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# Investigation on Physical and Chemical Characteration of Indian Sillimanite and Preparation of Aluminium - Silicon Master Alloy

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**Abstract:** In this study the results of physical and chemical characterizasition studies of sillimanite are presented. Sillimanite was collected from the area Manavalakurichi. Sillimanite is brownish in color and has a specific gravity of 3.21 with bulk density 2.14 gm/cc. It is conchoidal in nature and has a surface area of 0.12 $m^2$/gram. Particle size of the sillimanite falls between 90-250 µ. In order to check the quality, microscopic and X-ray diffraction analyses were done. The microscopic study revealed sillimanite properties under polarized light and crossed nicol prism. X-ray diffraction pattern showed all the characteristic peaks of Sillimanite. Carbothermic reduction using vaccuum induction furnace produced aluminum - silicon alloy. X-ray diffraction pattern of alloys confirmed the major peaks Si and Al. Micro morphological studies of sillimanite grains were studied by SEM. Chemical composition of sillimanite was found out by chemical analysis.

**Key words:** Sillimanite characterization % Alloy % XRD % SEM % EDAX

## INTRODUCTION

Sillimanite both in the form of rock and granular form has been considered as the excellent raw material only for refractory lining applications worldwide. More than 95% of the world production of sillimanite is consumed in the manufacture of heavy duty alumina rich high temperature brick lining and the balance quantity is used in non refractory areas. Apart from its application in the refractory lining, sillimanite has never been seriously considered for its exploitation as the raw material for aluminium or silicon metal recovery. Aluminium-Silicon master alloys are extensively used in automobile industries.

The term 'sillimanite minerals' has become firmly entrenched in the industrial minerals trade in the Anglo-Saxon part of the world as representing all three natural polymorphs. This is mainly because the refractory raw-material imported from India in the early years of the refractory industry was sillimanite. In a similar way, kyanite minerals have become the common name for the group in the USA whereas andalusite appears to be often used in a similar group sense in Russia and the former Soviet republics [1]. Sillimanite minerals comprising sillimanite and alusite and kyanite are naturally occurring anhydrous aluminium-silicate polymorphs with the chemical formula $Al_2SiO_5$. They are all common rock-forming minerals differing somewhat in crystallographic characteristics and thereby in physical properties. The industrial use of sillimanite minerals is especially related to their unique chemical composition, stability at high temperatures and transformation to mullite-rich aggregates utilised as refractory material. In this paper important results of the physical and chemical characterization and alloy preparation from sillimanite are presented.

## MATERIALS AND MATHODS

The dried samples were sieved using a +GF+ DIN 4188 sieve shaker for 15 minutes at half Phi interval [2]. For XRD analysis, the sillimanite grains were powdered and the powdered samples were subjected to X-ray diffraction with scan angle (2s) ranging from 10° to 80°, to understand the homogeneity of the substances following the procedure of Pryor and Hester [3]. Jeol-JSM 5600 LV Scanning Electron Microscop was used in the studies of sillimanite samples in order to understand mineral alteration and micro morphology. Preliminary experiments were carried out for the

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preparation of Al-Si alloy by the reduction of sillimanite with coal. Sillimanite mixed with equal quantity of leco char by weight was placed in a graphite crucible and heated gradually in an atmosphere of argon gas.

## RESULTS AND DISCUSSION

**Physical Characterization:** Sillimanite is brownish in colour with specific gravity 3.21. It is conchoidal, breaks across elongation with bulk density 2.14 gm/cc and surface area 0.12 m$^2$/gram.

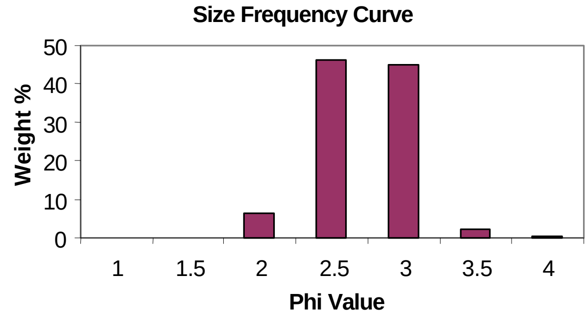
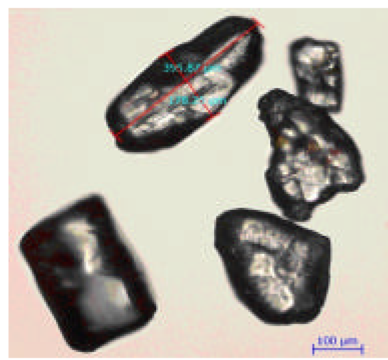
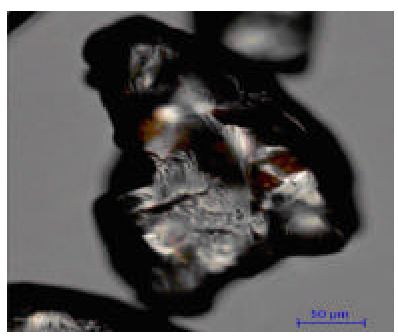



Fig. 1: Bar diagram of sillimanite

(a) Angular,brittle,euhedral and sub-rounded silliminite grains



(b) Elongated, subhedral, sub-rounded and broken sillimanite



(c) Zoomed broken Sillimanite polarized

Fig. 2: Microscopic studies of sillimanite

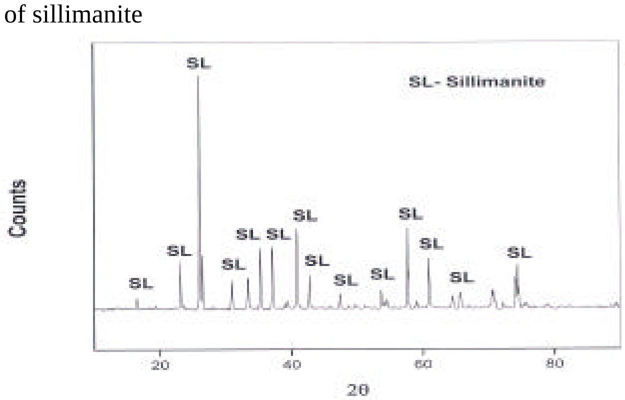
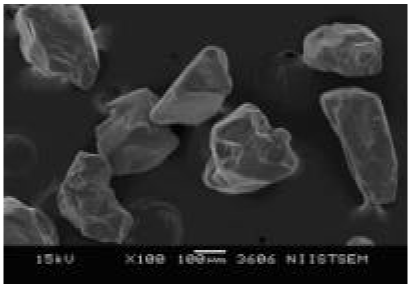
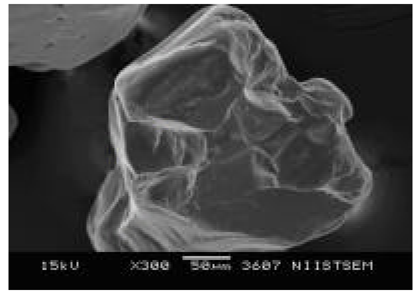


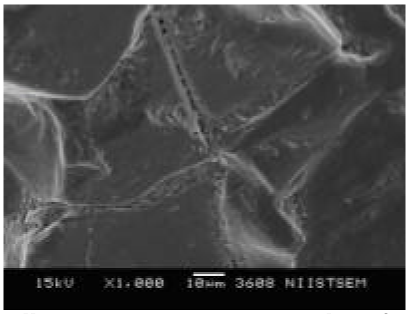

Fig. 3: X.R.D pattern of sillimanite



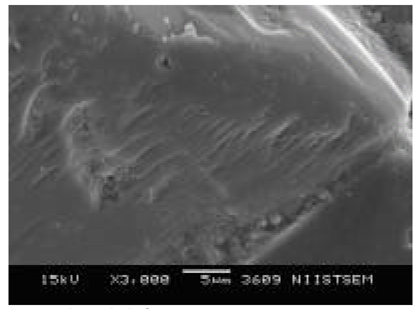

(a) Angular to sub rounded sillimanite



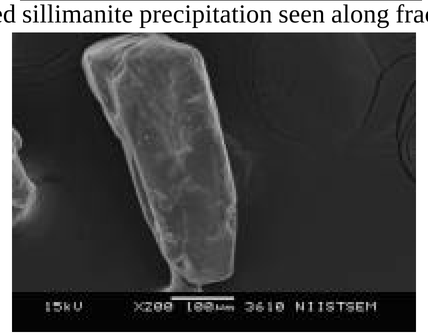

(b) Irregular grain showing angular edges



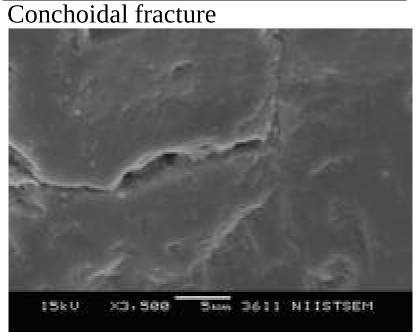

(c) Fractured sillimanite precipitation seen along fracture.




(d) Conchoidal fracture

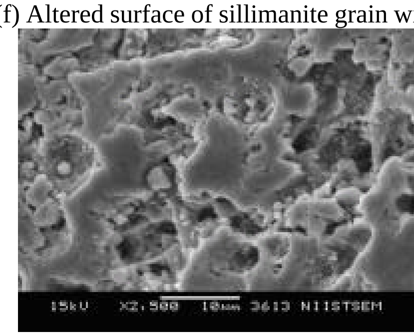



(e) Elongated sillimanite with etch'V's and pits

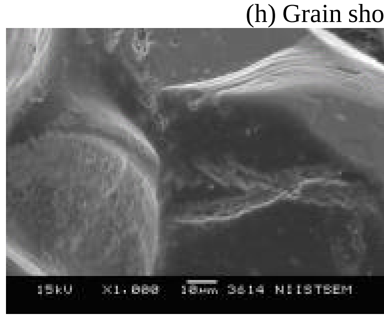



(f) Altered surface of sillimanite grain with fracture.


(g) sillimanite




(h) Grain showing altered surface.




(i) Conchoidal fractured and weathered surface.

Fig. 4: SEM studies

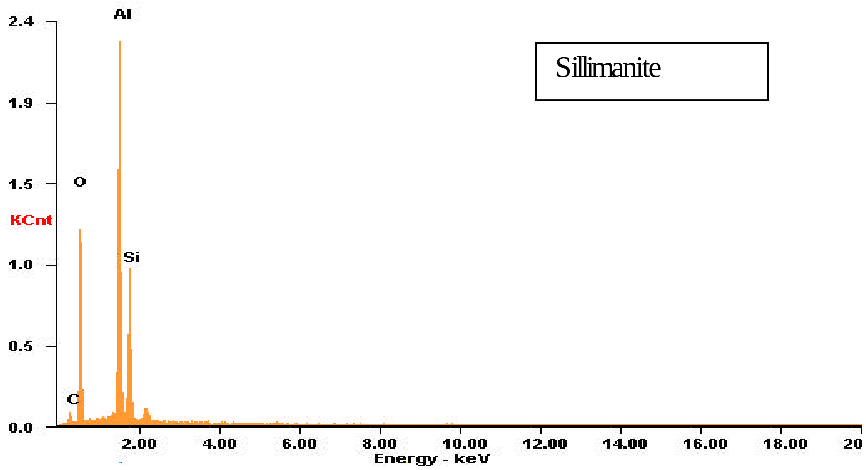



Fig. 5: Spectral results of Sillimanite from EDAX

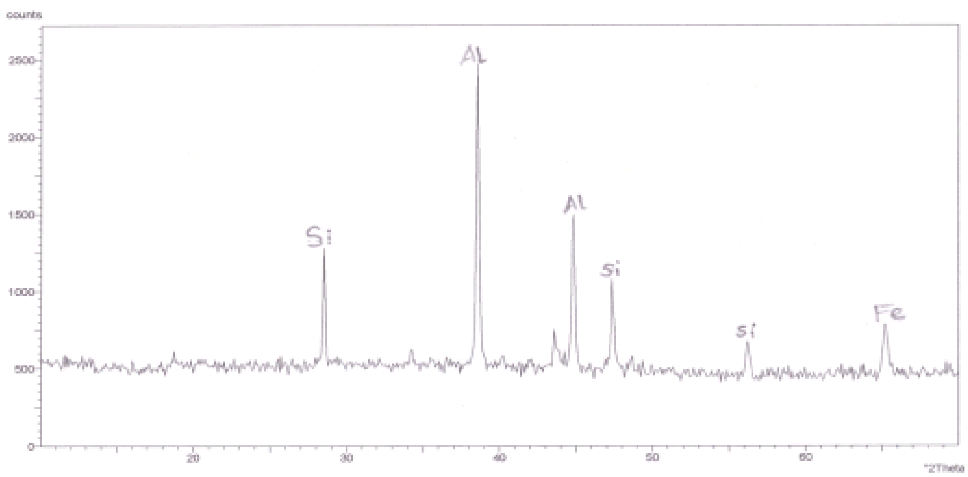



Fig. 6: X-ray diffraction pattern of the alloy

Bar diagram of sillimanite shows unimodal in nature with major quantity at 2.5 and 3 M size under finer fraction.

This study gives important details like structure, fracture, inclusion, size and shape of the individual grains. This type of study will be of good value in mineral processing.

X-ray diffraction pattern of sillimanite shows all major peaks of sillimanite.

**Characterization:** The sillimanite shows a value of 60.12 % $Al_2O_3$ and 37.20 % $SiO_2$. Micro morphological studies of sillimanite grains by SEM show angular to sub-rounded shapes and irregular grains showing angular edges are also observed (Fig. 4 a,b). Fractured sillimanite grains are observed (Fig. 4 c,d) due to the process of collision of particles under wave action in the tidal zone [4].

The development of a number of features like mechanical and chemical pits, etch-Vs and altered surface of sillimanite grain is shown in (Fig. 4 e, f). Sillimanite grains of chemically and mechanical hit fractured features are also observed (Fig. 4 g, h). Conchoidal fractures and weathered surfaces are also observed (Fig. 4 i).

EDAX analysis shows that there is slight change in Al and Si contents with respect to various fractions of sillimanite. The sillimanite shows a value of 35.57 % Al and 19.73 % Si by weight.

**Al-Si Alloy Preparation and X.R.D:** The alloy composition shows a value of 65.07% Al, 23.16 % Si and 9.9 % Fe by weight. Alloy composition very close to theoretical is observed feasible by cabothermic reduction using vacuum induction furnace.

Alloy nodules were physically separated from the reduction mixture and analyzed by chemical analysis and X-ray diffraction pattern.

## CONCLUSION

Majority of bulk sillimanite falls under finer fraction. The result of the sieve analysis of the mineral showed that 90% of the bulk of the sample was in the range of 80-120 ASTM size. X-ray diffraction pattern of sillimanite showed all the peaks of sillimanite. Micro morphological studies of sillimanite grains by SEM showed the development of a number of features like mechanical and chemical pits. Carbothermic reduction using vaccum induction furnace produced aluminum silicon alloy with 23% silicon and 65% aluminum. X-ray diffraction pattern of alloy showed major peaks of Si and Al.

## ACKNOWLEDGMENT

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