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Preparation and properties of colloidal nanosize silica dioxide for polishing of monocrystalline silicon wafers*

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Colloidal silica can be used for final general metallographic polishing. It is used to polish silicon single crystals for electronic applications and, subsequently, polycrystalline silicon for solar cells, gallium arsenide, indium phosphide, titanium, gadolinium, gallium garnet and sapphire. The silica dioxide is dispersed in water with alkaline compound added to obtain the desired pH.

Key words: *colloidal silica, metallographic polishing, silicon*

1. Introduction

Colloidal silica [1−3] can be used to polish most metals, alloys, minerals, ceramics and composites. It can also be used after one or two diamond polishing steps or after using alumina slurry. Colloidal silica, also referred to as a sol, contains very fine particles (1–300 nm in diameter) that remain in suspension over a long period of time (several years). In colloidal silica, the particles are amorphous rather than crystalline, and they have a negative electrical charge. The particles are nearly insoluble in the dispersing medium (distilled water). pH is the main factor influencing the stability of colloidal silica and, in addition, pH is the electrochemical factor, which plays a significant role in polishing semiconducting material slices.

The aim of the present work is to prepare colloidal nanosize silica dioxide used for final polishing of silicon wafers and to investigate their physicochemical properties.

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2. Experimental

Following chemical agents were used for synthesis of colloidal silica [3]: powder of silica dioxide or silica gel, potassium hydroxide (KOH) and distilled water. The preparation technique of colloidal silica sol consists of the following stages: mixing initial components, centrifuging the mixture obtained and control of parameters. Stable sol is centrifuged in order to remove large particles of silica dioxide and technological impurities, which can have negative effect on the process of polishing the silicon wafers. Centrifuge of the OC-6M type was used for purification at 2000−2500 rpms during a 15 minute time interval. Control of pH of the synthesized sols was carried out in the laboratory by pH-meter − millivoltmeter pH-121. Areometers were used to determine the density of colloidal silica. Rotary viscosimeter (PEOTECT RV 2.1) was used to determine the viscosity of suspension. Observation of the shapes of the silica particles was conducted by examining the samples with scanning electron microscopy (SEM, JSM-50 A (JEOL, Japan)).

3. Results and discussion

Amorphous silica particles in the colloidal silica dispersions are in closed spherical shape. Figure 1 shows a SEM view of amorphous silica particles in sol. The differences in particle sizes, as it is visible in Fig. 1, are 300 nm and less.

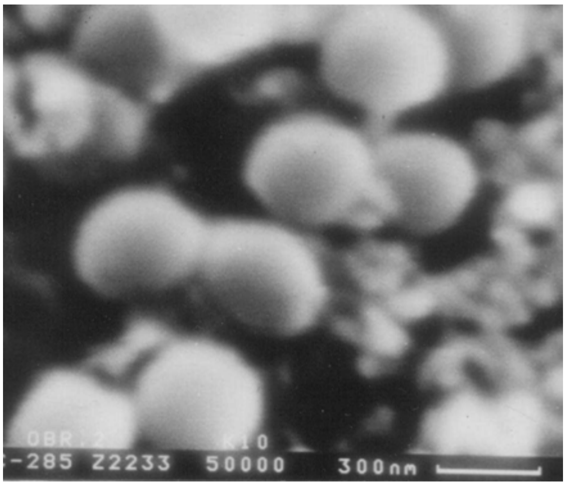

Fig. 1. SEM picture of colloidal silica dioxide

The hydroxide of potassium and silica particles were added to water, so that the pH of the synthesized colloidal silica was at least 10.5−11.0. Dependence of the colloidal silica dioxide sedimentation stability on pH is described in [4] and is shown in Fig. 2.

The colloidal silica dioxide flocculates between pH 4 and pH 8, approximately at pH = 6. In our case, the particles of silica sols did not flocculate. Negative charge accumulated on the surface of the colloidal silica particles in the basic conditions and the particles were repulsed from each other.

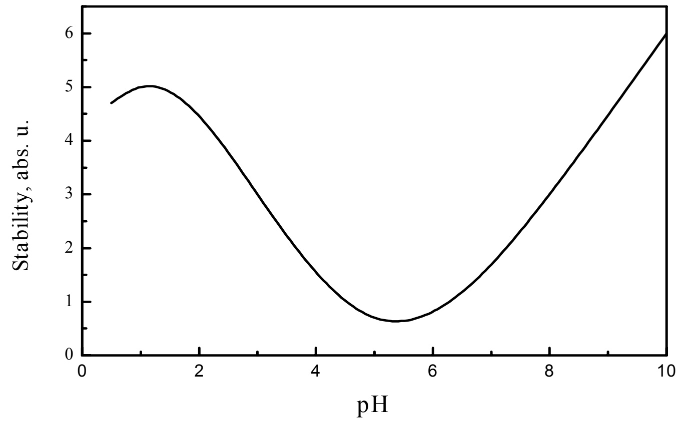

Fig. 2. Effect of pH on sedimentation stability of colloidal silica

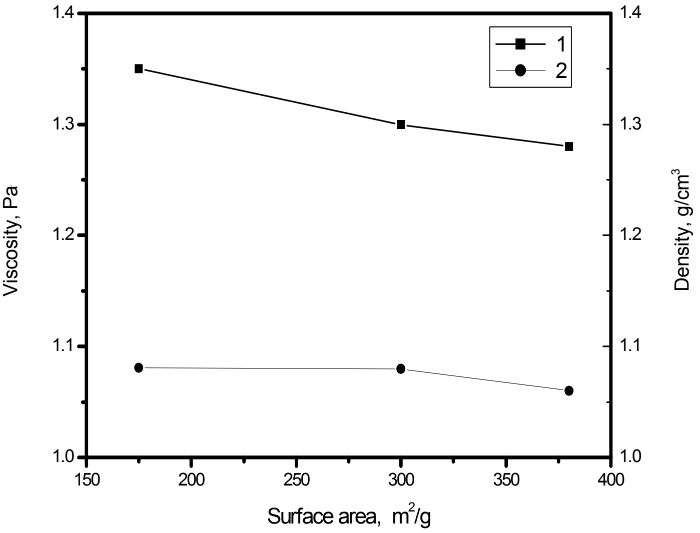

Fig. 3. Relation of viscosity and density of colloidal silica sol to specific surface area of particles silica dioxide: 1 – viscosity of silica sols, 2 – density of colloidal silica

Even though the maximum sedimentation stability is reached at basic values of pH, the stability begins to decrease when the pH level exceeds 11. Temperature also influences the sedimentation stability of colloidal silica dioxide. The colloidal silica dioxide congeals at the temperature below 6 ºC. If the suspension is frozen, it becomes less dense in the upper layer of a vessel and more dense at the bottom. The dependence of the viscosity of the suspensions obtained on the specific surface of the particles is shown in Fig. 3.

Density and viscosity of the colloidal silica dioxide particles decrease with the increase of the specific surface of the SiO_2 particles. Thus, the viscosity of synthesized suspensions increases with reduction of the specific surface of the silica dioxide particles and the increase in their size. It has been established that centrifugation of the identical quantity of silica oxide dispersed in water (a suspension with higher specific surface of the particles) leads to precipitation of the large part of the silica dioxide.

4. Conclusion

Amorphous silica particles in the colloidal silica dispersions are nearly spherical in shape. The density and viscosity of the colloidal silica dioxide obtained decreases with the increasing specific surface of SiO_2 particles. The hydroxide of potassium is added to colloidal silica, so that pH of the synthesized sols is at least 10.5−11.0.

The synthesized colloidal nanosize silica dioxide can be used for final polishing of silicon wafers.

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