electrodes constitutes an electrostatic actuator array. An SOI wafer and a silicon wafer (see Figure 1) are used as the carrier and electrode wafers, respectively. After oxidation, both wafers are patterned and etched to define a corrugation profile and electrode array, respectively. The polysilicon layer is deposited on the SOI wafer. The carrier wafer is bonded to the electrode wafer by using evaporated indium bumps. The piston pressure of 4 kPa is applied at 156 °C in a vacuum chamber to provide hermetic sealing. The substrate of the SOI wafer is etched in a 25 weight percent TMAH bath at 80 °C. The exposed buried oxide is then removed by using 49 percent HF droplets after an oxygen plasma ashing. The SOI top silicon layer is etched away by using an SF_6 plasma to define the corrugation profile, followed by the HF droplet etching of the remaining oxide. The SF_6 plasma with a shadow mask selectively etches the polysilicon membrane, if the transferred membrane structure needs to be patterned. Electrostatic actuators with various electrode gaps have been fabricated by this transfer technique. The gap between the transferred membrane and electrode substrate is very uniform (±0.1 μm across a wafer diameter of 100 mm, provided by optimizing the bonding control). Figure 2 depicts the finished product.

This work was done by Eui-Hyeok Yang and Dean Wiberg of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.

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A Reactive-Ion Etch for Patterning Piezoelectric Thin Film

Gaseous mixtures BCl_3 and Cl_2 are highly selective for etching $PbZr_{1-x}Ti_xO_3$ films.

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Reactive-ion etching (RIE) under conditions described below has been found to be a suitable means for patterning piezoelectric thin films made from such materials as $PbZr_{1-x}Ti_xO_3$ or $Ba_xSr_{1-x}TiO_3$. In the original application for which this particular RIE process was developed, $PbZr_{1-x}Ti_xO_3$ films 0.5 μm thick are to be sandwiched between Pt electrode layers 0.1 μm thick and Ir electrode layers 0.1 μm thick to form piezoelectric capacitor structures. Such structures are typical of piezoelectric actuators in advanced microelectromechanical systems now under development or planned to be developed in the near future.

RIE of $PbZr_{1-x}Ti_xO_3$ is usually considered to involve two major subprocesses: an ion-assisted-etching reaction, and a sputtering subprocess that removes reactive byproducts. RIE is favored over other etching techniques because it offers a potential for a high degree of anisotropy, high-resolution pattern definition, and good process control. However, conventional RIE is not ideal for patterning $PbZr_{1-x}Ti_xO_3$ films at a thickness as great as that in the original intended application. In order to realize the potential benefits mentioned above, it is necessary to optimize process conditions — in particular, the composition of the etching gas and the values of such other process parameters as radio-frequency power, gas pressure, gas-flow rate, and duration of the process. Guidelines for determining optimum conditions can be obtained from experimental determination of etch rates as functions of these parameters.

Etch-gas mixtures of BCl_3 and Cl_2, some also including Ar, have been found to offer a high degree of selectivity as needed for patterning of $PbZr_{1-x}Ti_xO_3$ films on top of Ir electrode layers in thin-film capacitor structures. The selectivity is characterized by a ratio of ≈10:1 (rate of etching $PbZr_{1-x}Ti_xO_3$ ÷ rate of etching Ir and IrO_x). At the time of reporting the information for this article, several experiments on RIE in BCl_3 and Cl_2 (and sometimes Ar) had demonstrated the 10:1 selectivity ratio, and further experiments to enhance understanding and obtain further guidance for optimizing process conditions were planned.

This work was done by Eui-Hyeok Yang and Larry Wild of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.

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