ELECTROSTATIC CLAMP MANUFACTURED BY NOVEL METHOD

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ELECTROSTATIC CLAMPS (ESCS), USED IN RETICLE AND WAFER HANDLING, ARE PRESENTLY MANUFACTURED USING GLASS BONDING AND POLISHING TECHNOLOGIES. WE PRESENT A PATENTED ALTERNATIVE CONCEPT TO THIS PROCESS, RELYING ON COATING AND ETCHING PROCESSES RATHER THAN BONDING. WE MANUFACTURED A FIRST PROTOTYPE CLAMP BASED ON A SILICON-ON-INSULATOR WAFER. THE CLAMPING OPERATION WAS DEMONSTRATED, AND THE CLAMP'S PERFORMANCE WAS CHARACTERIZED. CLAMPING FORCE, COATING QUALITY, AND ACHIEVED MORPHOLOGY ARE CHARACTERIZED AND UNDERSTOOD.

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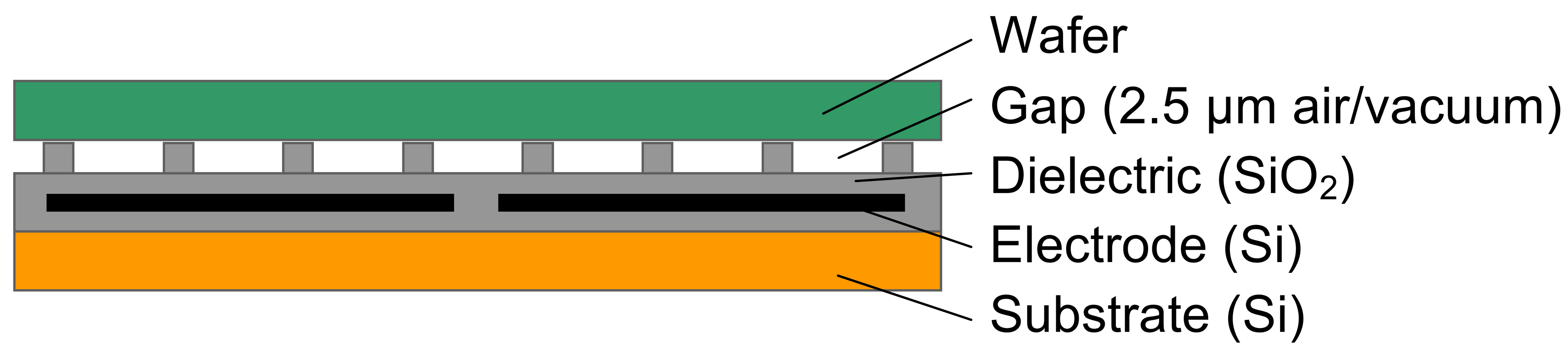

Figure 1: Electrostatic clamping. Applying a voltage to the electrodes charges them, resulting in a mirror charge on the wafer. These charges attract each other, and the wafer sticks to the clamp. It is released by switching off the voltage.

Electrostatic clamps operate by applying a voltage to electrodes buried in an insulator, as shown in Figure 1. The resulting charges and counter charges attract each other, causing the wafer to stick to the clamp. The operating principle of our prototype is not different from that of any other electrostatic clamp.

The use of coating technology to manufacture this clamp enables thinner dielectric layers (down to 2 μm in the prototype), reducing the operating voltages required. The sensitivity to particles on the backside of the wafer is minimized by creating a 2.5 μm high protrusion pattern on the clamp. The expected clamp pressure for this configuration is 1 bar at 450 V applied voltage.

The production process of our prototype was expedited by choosing a commercially available 100 mm silicon-on-insulator (SOI) wafer as starting point. This has the advantage that backside insulation and electrode material do not have to be deposited. All subsequent production steps were carried out using standard semiconductor processing equipment. From the top Si layer, the electrode pattern was lithographically defined and etched out by a plasma process with a 0.5 μm SiO_2 mask layer. A 2 μm SiO_2 layer was then grown thermally, after which another 2 μm was deposited by PECVD. From the total 4.5 μm SiO_2 layer, 2.5 μm was etched away in a lithographically defined pattern to create the gap. The end result is shown in Figure 2.

The pertinent electric properties of the SiO_2 insulator layer were measured on a test coating. The dielectric strength was measured to be around 700 V/μm, regardless of oxide growth method. Putting the voltage of 450 V entirely across the 2 μm insulator layer would result in 225 V/μm, 3 times less than the breakdown voltage. The oxide resistivity was estimated from leak current measurements to be in excess of $7e^{16}$ Ohm-cm.

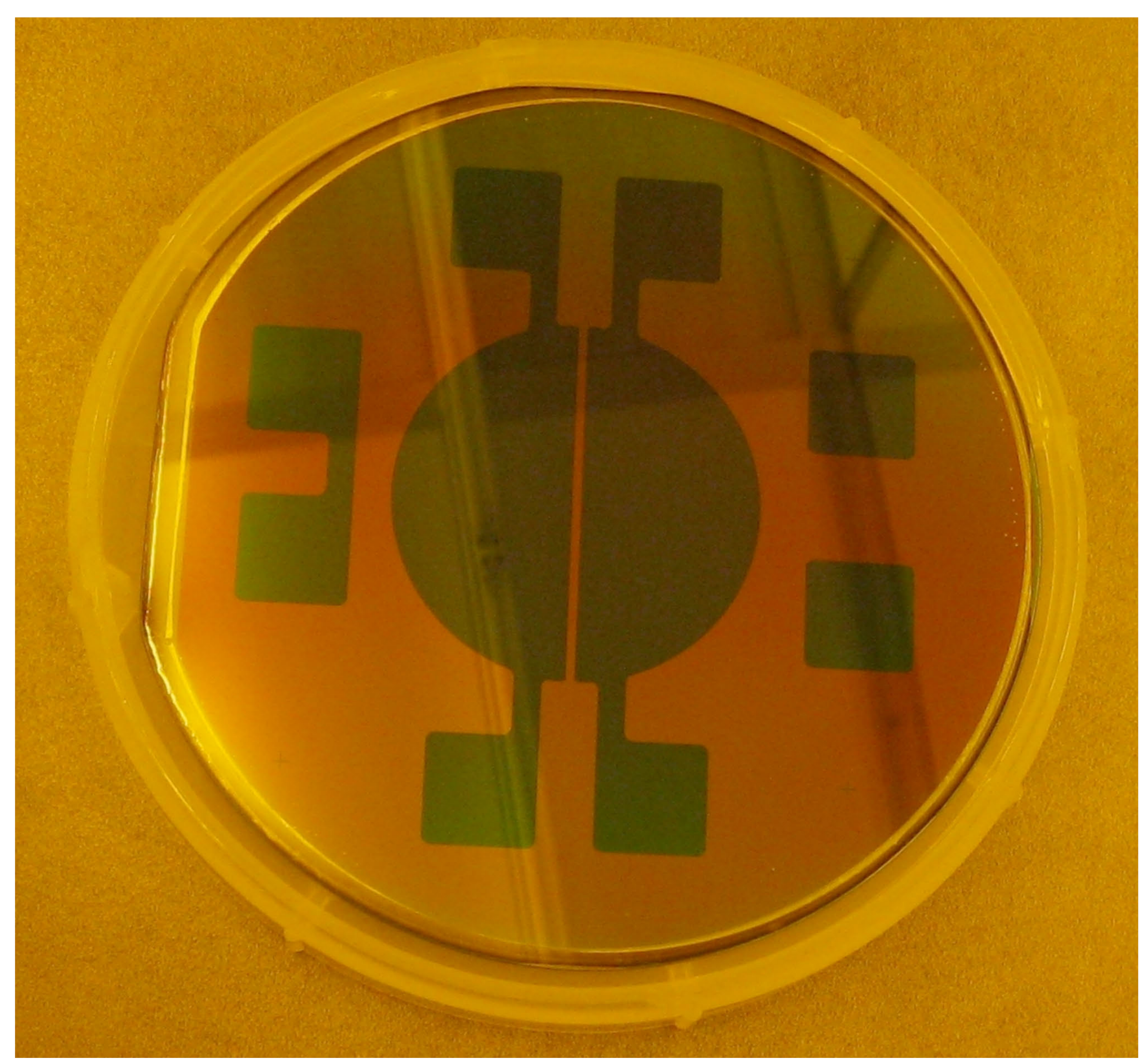

Figure 2: Electrostatic clamp prototype, with 20 mm radius semicircular electrodes and contact pads on the remainder of the wafer.

The finished clamp was mounted on a metal substrate, after which the surface of the clamp was characterized by profilometer. The radius of curvature was found to be 10 m, resulting in a 20 μm additional gap at the edge of the 40 mm diameter electrode area. After subtraction of the spherical fit, the profile across the electrodes is shown in Figure 3. The electrodes form plateaus of 10.5 μm high, corresponding to the height of the Si layer with its mask layer. The burl height was measured to be 2.5 $\pm$ 0.1 μm. Nonspherical figure variations were seen to be less than 500 nm in height.

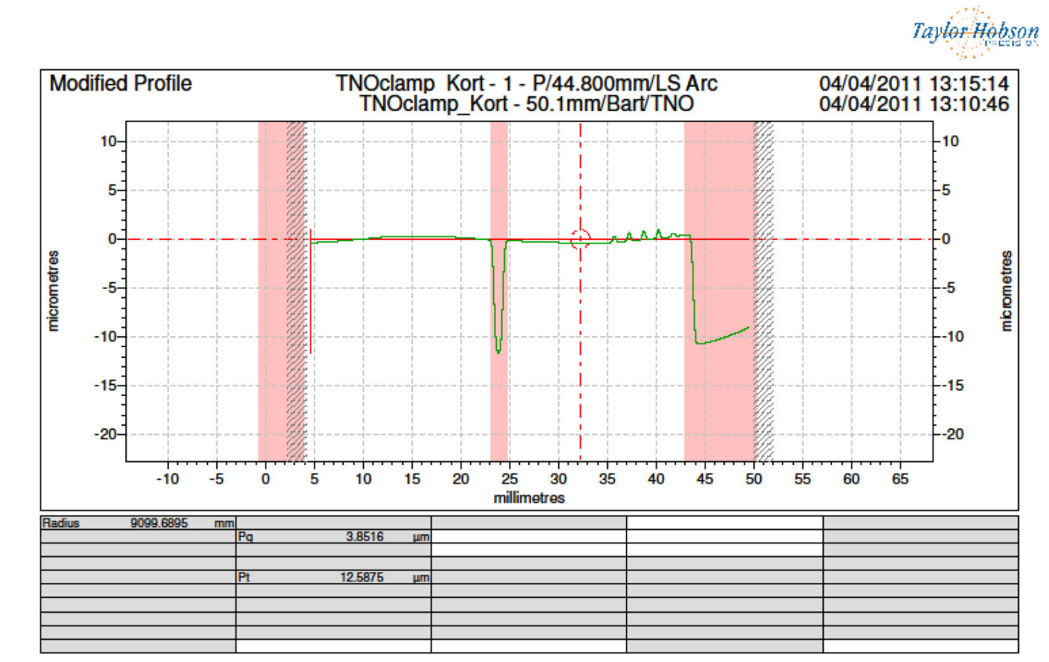

Figure 3: Profile measurement after subtraction of spherical shape.

The clamping functionality of the electrostatic clamp was assessed by measuring the force required to pull off a rigid counterelectrode. The results are shown in Figure 4; The correspondence to a parabolic fit is excellent. The clamp force at 200 V is 3.44 N; that for an ideally flat clamp would be 25.7 N. Correcting the theoretical prediction for the spherical shape of the clamp results in a predicted clamping force of 3.3 N, less than 5 % off the measured value.

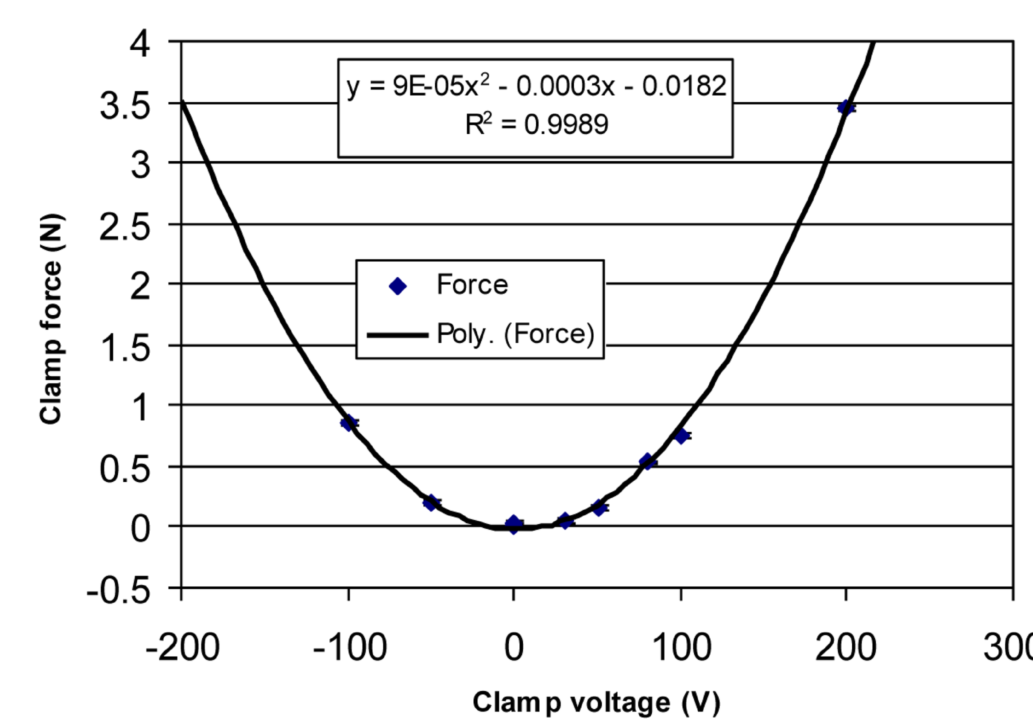

Figure 4: Clamp force measurement and parabolic fit.

We have fabricated a working prototype electrostatic clamp using nothing but standard lithographic technology. The lithographic process allows for maximum flexibility in clamp design. The quality of the materials obtained is such that the manufacturing process may be scaled up to the most demanding applications, such as high-volume lithography tools.