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利用形態　：技術代行
利用課題名（日本語）　：プラズマを利用しない MEMS 犠牲層 Si エッチング
Program　Title（in English）　：Plasmaless Si etching for MEMS sacrificial layer removal
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## １．概要（Summary）：

The generation of F by the reaction of $F_2$ + NO → F + FNO plays a crucial role to perform chemical dry etching of Si. However, the loss of F by the reaction in the gas phase F + NO → FNO and by the reaction between F and Si surface leads to the significant Si etch rate reduction when the Si was placed at the downstream of the $F_2$ and NO gas mixing point. In order to apply this chemical dry etching method to the large-scale Si wafer MEMS sacrificial layer etching to replace the conventional $XeF_2$ etching [Ibbotson et al. J. Appl. Phys. 56 (1984) 2939.], the etch uniformity across the wafer must be guaranteed by designing the $F_2$ and NO gas mixing method.

In this study, we evaluated the loss of F while varying the process parameters such as the gas mixing point-sample distance, *d*, and the process pressure, *P*. The MEMS structure and line and space patterns were fabricated at Toyota Technological Institute with the support of Nanotechnology Platform Program to measure the vertical and lateral etch rates, $E_V$, and $E_L$, of Si.

## ２．実験（Experimental）：

The MEMS structure and line and space patterns of Si samples were fabricated by Professor Minoru Sasaki at Toyota Technological Institute as a part of Nanotechnology Platform Program. Ar/NO/10%$F_2$ at the total flow rate of 107 sccm was introduced in the process chamber while varying the *P* between 100 ~ 1000 Pa, and the *d* from 30 to 70 mm during the process time of 5 min. $E_V$ and $E_L$ of Si were measured by scanning electron microscopy (SEM). The mean free path, $\lambda$, and the number of collisions, *n*, between the gas mixing point and the sample surface were calculated based on the *P* and *d*. The relationship between the $E_V$, $E_L$, and *n* were studied to elucidate the effect of F loss due to collision in the gas phase and the reaction at the Si surface.

## ３．結果と考察（Results and Discussion）：

Figure 1 shows the relationship between the $E_V$ and n calculated from *P* and *d*. $E_V$ increased linearly proportional to the n up to ~ 4000 (Region (I)). Then the $E_V$ gradually decreased at 4000 < n < 5500 by the function of ~1/d2 (Region (II)). When n > 5500, the

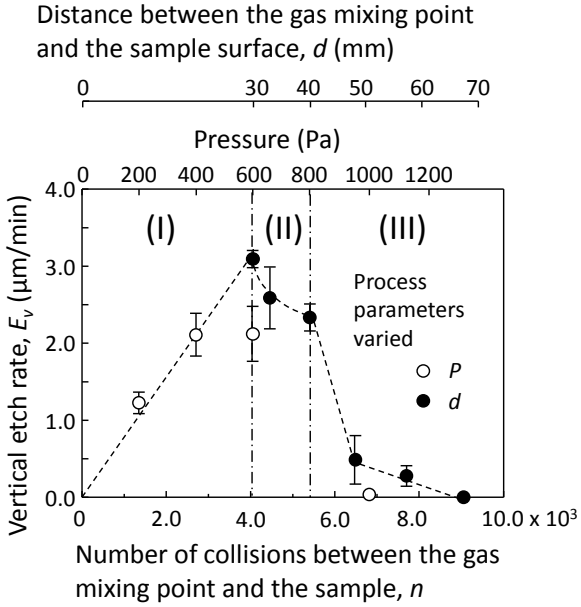


Fig. 1 Relationship between the vertical etch rate, $E_v$, and the number of collisions between the gas mixing point and the sample, *n*. Two experimental parameters were varied, one was the pressure, *P*, and the other was the distance between the sample and the mixing point, *d*.

significant drop of $E_V$ was observed (Region (III)) with the increase of *P* and *d*. Preliminary, we have been considering that the F generation is increased by the reaction of $F_2$ + NO → F + FNO (Region (I)) but as the n increased, the F is lost at the gas phase by the reaction of F + NO → FNO (Region (II)). The further increase of n leads to the complete loss of F in the gas phase as well as the encapsulation of adsorption site at the Si surface with NO and FNO (Region (III)).

## ４．その他・特記事項（Others）

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５．論文・学会発表（Publication/Presentation）：
学会発表

(1) S. Tajima, T. Hayashi, K. Ishikawa, M. Sekine, M. Sasaki, K. Yamakawa, and M. Hori, “The relationship between the pressure and the Si etch rate using the reaction of $F_2$ + NO → F + FNO,” 6th International Symposium on Advanced Plasma Science and its Applications for Nitrides and Nanomaterials / 7th International Conference on Plasma-Nano Technology & Science (ISPlasma 2014/IC-PLANTS 2014), March 2-6, 2014. Poster presentation on March 6, 06AP82LN. Meijyo University, Nagoya, Aichi, Japan.

(2) S. Tajima, T. Hayashi, K. Yamakawa, K. Ishikawa, M. Sasaki, M. Sekine, and M. Hori, “Evaluation of the loss of F during the Si chemical dry etching using the reaction of $F_2$ + NO → F + FNO,” 8th International Conference on Reactive Plasmas/31st Symposium on Plasma Processing (ICRP-8/SPP-31), Feb 3-7, 2014. Poster presentation on Feb. 6, 6P-AM-SPD-P05. Fukuoka Convention Center, Fukuoka, Japan.

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６．関連特許（Patent）：合計 3 報

(1) エッチング装置およびエッチング方法およびクリーニング装置（特許出願 2012-41355 出願日：2012 年 2 月 28 日 公開番号：特許公開 2013-179126）ほか 2 報

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