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Development of a new porous pin chuck for lithography

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Abstract

The feature size for next-generation devices is decreasing and edge exclusion widths are becoming stricter, decreasing from 2 to 1.5 mm. The development of a new porous pin chuck is thus necessary for flattening large wafers, including the periphery, which has small and extremely low pins. A reverse production process from the conventional method was adopted to form pins after careful polishing of the chuck surface. It is now possible to both measure and achieve a high level of flatness for pin chucks, while reducing vacuum leakage. Average pin heights were 33 μm in the suction region and 5 μm in the static-pressure seal. The uniformity of pin heights in the seal was improved compared with the conventional static-pressure-seal pin chuck. In addition, the contact ratio between the back surface of a wafer and the pin tops was reduced to 25% that of conventional static-pressure-seal pin chucks by using pins with smaller diameters and porous material.

Keywords: Vacuum pin chuck; Wafer flatness; Porous material; Alumina ceramic; Porous pin chuck; Contact ratio; Static-pressure seal

1. Introduction

The decrease in the feature size of next-generation devices to 45 nm will require a decrease in the depth of focus for lithographic processes and an improvement in the flatness of large wafers. Edge exclusion widths will become stricter, decreasing from 2 to 1.5 mm [1]. To address these challenges, a new static-pressure-seal porous pin chuck was designed [2]. This newly devised chuck is capable of overcoming the degradation in vacuum pressure that occurs with conventional static-pressure-seal pin chucks. Compared to extant ring-seal-type pin chucks, there is less degradation in the flatness around the periphery of the new chuck. This degradation occurs because ring seals with a large contact area per unit area are usually machined to be higher than the pin tops [3].

Conventional static-pressure-seal pin chucks have the additional disadvantages of large leakage from the static-pressure seals and it is difficult to effectively polish the pin tops to high flatness because accurate flatness measurements with interferometry are not possible given the low intensity of the light reflected from small pin tops.

This paper describes the advantages of the new porous pin chuck and clarifies the method employed for measuring the pin height in porous material after machining. In addition, measurements of polished chuck flatness before pin formation, pin heights in the static-pressure seal and the suction region, and the contact ratios between the back surface of a wafer and the pin tops, are presented and the leakage associated with static-pressure seals is elucidated.

2. Structure of the new porous pin chuck and the new production process

2.1. Structure of the new porous pin chuck

Fig. 1 is a schematic diagram of the new porous pin chuck. The pin has a diameter of 180 μm and pin heights of 20 μm in the suction region and 3 μm in the seal, and

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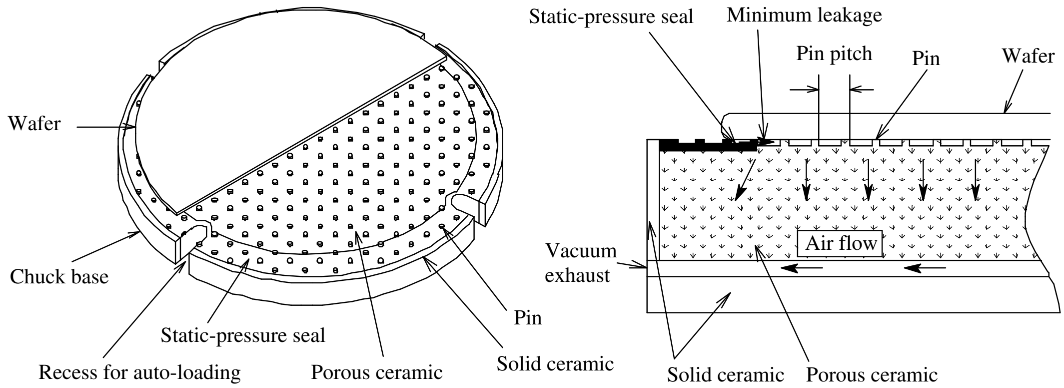

Fig. 1. Schematic diagram of the new porous pin chuck.

the pin pitch is 1 mm. The outer diameter of the static-pressure seal is a several millimeters larger than that of a wafer, the size of which is such that wafer diameter error and positioning error due to auto-loading are accounted for, with an inner diameter that is 2 mm smaller than that of the wafer. In addition, the periphery of the chuck has four recesses along its circumference to accommodate the loading arms. Very low pins are formed in the seal and in the suction region by sandblasting. Since vacuum flow resistance is not increased by air flowing vertically through the porous ceramic material, the pin heights in the suction region are as little as one tenth those of conventional static-pressure-seal pin chucks (Fig. 1; right). Moreover, pin heights in the seal are machined to be considerably lower than that in the suction region. If the pin is even slightly higher than the size of a dust particle, then it is possible that dust will move between the pins. Since low pins decrease the machining time, the masks on the top of the pins are not removed from the surface during sandblasting.

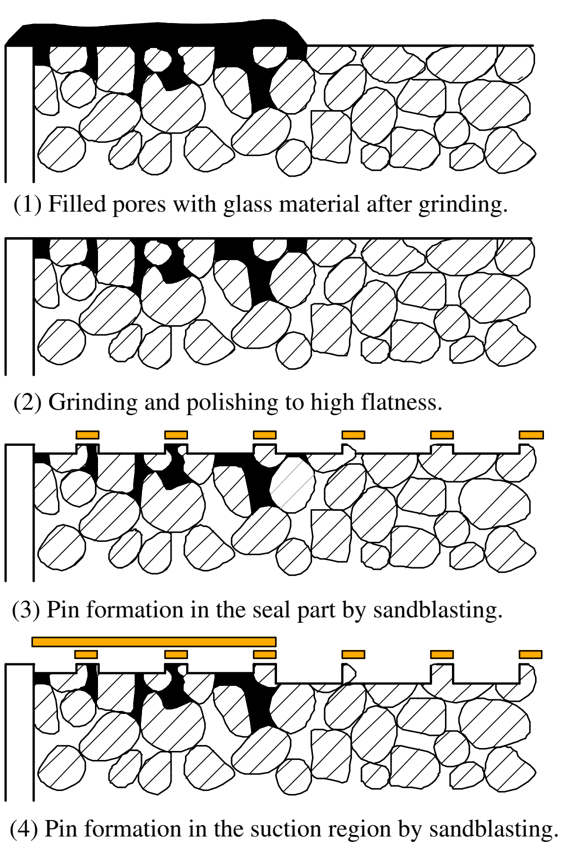

Fig. 2. New production process of the new porous pin chuck.

2.2. New production process

Fig. 2 shows the production process of the new porous pin chuck. Briefly, (1) after grinding the surface of the porous material, the glass material is applied to a suitable thickness and is melted to fill the pores. (2) After grinding to remove the extra glass material from the seal, the entire chuck surface is highly polished, and the flatness is accurately measured by interferometry. (3) After masking all of the intended pin tops, the entire chuck surface is sandblasted for a very short time until the pin heights in the seal reach a specified value. (4) Finally, the seal is covered with a mask and the pins in the suction region are re-machined for a short time to a specified height. Thus, by employing a process in which the pins are formed after the porous chuck surface is polished to high flatness, a highly accurate chuck surface can be machined with relative ease.

3. Pin characteristics formed by sandblasting

3.1. Polished surface before pin formation

Fig. 3 shows the polished chuck surface, which contains porous alumina ceramic material with a grain size of #220 before sandblasting. The flatness of the 300 mm diameter chuck is 0.36λ, or approximately 0.2 µm (Fig. 3a). The average roughness Ry of the ceramic grain and the glass material within the seal (Fig. 3b) is 40 nm and 50 nm, respectively (see Fig. 3c and d). The distinct narrow grooves observed on both surfaces are scratches made by diamond grains during polishing. In addition, the glass surface in the seal has numerous depressions and peelings. The