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Dry Etching of *Escherichia coli* by O_2-, Ar-, Air-, and H_2O- Plasma

O_2-, Ar-, Air-, H_2O-プラズマによる大腸菌のドライエッチング

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We demonstrated a relationship between size of *E. coli* cells and O_2 plasma irradiation time and carried out SEM observation about dry etching of *Escherichia coli* cells by O_2-, Ar-, Air-, and H_2O- plasma. It was found that oxygen or argon ions contributed for the degradation of *E. coli* cells.

1. Introduction

Recently, the sterilization technique of bacteria using plasma has been investigated with some plasma sources such as atmospheric pressure plasma, low-pressure discharge plasma and so on [1-3]. However, the mechanism of degradation of *Escherichia coli* has not been clear. We investigated the etching gas species dependence of the degradation of the *E. coli* cells.

In this paper, we describe the etching behavior of *E. coli* cells by O_2-, Ar-, and H_2O- plasma.

2. Relationship between size of *Escherichia coli* cells and O_2 plasma irradiation time

Generally, it is difficult to evaluate size change every *E. coli* cell in plasma treatment of bacteria, because it is difficult to identify one bacteria cell from among many bacteria cells in culture. We can identify each bacteria cell by using the microenclosure [4]. Figure 1(a) and 1(b) show optical microscope images of degradation of *E. coli* before and after O_2 plasma etching, respectively. Figure 2 shows the relationship between O_2 plasma irradiation time and size of *E. coli* cells. RF power was 100 W, O_2 flow rate was 25 sccm, process pressure was kept at 13.3 Pa and etching time was 30 sec. In this etching condition, *E. coli* cells were eliminated by O_2 plasma etching of 120 sec.

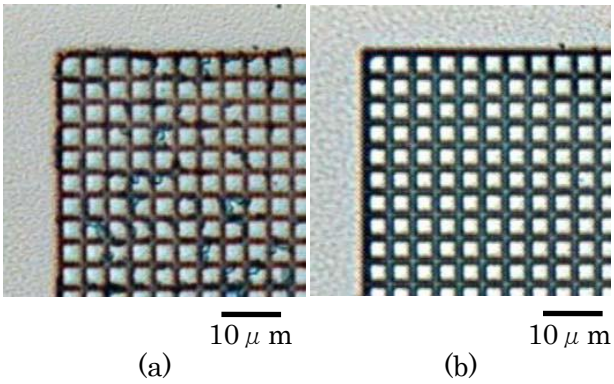

Fig. 1 Optical microscope images of degradation of *E. coli* by O_2 plasma using microenclosure for single cell isolation: (a) before etching and (b) after etching.

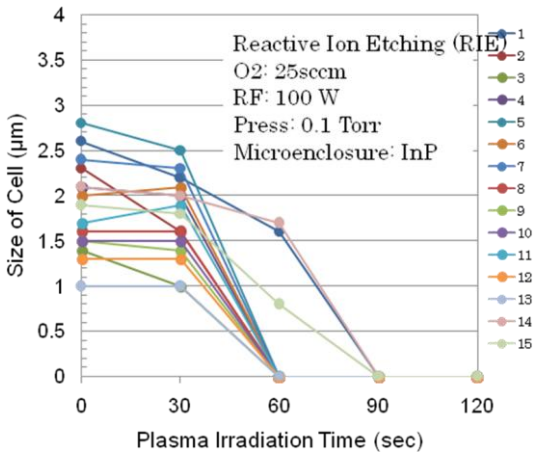

Fig. 2. Relationship between O_2 plasma irradiation time and size of *E. coli* cells.

3. Dry Etching of *Escherichia coli by* Discharge Plasma

We used a reactive ion etching system (Samco RIE-1) and pure O_2, Ar, Air as etching gases. H_2O plasma etching was performed by supplying water vapor from ice placed on the RF electrode in a process chamber [5]. In this experiment, *E. coli* K-12 strain W3110 was used. We used *E. coli* cells dropped on Si substrate as samples. Figure 3(a)-3(d) show SEM images of *E. coli* etched by O_2-, Ar-, Air- and H_2O- plasma, respectively. In Fig. 3(a)-3(c), the RF power was 100 W, O_2-, Ar- and Air- flow rate was 25 sccm and process pressure was kept at 13.3 Pa. In Fig. 3(d), the process pressure was at 27 Pa. We confirmed that *E. coli* cells were not etched by O radicals in this etching condition. *E. coli* cells were mainly etched by ions because they were placed on the RF electrode. In Fig. 3(a), it is found that *E. coli* cells were etched by oxygen ion. In Fig. 3(b), it is found that *E. coli* cells were etched by Ar ion. *E. coli* cells were degraded by Air plasma including O_2 of 20% as shown in Fig. 3(c). While, *E. coli* cells were not almost etched by H_2O plasma including H, OH and O as shown in Fig. 3(d). Oxygen ratio in H_2O plasma was smaller than that in O_2- or Air-plasma [6]. We think that yields of etching and sputtering for *E. coli* by hydrogen was much smaller than that of oxygen , because the mass of hydrogen is smaller than that of oxygen.

4. Conclusions

We demonstrated a relationship between size of *E. coli* cells and O_2 plasma irradiation time and carried out SEM observation about dry etching of *E. coli* cells by O_2-, Ar-, Air-, and H_2O- plasma. It was found that O or Ar ions contributed for the degradation of *E. coli* cells.

References

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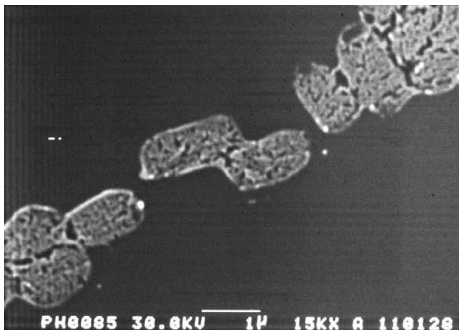
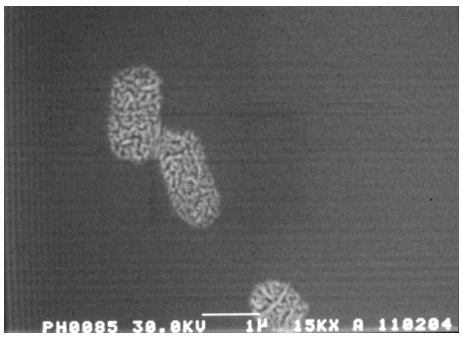
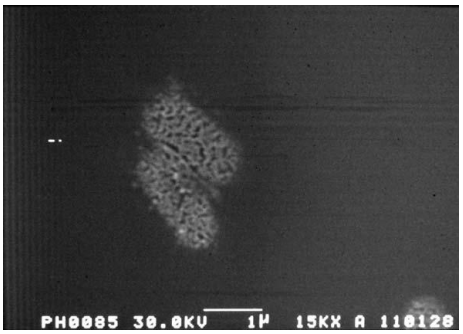


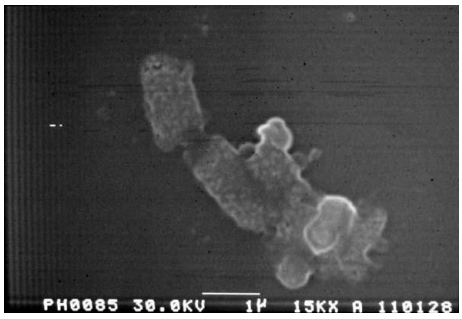
(a)



(b)



(c)



(d)

Fig. 3 SEM images of *E. coli* cells etched by discharge plasma: (a) O_2 plasma, (b) Ar plasma, (c) Air plasma and (d) H_2O plasma.