Non-destructive measurement of longitudinal piezoelectric properties for thin films

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[Introduction] Piezoelectric MEMS devices, provide a versatile platform for high-performance sensors, actuators, energy harvesters and filters, for Internet of Things (IoT) society. To develop piezoelectric MEMS devices, piezoelectric properties of thin films are commonly characterized in terms of the transverse piezoelectric coefficient $e_{31,f}$, which is effective to account for the constraint of the film and substrate [1]. However, the measurement of the $e_{31,f}$ constants is a destructive test, e.g. by cutting the sample into a cantilevered beam shape [2]. Methods for measuring in wafer shape have also been reported, but it is difficult to measure the entire wafer surface [3,4]. In this study, the possibility of measuring the d_{33} coefficient by a quasi-static method using the direct piezoelectric effect as a non-destructive piezoelectric evaluation method is investigated.

[Experiment and Results] The epitaxial (100)$BiFeO_3$ films epitaxially growth on (100)Si substrate was used as a sample. The films were fabricated by combinatorial rf sputtering method. Epitaxially grown (100)Pt bottom electrodes were uniformly prepared on (100)Si substrate with a TiN buffer layer. Then, $LaNiO_3$ was uniformly deposited as a seed layer, and 800 nm-thick BFO film was fabricated with composition and temperature gradient. The composition ratio was various by using $BiFeO_3$ with 10% and 30% excess Bi targets, the substrate temperature is inclined perpendicularly to direction to the composition gradient. The XRD results confirm high quality epitaxial (100)BFO film in all of the condition on wafer. The d_{33} coefficient was measured by applying dynamic force on each point of the wafer. The sphere head contact probe with 3 mm diameter was used. A static preload of 1 N was applied to fix the sample, and 0.3 N (RMS) force was applied by an AC loading shaker with frequency of 40Hz to the sample. After poling treatment using pulse voltage, d_{33} was determined using the generated current. The distribution of the d_{33} on the combinatorial fabricated film is shown in Fig.1. As can be seen, d_{33} shows higher value in low temperature areas. This result is roughly consistent with the previous, in which $|e_{31,f}|$ of ~6 C/m^2 are obtained only at 440°C region, and unable to be measured at higher temperature region [5]. Further analysis in piezoelectric properties of thin film by d_{33} coefficient and the relationship with $e_{31,f}$ and will be discussed.

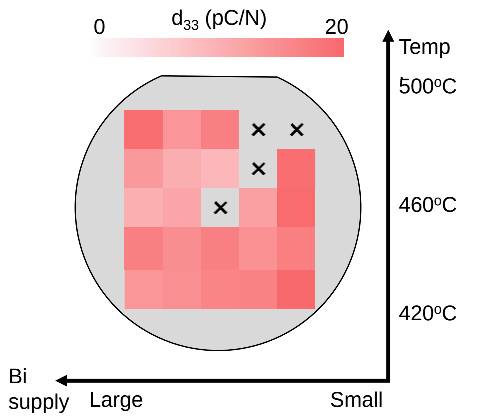

Fig.1. Distribution of d_{33} coefficient on combinatorial fabricated BFO film wafer.

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