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Disposal of metal fragments released during polycrystalline slicing by multi-wire saw

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ABSTRACT

The environmental and economic impacts linked with solar systems are largely based on discharges of slurry generated during the various stages of sawing and cutting ingots. These discharges into the environment are subject to the general regulations on hazardous and special industrial waste disposal. Therefore, they should not be abandoned or burned in open air. The cutting of Silicon ingots leads to the production of Silicon wafers additional costs, losing more than 30% of Silicon material. Abrasive grains (Silicon Carbide) trapped between the wire and the block of Silicon need to be removed by various mechanisms to be later evacuated by slurry fragments. In the interest of decreasing operational costs during polycrystalline ingot slicing at Semiconductors Research Center, and, avoid environmental problems; it is necessary to recover the solar grade Silicon from the Silicon sawing waste. For this reason, the removal of metal fragments has become a preliminary requirement to regenerate the slurry; in addition, the solid phase needs to be separated from the liquid phase after the dissolution PEG with the solvent. In the present study, magnetic separation and centrifugation methods were adopted for metals removal, followed by the analysis of some operating parameters such as: washing time, pH, and initial concentration of Silicon. Finally, analytical, morphological and basic methods were performed in order to evaluate the efficiency of the process undertaken.

1. Introduction

The worldwide energy production of solar cells had increased to 2.6 GW in 2006 [1] and has been growing continuously in recent years, During monocrystalline silicon wafer manufacturing, 30 wt% of silicon goes into slurry waste due to kerf loss during this processing [2–4]. Consisted of fine silicon particles, silicon carbide (SiC) particles, metal impurities from cutting wire, lubricating oil (poly-ethylene glycol), and the additives for better particle suspension [5].

In order to amortize the cost of silicon and preserving the environment, it is necessary to remove metal fragments to regenerate the slurry. The kerf loss slurry waste has recently attracted attention on the separation of the components due to the high purity silicon material [6].

In 2008, a novel approach for recycling of kerf loss silicon from cutting slurry waste for solar cell application [7–10]. After one year, Tzu-Hsuan and Jui-Hsiung began a research project by metal removal from silicon sawing waste using the electrokinetic method [11]. Tzu-hsuan [12], applied electrophoresis and gravitational settling.

In this paper, we report a novel approach to eliminate the fragment metals from the slurry by wet magnetic separation.

2. Materials and methods

2.1. Preparation of slurry/solvent mixtures

The effect of solvent type on PEG removal from waste slurry was studied by using distilled water or acetone at varying w/v concentrations (Table 1). The washing procedure followed is illustrated in Fig. 1.

The kerf slurry waste was obtained from Research Center in Semiconductors for Energetics (CRTSE). The composition of the slurry waste was determined by measuring the weight of cutting. The lubricating oil (poly-ethylene glycol) of the slurry was washed

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Table 1
Composition of the solvents applied in this work.

Solvent	%w/v				
Distilled water	1.00	1.25	1.00	1.75	2.00
Acetone	1.00	1.25	1.50	1.75	2.00

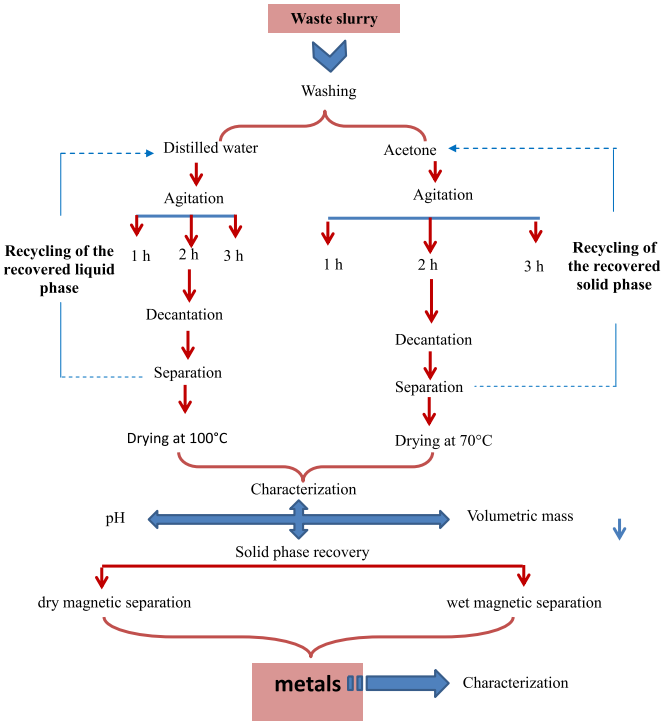

Fig. 1. Schematic diagram of the washing procedure and characterization.

off by acetone and further by spent acetone; this latter was then dissolved. After the cutting oil was removed, the residual material is Si and SiC. The mixture was stirred and evaporated at 800 in vacuum oven until dry; the dried mass was pulverized and sieved (50–150 μm). All the samples were stored in a desiccator over silica gel till further use.

3. Results and discussion

3.1. Liquid phase extraction

3.1.1. pH variation

Fig. 2 shows the pH variation of the three liquid phases occurred during the slurry washing procedure (recycled acetone, recycled distilled water and recovered liquid phase) as function of the treatment time, in a period of seven days. A sharp increase of the pH of the recycled liquid phase is observed only after the third day of treatment, after which is stabilized at a value similar to that of the washing acetone. As the results indicate, the influence of pH for lubricating oil extraction was negligible. The pH of the recycled distilled water remains unchanged in the time-frame of the experiment (Fig. 3).

3.1.2. PEG volumetric mass variation

A sharp increase of the PEG volumetric mass is observed in the case of the recovered acetone, due to PEG dissolution in the organic matrix. On the contrary the PEG content in the distilled water and/or liquid phase remains unchanged. The stabilization of PEG volumetric mass after the sixth day of treatment is attributed probably to the saturation of the recovered acetone with PEG.

3.2. Recovery of the solid phase

The solid phase was obtained in powder form, as shown in Fig. 4b. Thereafter, solid was immersed in acetone at a ratio of 1/1 weight and agitated continuously for 1 h at room temperature. Finally, three different methods of separation were implemented:

- Wet magnetic separation;
- Dry magnetic separation;
- Centrifugation.

4. Wet magnetic separation

The liquid phase recovered during the wet magnetic separation was filtered and the residue was analyzed by X-ray diffraction. Fig. 5 shows the X-ray crystallographic diagram of the solid phase obtained.

This diagram shows:

- The presence of SiC;
- The presence of Si;
- The absence of metals.

These results show that metals were retained in the second liquid phase obtained from the separation it confirms the previous results.

5. Dry magnetic separation

After placing a quantity of the powder in the magnetic separator to dry by means of an electromagnetic field, a negligible

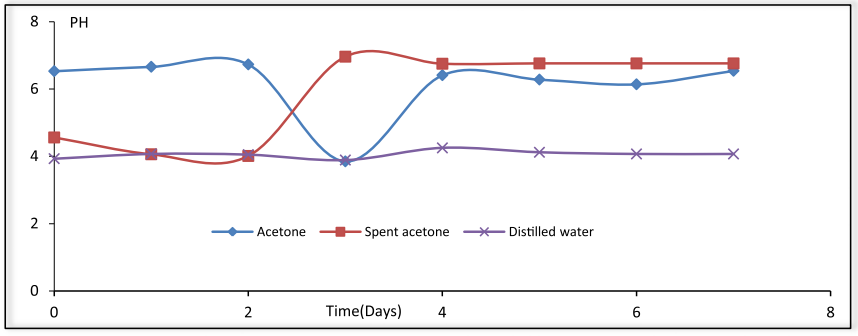

Fig. 2. Change of the pH of the recovered liquid phase, the recovered acetone and recovered distilled water with treatment time.