show that Bipinganj sand has the highest SiO_2 content (~97%), whereas Kuakata sand has the lowest SiO_2 content. It contains around 35% of oxides other than silica, including oxides of iron, aluminum, titanium etc. All samples, except the Bipinganj sand, contained Al_2O_3 in good quantity. Aluminum, calcium and other metal oxides are undesirable in the silica[11] for high tech applications. The most troublesome elements in the use of the silica for the manufacturing of the photovoltaic cells are boron and the phosphorus[12]; from TABLE 2 presence of phosphorus as P_2O_5 can be seen.

Grain size

The results of sieve analysis (TABLE 4) show that more than 85% of Dalia sands are sized within 212 μm to 600 μm. The result shows among all five samples Kuakata sand size is most tightly distributed, around 84% is 106 μm (>75 μm). Sylhet sand is also quite tightly distributed. Around 93% of sylhet sand is sized within 425 μm to 106 μm, where 60% of Sylhet sand is sized around 212 μm (>106 μm).

Figure 3 shows non-uniformity in Dalia, Patgram and Bipinganj sand. If equal size distribution becomes necessary for subsequent processing, these three sand samples will require grinding and/or screening.

Bulk density

The bulk density of all five samples measured at a room temperature of 20 °C is given in TABLE 5.

The result shows Kuakata sand sample has the highest density (2.9 g/cc). The reason for this can be

TABLE 4 : Sieve analysis of sand samples

Mesh Size	Size (μm)	% of Sand retained				
		Dalia	Kuakata	Patgram	Bipinganj	Sylhet
6	3.35E03	0.83	Nil	1.55	0.88	0.42
12	1.70E03	3.88	0.03	4.53	3.30	0.65
30	600	29.88	0.01	32.75	23.08	3.44
40	425	26.44	0.01	25.47	15.32	11.53
70	212	29.32	0.66	27.88	29.93	59.96
140	106	7.30	84.46	5.60	20.03	21.50
200	75	0.86	12.34	0.85	3.25	1.26
270	53	0.97	2.47	0.70	2.13	0.65
Pan	Pan	0.52	0.02	0.67	2.09	0.60
AFS Grain Fineness No		40.78	107.06	38.61	59.46	60.53

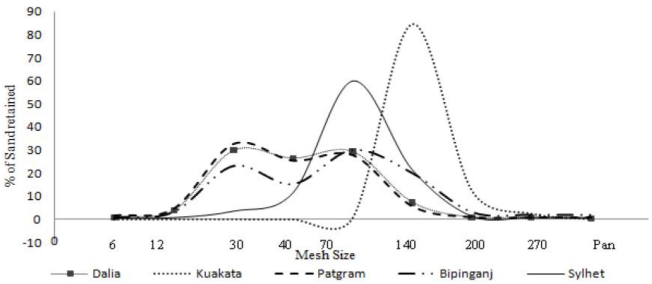

Figure 3 : Particle Size Distribution

served that Patgram sand is slightly moist (than TABLE 5) in winter. It may be necessary to dry it prior any further processing.

Phase identification

The x-ray diffraction patterns showed the presence of large amount of quartz-form of silica in the samples (Figure 4). The result shows samples of Bipinganj and Sylhet contain only quartz. The other three samples also

TABLE 5 : Sample Characterization

Sample	Moisture %	Density (g/cc)	Organic Material %	Sphericity
Dalia	0.49	2.58	0.39	0.83
Kuakata	0.98	2.90	0.63	0.838
Patgram	0.59	2.57	0.50	0.84
Bipinganj	0.58	2.60	0.07	0.859
Sylhet	0.78	2.69	0.55	0.86

understood from XRF result (TABLE 2), which shows presence of heavier materials in Kuakata sand. The density of the pure SiO_2 is in the range 2-2.3 g/cc and the density of pure quartz is 2.65 g/cc; cristobalite and tridymite have much lower densities because these two have comparatively open structures, whereas the atoms in quartz are more loosely packed[13]. The collected samples show slight deviation from the ideal value.

Organic matter

The percentage of organic content is listed in TABLE 5. The result shows presence of negligible amount of organic matter in all five samples. The highest content of only 0.07% was found in Bipinganj sand; this minor percentage may be from the dry leaves' particle mixed in the sand. These results are in good agreement with the results of thermal analysis.

Roundness and sphericity

Though the five samples were collected from different locations the sphericity measurement shows (TABLE 5) similar values. This indicates that the samples have gone through similar amount of erosion.

Moisture

TABLE 5 shows that all five samples contain negligible amount of moisture, which reduce the necessity of drying the sand prior beneficiation step. The result shows Dalia sand sample contains least amount of moisture whereas Kuakata sand contains the highest. It was observed

showed traces of phases other than silica. The unidentified peaks may be of feldspars' or other silicate minerals.

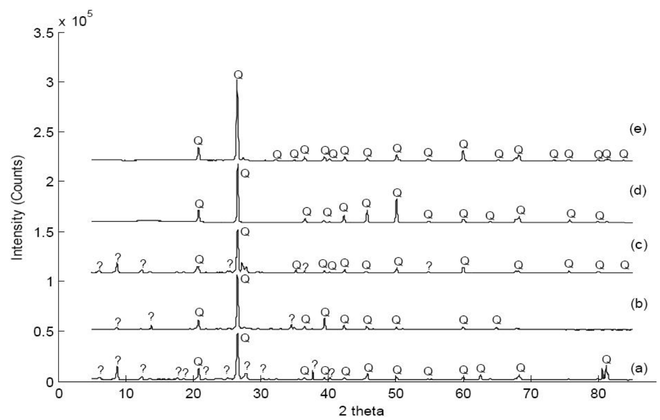

Figure 4 : X-Ray Diffraction patterns: (a) Dalia, (b) Kuakata, (c) Patgram, (d) Bipinganj and (e) Sylhet sand

Dependence on temperature

All five of the samples show peaks at ~ 573°C indicating a transformation. It is well-known that α-quartz transforms to β-quartz at that temperature[14].

In the patterns of Sylhet sand, there were two additional peaks at 450°C and 810°C (Figure 5). These peaks could be due to loss of combined water and/or carbon dioxide, change of polymorphic form, recombination of the elements into a different compound. To clearly identify the reason, the sample was heated at 580°C for an hour and DTA was performed again. This time other than peak at ~573°C no additional peaks were found (Figure 6), which confirms that there is only one change in polymorphic form of the samples under

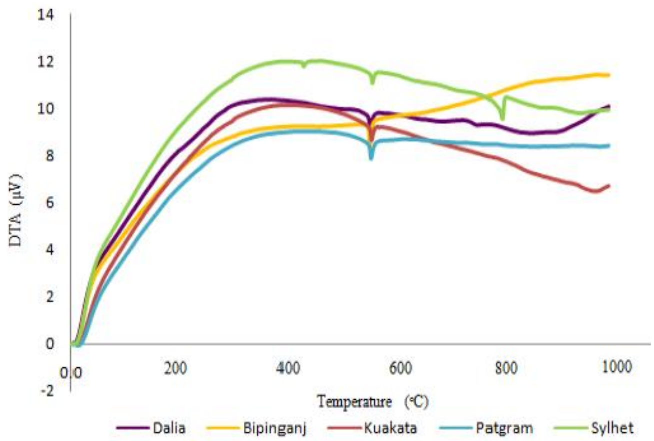

Figure 5 : Differential thermal analysis

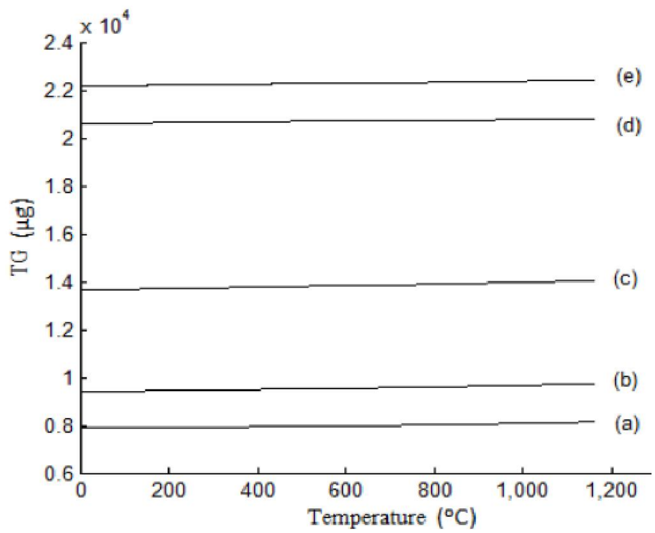

Figure 6 : Thermogravimetric analysis of (a) Sylhet, (b) Bipinganj, (c) Dalia, (d) Patgram and (e) Kuakata sand

investigation (i.e. from α-quartz to β-quartz).

CONCLUSIONS

This study shows that Bipinganj sand with about 97% quartz, low moisture content, negligible clay binder and least organic matter is the most serious contender for use for the production of silicon for high-tech application. Sylhet, Patgram and Dalia sands, with certain limitations, also have good potential. Kuakata sand has the least silica content. Studies may be undertaken to further upgrade the samples from Bipinganj, Sylhet, Dalia and Patgram.

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