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MICRO-ELECTRO-MECHANICAL CHARGE SENSING DEVICES

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Plasmas are being widely used in the semiconductor industry for delineation of fine line pattern and deposition at low temperature. In recent years, it has been reported that plasma non uniformity across the wafer due to non-uniformities in RF current flow, electron current flow, and ion current flow can cause significant charging of surfaces, which can severely degrade or destroy devices, especially MOS gate dielectrics. In this work we report for the first time, a device which can *non-invasively* measure this charging *in-situ*, in real time, in the plasma reactor, as opposed to the conventional method of inferring the charge from later measurement of device degradation. The charging is measured *in-situ* by measuring the deflection of micro-cantilevers.

A microscopic cantilever made from a conducting material, suspended above, and electrically isolated from a conducting surface, can act as a charge-sensing structure. If an interaction with plasma or fluid were to add electrons or ions to the cantilever surface, the cantilever would become charged. The substrate would mirror that charge, resulting in an electric field between the cantilever and the surface below and hence causing deflection of the beam as shown in fig. 1. The charge on the cantilever can be calculated from the deflection. The deflection may be measured by the change in the angle of reflection of a laser beam probe. To increase the sensitivity, paddle structures were designed (fig.2). These structures are more sensitive to electrostatic force than cantilevers and also have larger reflecting area, so that deflection is easier to detect. Further a majority of the distortion occurs in the arms, with the pads being flat, so that most of the beam is deflected at a single angle. Various sizes of these structures were made so that each paddle detects a particular range of voltage.The devices were externally calibrated by observing the deflection in response to an applied electrical voltage (fig. 4).

Figures 5, 6 & 7 show the results of charging experiments in a parallel plate Reactive Ion Etcher (RIE) (fig.3). The laser beam covers several identical paddles so no focusing is necessary. The results clearly show the effect of power, pressure and flow rate of oxygen on the charging. To the best of our knowledge, this is the first time such real time, in-situ data with a non-invasive probe has been reported.

Cantilevers that deflect far enough to touch the substrate, generally suffer from "stiction", i.e. they remain stuck after the removal of the charge. This can be detected by inspection under an optical microscope after plasma exposure. Charging voltages inferred by this approach agree well with those measured directly in-situ. Thus our device can also be used to measure charging in reactors without optical ports, and to quickly map charging non-uniformities across a wafer surface. In addition to being useful as a charge sensing device for plasma processing, the device may be useful for general purpose sensing of surface charge.

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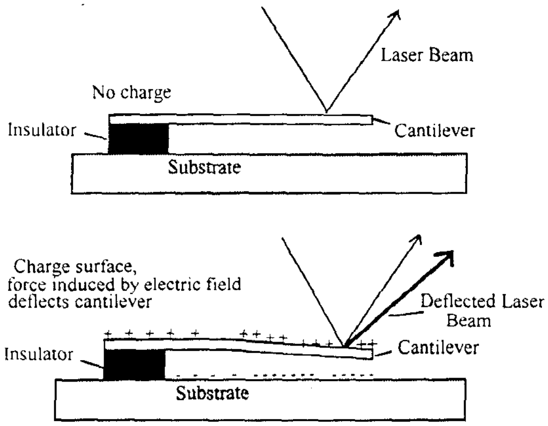

Figure 1. Microscopic Charge Sensing Structure

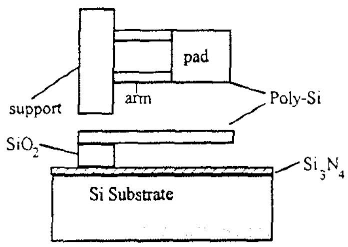

Figure 2. Top and side views of Paddle

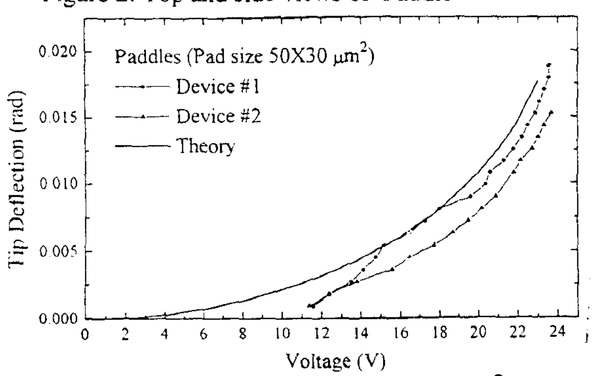

Figure 4. External Calibration of 50X30 μm^2 paddles

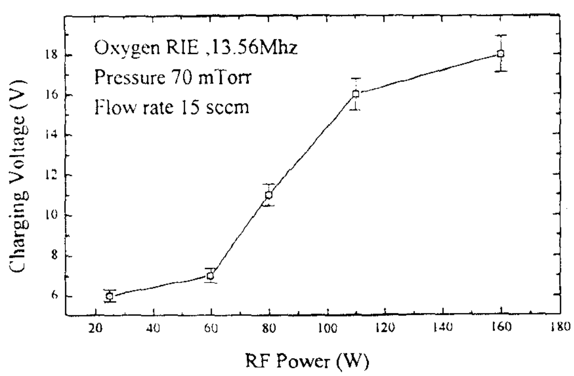

Figure 6. Charging Voltage in Oxygen Plasma as a function of input RF Power

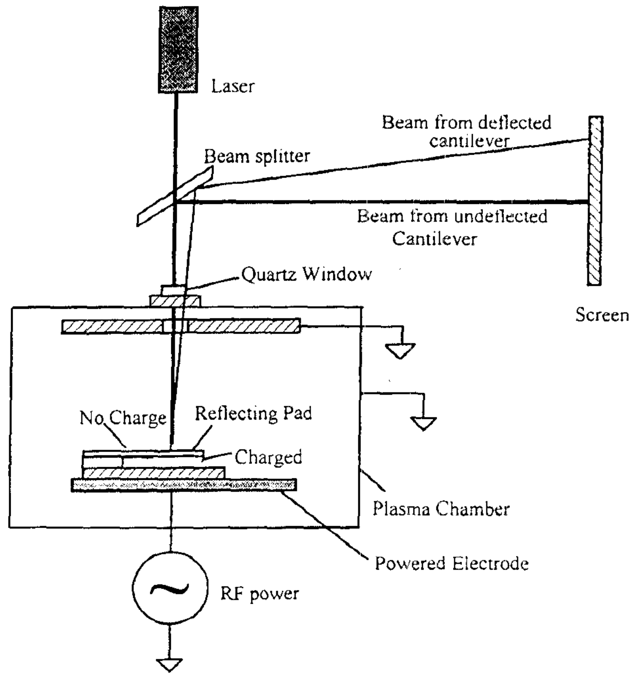

Figure 3. Experimental setup used to detect charge in plasma, showing reflected beam from charged & uncharged sensor

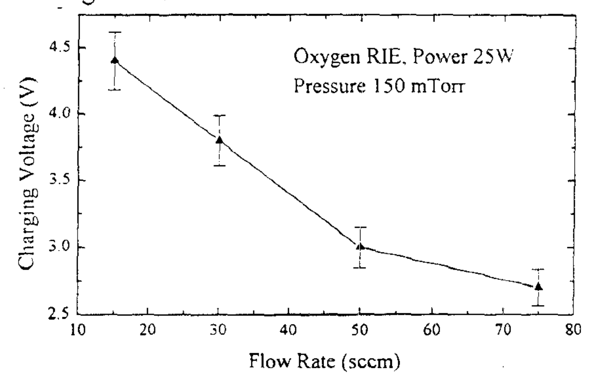

Figure 5. Charging Voltage in Oxygen Plasma as a function of flow rate of oxygen

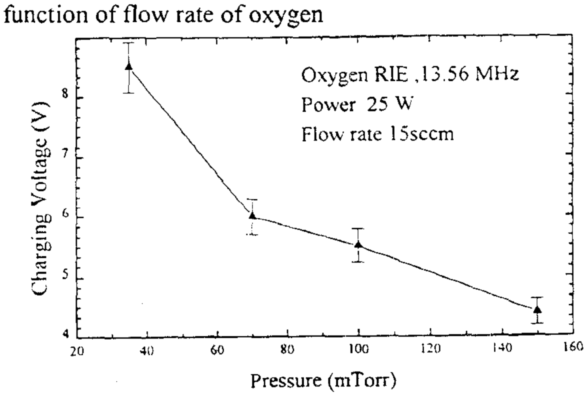

Figure 7. Charging Voltage in Oxygen Plasma as a function of chamber pressure