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# Effect of UV irradiation in plasma on Pohotoresist LER

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## 1. Introduction

In nano-scaled regime of semiconductor devices, MOSFETs' gate line edge roughness (LER) is the most crucial issue for their precise characteristic control in production. Actually, there is a possibility to degrade systematic yield due to the gate LER such as stand-by leakage or slow functional speed. Therefore, the precise gate LER control is one of key issues to realize the next generation semiconductor products. For this purpose, many studies of gate LER in ArF lithography have been done, [1,2] but the cause of LER formation has not been enough studied yet. In this study, we focused on the effect of ultraviolet light irradiation from etching plasma on photoresist (PR) LER and investigated the mechanism of LER formation. From the changing of PR composition and profile, we suggest PR LER is related with the size of polymer changed by UV light exposure in etching plasma.

## 2. Experimental

In order to investigate the effect of UV light irradiation from plasma on PR LER, plasma condition was following. Experiment was carried out in an inductively coupled industrial reactor. He gas was used to eliminate the influence of chemical reaction with radical. RF biasing at bottom electrode was also off to restrain the effect of incident ion and electron. UV spectrum of in-situ plasma was measured through the MgF window by a vacuum UV spectroscopy equipped with the chamber wall. The sample consists of a positive-type KrF PR mask, bottom anti-reflection coating (BARC), and Si substrate. The exposure region of UV wavelength of evaluated PR was less than 300nm. PR LER was measured by 3D atomic force microscope that enables to measure the sidewall roughness directly.[3,4]

## 3. Result and discussion

Fig.1 shows dependence of irradiation time of He plasma on PR LER. It indicates PR width was shrunk drastically in a short time and was saturated. On the other hand, PR LER increased about 2 times for 90sec. We suggest these results were occurred by UV exposure in plasma for PR. Fig.2 shows the SEM pictures of PR profile with plasma irradiation time. This result indicates the size of polymer seems to be getting large with time and, increasing of PR LER is closely related with swelled polymer.

From these results, we investigated the change of PR composition after plasma irradiation and effect of UV exposure in plasma. Fig.3 shows de-protection reaction of the positive-type chemically amplified resist by UV exposure. The positive-type PR generates acid from photo-acid generator (PAG), and these acids remove protection groups and change the polymer from hydrophobic character to hydrophilic character.[5,6] In order to investigate whether UV light exposes PR, UV spectrum of in-situ plasma was measured. As shown Fig.4, the UV spectrum peaks in He plasma were observed at 122nm and 283nm. This result indicates He plasma has the UV spectrum that enables to expose PR. In addition to this, PR composition was also analyzed. Fig.5 shows dependence of contact angle on He plasma irradiation time. It decreased drastically in a short time, and the polymer composition was also changed from hydrophobic character to hydrophilic character. Fig.6 shows the result of thermal desorption spectroscopy (TDS) analysis before and after plasma irradiation. From this result, $-C(CH_3)_2$ and $CO_2$ were not detected after plasma irradiation. Therefore, de-protection reaction is occurred by UV exposure, and PR width also seems to be shrunk by de-protection from the base polymer. From these results, we found that PR is exposed by plasma irradiation and PR LER seems to be related with the change of PR composition exposed by UV.

## 4. Conclusion

From the analysis of PR composition after plasma irradiation, we found PR was exposed by UV light in plasma. PR LER was increased with plasma irradiation time, and LER seems to be related with the change of PR composition by UV exposure. From the PR profile after plasma irradiation, the size of polymer also seems to be swelled. Therefore, we considered that PR LER was influenced by not only polymer composition but also the polymer size changed by UV exposure in plasma.

## References

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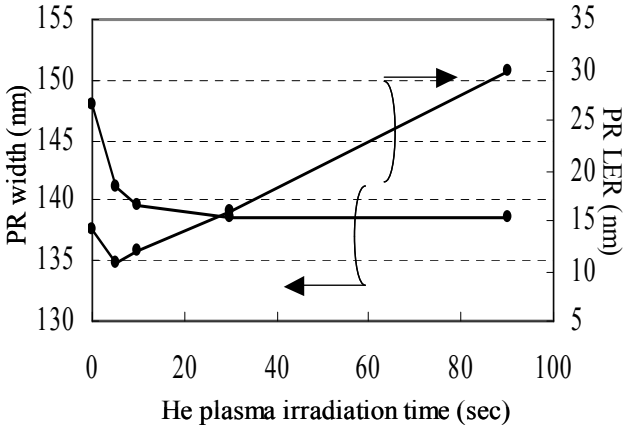


Fig.1 Dependence of He plasma irradiation time on PR width and PR LER

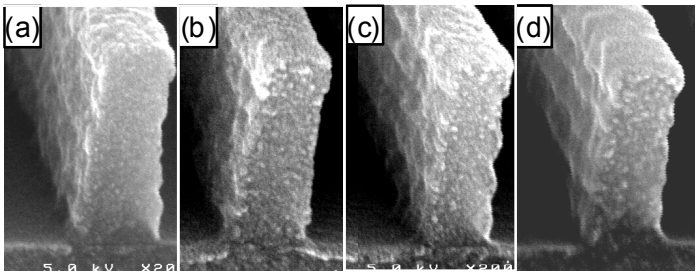


Fig.2 SEM picture of PR profile irradiated by He plasma
(a) Initial PR with LER of 14nm
(b) PR after 10sec irradiation with LER of 12nm
(c) PR after 30sec irradiation with LER of 16nm
(d) PR after 90sec irradiation with LER of 30nm

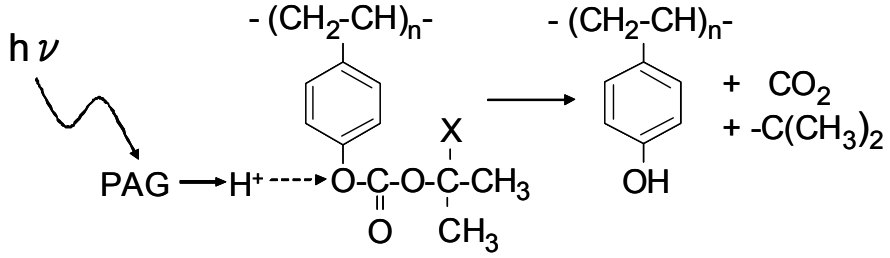


Fig.3 De-protection reaction of the positive-type chemically amplified resist by UV exposure

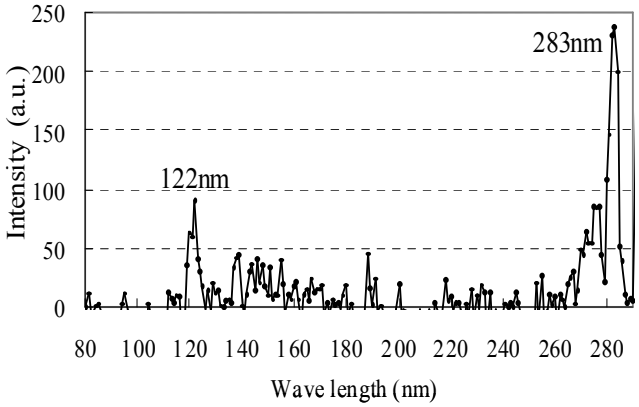


Fig.4 The UV spectrum of in-situ He plasma

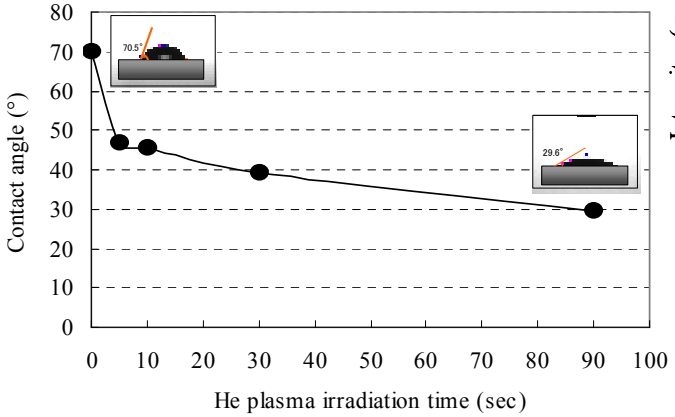


Fig.5 Dependence of He plasma irradiation time on contact angle.

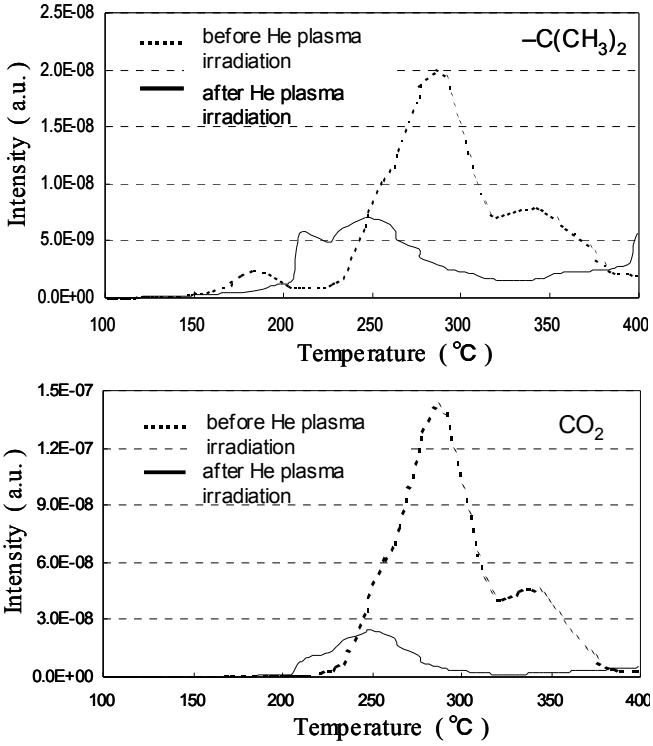


Fig.6 The result of TDS analysis of PR before and after He plasma irradiation