262 *KIEE International Transactions on EA, Vol. 2-C, No. 5, 262-267 (2002)*

Signal Analysis of Motor Current for End Point Detection in the Chemical Mechanical Polishing of Shallow Trench Isolation with Reverse Moat Structure

Chang Jun Park, Sang-Yong Kim and Yong-Jin Seo

Abstract - In this paper, we first studied the factors affecting the motor current (MC) signal, which was strongly affected by the systematic hardware noises depending on polishing such as pad conditioning and arm oscillation of platen and recipe, head motor. Next, we studied the end point detection (EPD) for the chemical mechanical polishing (CMP) process of shallow trench isolation (STI) with reverse moat structure. The MC signal showed a high amplitude peak in the fore part caused by the reverse moat pattern. We also found that the EP could not be detected properly and reproducibly due to the pad conditioning effect, especially when conventional low selectivity slurry was used. Even when there was no pad conditioning effect, the EPD method could not be applied, since the measured end points were always the same due to the characteristics of the reverse moat structure with an open nitride layer.

Keywords : end point detection (EPD), chemical mechanical polishing (CMP), shallow trench isolation (STI), pad conditioning, motor current (MC)

1. Introduction

Chemical Mechanical Polishing (CMP) has become the most common technique used in wafer polishing for dynamic memory and microprocessor application. These techniques enable one to 0.13 ㎛ or below.

To properly determine when a chemical mechanical polishing (CMP) process reaches the end point (EP) is one of the most important issues in the CMP process, but its study is still in an early stage. The widely used method to obtain the polishing time needed to remove a film to a target thickness is to perform the pre-polishing test of non-patterned blanket wafers and then estimate the required polishing time for actual patterned wafers based on the pre-polishing rate. In this case, however, because the pre-determined polishing time is equally applied to all the patterned wafers, the process seriously suffers from the wafer-to-wafer thickness variation due to the polishing rate decline caused by the aging of the polishing pad. Even though the re-polishing of wafers to a target thickness can compensate the variation, the throughput of the process becomes seriously aggravated. Therefore, the end point detection (EPD) method has attracted considerable attention lately, and many studies have been reported [1, 2]. The typical EPD methods include the motor current (MC) method detecting the MC changes from polishing the platen or carrier head, the optical method using infra-red radiation [3], and the acoustic method [4], etc. Among them, the MC method is widely used nowadays [5-7].

In this paper, we first studied the factors affecting the MC signal, which was strongly affected by the systematic hardware noises depending on the polishing recipe, such as pad conditioning and arm oscillation. Next, we studied the EPD for the CMP process of the shallow trench isolation (STI) structure [8, 9] with reverse moat pattern. The MC signal showed a high amplitude peak in the fore part caused by this pattern. We also found that the EP could not be detected properly and reproducibly due to the pad conditioning effect, especially when conventional low selectivity slurry was used. Even when there was no pad conditioning effect, the EPD method could not be applied, since the measured end points were always the same due to the characteristics of the open nitride structure.

2. Experiments

Test structures of the reverse moat patterned wafer were fabricated on p-type (100) silicon. Fig. 1 shows a schematic diagram of the sequence for the STI-CMP process with a reverse moat pattern and etch. First, the 150 Å of thermally grown pad oxide and 2000 Å of silicon nitride were fabricated. Silicon trenches of 3500 Å were etched using a moat pattern and dry etch. After the removal of the photo resist,

---

This work was supported by the University Research Program (Grant NO: 2002-042-185-3) from the Ministry of Information & Communication in South Korea.

Manuscript received: July 18, 2002 accepted: Sep. 27, 2002

Chang Jun Park and Yong-Jin Seo are with school of Electrical Engineering, Daebul University, Chonnam, Korea.

Sang-Yong Kim is ANAM Semiconductor Inc., Korea.

the wafers were cleaned. A sidewall oxide layer of 270 Å was grown by dry oxidation followed by atmosphere pressure chemical vapor deposition (APCVD) of an 8000 Å thick oxide to refill the shallow trenches. After the shallow trenches were refilled, the sample wafers with reverse moat structure were formed by the reverse moat pattern and etch process. Finally, the STI-CMP process was performed using the Avanti 472 polisher of the SFI Company. Platen speed was 46 rpm, carrier speed was 28 rpm, down force was 7 psi, back pressure was 2 psi, and arm oscillation ranged from 126 mm to 131 mm with an oscillation speed of 5 mm/sec. Rodel's IC 1000/Suba IV pad was used, and the mode of pad conditioning was Just While, where the inter sweep delay time was 11 sec and conditioning time per segment was 1.3 sec with total 10 segments. KOH based slurry with 12 wt. % fumed silica was used, and the slurry flow rate was 150 ml/min.

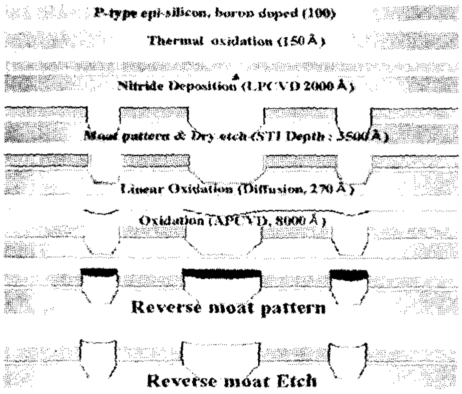


Fig. 1 Schematic diagram of STI CMP processes sequence with reverse moat etch.

Table 1 CMP process parameters.

Polisher	SFIs avanti 472
Pad	IC 1000 / Suba IV
Platen speed	46 rpm
Carrier speed	28 rpm
Down force	7 psi
Back pressure	2 psi
Conditioner	Just while
Slurry flow rate	150 ml / min

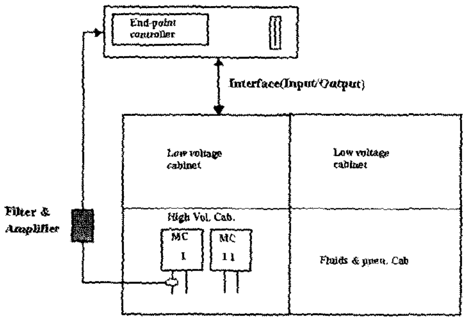


Fig. 2 Schematic diagram of EPD 2350 system manufactured by Luxtron.

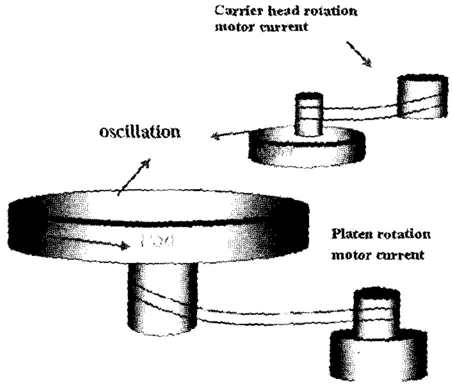


Fig. 3 Schematic diagram of motor oscillation between polishing platen and carrier head motor.

Fig. 2 and Fig. 3 show the schematic diagram of the Luxtron 2350 system and motor current detection method, respectively. In this system, we obtained the motor current signal value due to the oscillation difference between the polishing platen motor and carrier head motor during the CMP polishing. Table 1 summarizes the CMP process parameters.

3. Results and discussion

3.1 MC signal analysis for CMP of non-patterned blanket wafer

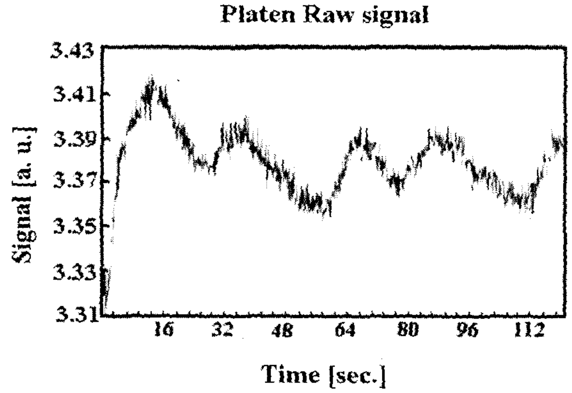


Fig. 4 MC signal from polishing platen for CMP of non-patterned blanket wafer for CMP of non-patterned blanket wafer.

We first analyzed the MC signal of a non-patterned blanket wafer in order to investigate the noise factors affecting the EPD. From the test, we found that the MC signal is strongly affected by the systematic hardware noises depending on polishing recipe, such as pad conditioning and arm oscillation. Fig. 4 shows the raw MC signal from the polishing platen, where we can observe several different frequencies.

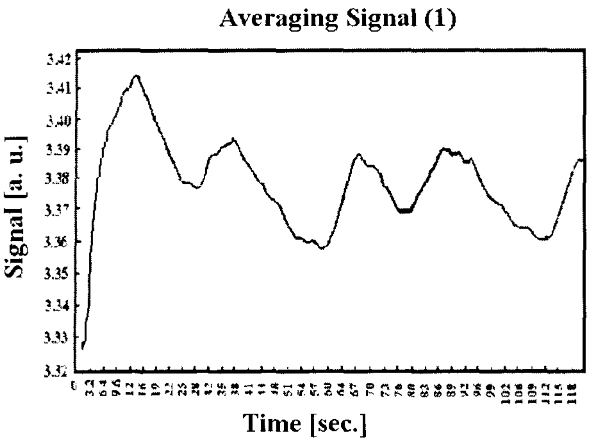


Fig. 5 Averaging MC signal based on period of 2 seconds for CMP of non-patterned blanket wafer.

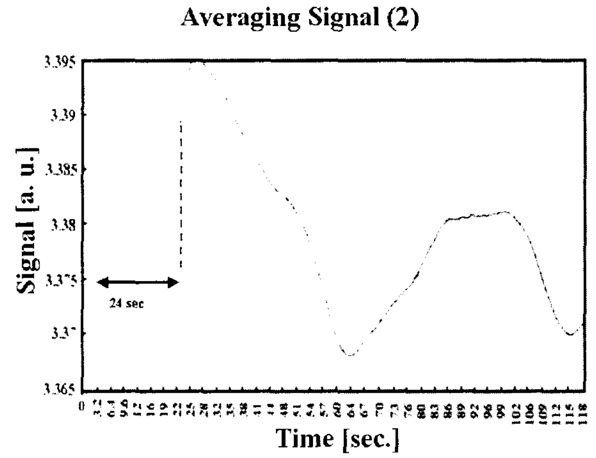


Fig. 6 Averaging MC signal based on period of 24 seconds for CMP of non-patterned blanket wafer.

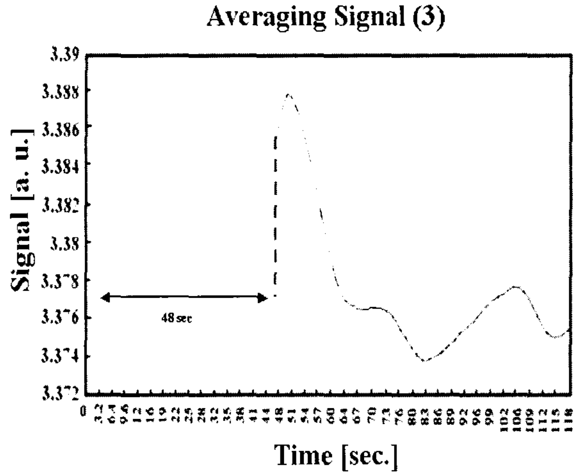


Fig. 7 Averaging MC signal based on period of 48 seconds for CMP of non-patterned blanket wafer.

At first, we can find an initial cycle feature with the period of about 2 seconds. The behavior seems to be caused by arm oscillation since the values of arm oscillation distance and velocity are set to 5 mm and 5 mm/sec, respectively, and therefore it takes 2 seconds to complete one oscillation cycle. To eliminate the effect of arm oscillation in the raw MC signal, we used the period based on the averaging technique, 2 seconds in this case, and the result is shown in Fig. 5. In Fig. 4, we can also find another cycle feature with a period of about 24 seconds. The behavior seems to be caused by pad conditioning since the inter sweep-delay time in pad conditioning is 11 seconds and the pad conditioner passes through 10 pad segments with the velocity of 1.3 sec/segment, and therefore takes 24 seconds to complete a half conditioning cycle. An M shape curve during the period of 48 seconds, as show in Fig. 4, is also caused by pad conditioning, where the period of 48 seconds explains one complete conditioning cycle. M shape behavior explaining the difference between a half cycle and others in pad conditioning seems to be caused by the torque difference depending on the radius of rotation of the polishing platen. Figs. 6 and 7 present the averaging signals based on the period of 24 and 48 seconds, respectively, to eliminate the effects of the pad conditioning in Fig. 4.

3.2 EPD for CMP Process of STI structure with reverse moat pattern

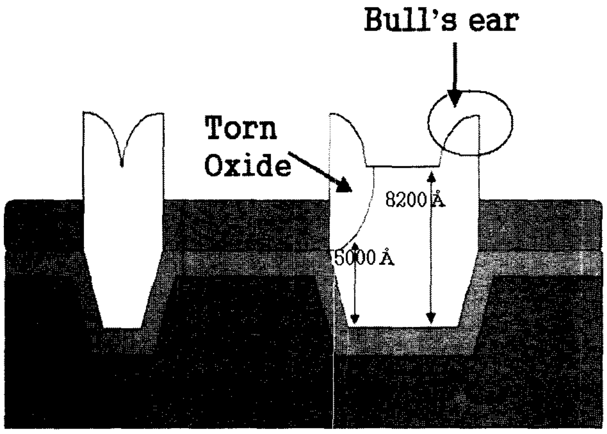


Fig. 8 Typical sharks fin (bulls ear) shape of reverse moat pattern.

We studied the MC signal and the EPD for the CMP process of the STI structure with reverse moat pattern, based on the results in previous section. Fig. 8 shows the typical sharks fin shape of the reverse moat pattern and the pattern size used in the test. The oxide layer deposition, and all the polishing and detection conditions are the same as in previous section. Fig. 9 shows the raw MC signal and the averaging signals based on the periods of 24 and 48 seconds from polishing platen. The raw signal shows a high amplitude peak in the fore part. The inflexion point where the declining signal from the peak shows a sudden turn to the increasing signal is considered as the end point (EP). The abrupt change of the signal at this point occurs due to the polishing rate difference between silicon oxide and silicon nitride, where the polishing rate of silicon oxide is higher than that of silicon nitride. The averaging signals based on the period of 24 and 48 seconds, respectively, were obtained after averaging the raw signal based on the period of 2 seconds in order to eliminate the effects of both arm oscillation and pad conditioning.

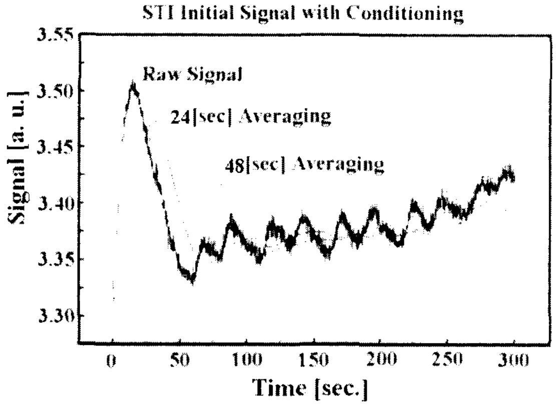


Fig. 9 Raw and averaging MC signal from polishing platen for CMP of STI structure with reverse moat pattern.

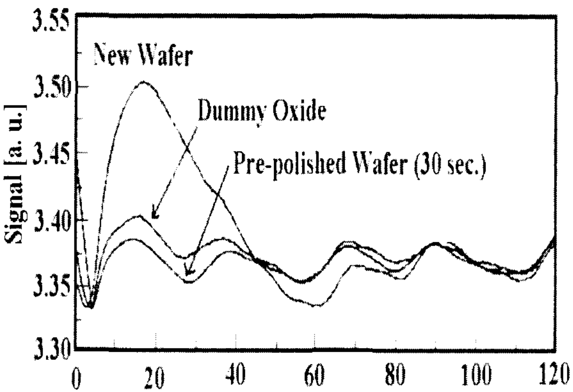


Fig. 10 MC signals for CMP of 3 different kinds of reverse moat patterned wafers with pad conditioning.

In order to study the origin of the initial high amplitude peak, we performed the CMP tests of one blanket wafer as in the previous the section and two reverse moat patterned wafers. One of the patterned wafers was prepared by prepolishing the original reverse moat pattern for 30 seconds in order to reduce the effect of the reverse moat pattern to some extent. The results are shown in Fig. 10. The signal from the original reverse moat patterned wafer shows the highest amplitude peak in the beginning, and the signals from all the wafers show about the same behaviors after some period. Fig. 11 shows the MC signals for the CMP of two types of reverse moat patterned wafers without pad conditioning. Pad conditioning about the same as in Fig. 10 except that the periodic oscillation causes the results. Therefore, we can conclude that the high amplitude peak is mainly caused by the reverse moat pattern with an open nitride structure.

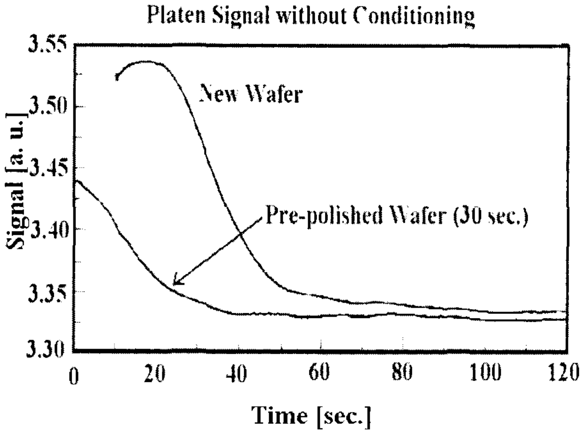


Fig. 11 MC signals for CMP of 2 types of reverse moat patterned wafers without pad conditioning.

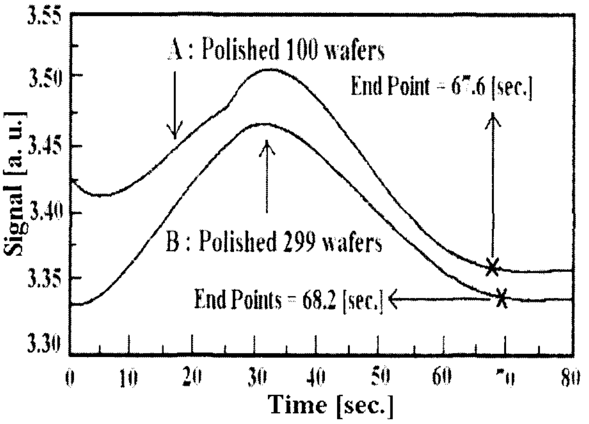


Fig. 12 EP signals for CMP of STI structure with reverse moat pattern.

When we compare Fig. 10 with Fig. 11, we can find that the pad conditioning effect deteriorates the MC signal significantly, and therefore makes it difficult to detect the EP properly and reproducibly, especially for the STI-CMP process with conventional low selectivity slurries where the oxide to nitride selectivity ranges from 2.5:1 to 3:1. In the case of the high frequency signal with small amplitude caused by arm oscillation, the signal can easily be removed by the proper noise filtering technique and therefore does not have much effect on the EPD. On the other hand, the signal caused by pad conditioning has a long period with high amplitude, and therefore has a detrimental effect on the EPD. Even when there was no pad conditioning effect, the motor current based EPD method could not be applied to the CMP process of the STI structure with reverse moat pattern. The typical CMP process always suffers from the decline of polishing rates of lot-to-lot (even wafer-to-wafer) due to the pad aging. Therefore, if each patterned wafer with the same initial condition is polished on the same pads with different degrees of aging, the polishing rates (and therefore the EPs) of the wafers could be different.

However, contrary to the expectation, Fig. 12 shows that the measured EPs are about the same regardless of the degree of pad aging. The measured EPs were 67.6 seconds for signal A and 68.2 seconds for signal B. Signals A and B present the MC signals for the CMP (without pad conditioning) of two reverse moat patterned wafers on the same pads, which have already polished 100 and 299 wafers, respectively. This is mainly because the CMP process is performed with the silicon nitride open, and therefore the polishing pad contacts the nitride early, and then stops the process too early due to the visco-elastic deformation of the pad.

4. Conclusions

In this paper, we tested the EPD method based on the MC for the CMP process with non-patterned blanket wafers and reverse moat patterned wafers in 0.18 ㎛ semiconductor device fabrication. We first studied the factors affecting the MC signal of a non-patterned blanket wafer and found that the MC signal was strongly affected by the systematic hardware noises depending on polishing recipe, such as pad conditioning and arm oscillation. Next, we studied the EPD for the CMP process of the STI structure with reverse moat pattern. The MC signal showed a high initial amplitude peak caused by the reverse moat pattern. We also found that the EP could not be detected properly and reproducibly due to the pad conditioning effect, especially when conventional low selectivity slurry was used. Even when there was no pad conditioning effect, the motor current based EPD method could not be applied, since the measured EPs were always the same due to the characteristics of the open nitride structure, irrespective of the decline of polishing rate caused by pad aging. Therefore, we expect that the above problems can be solved using modified slurry with a high selectivity between silicon oxide and silicon nitride film.

Acknowledgement

This work was supported by the University Research Program (Grant NO: 2002-042-185-3) from the Ministry of Information & Communication in South Korea.

References

[1] W. J. Patrick, W. L. Guthrie, C. L. Standley and P. M. Schiable, *"Application of Chemical Mechanical Polishing to the Fabrication of VLSI Circuit Interconnections"*, J. Electrochem. Soc., Vol. 138, p.555, 1991.

[2] W. T. Tseng, J. H. Chin and L. C Kang, *"A Comparative Study on the Roles of Velocity in the Material Removal Rate During Chemical Mechanical Polishing"*, J. Electrochem. Soc., vol. 146, p.1952, 1991.

[3] K. Kato, A. Ueki and T. Kaga, *"High Signal-to-Noise Ratio Inspection of Sub-quarter Micrometer Oxide CMP Defect by Using Laser Scattering Inspection Tool"*, IEEE 1999, p.187, 1999.

[4] M. Berman, T. Bibby and A. Smith, *"Semiconductor Fabtech"*, 8th ed., p267, 1998.

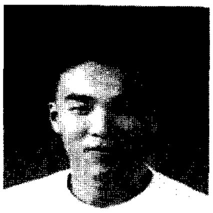
[5] B. T. LIN and S. N. Lee, *"An Effective End Point Detector on Oxide CMP by Motor Current"*, IEEE 1999, p.295, 1999.

[6] G. Popescu, M. Lauwidjaja and L. Denney and K, Richardson, A. Dogariu, *"Aging Effect in CMP Slurries Probed by Multiple Light Scattering"*, Electrochem. Soc. Proc., Vol. 98 p.59, 1999.

[7] Ohmori and T. Kasai, *"New Ultra-precision CMP Technique Applying Direct Air-Back Method and Non-foaming Plastic Pad"*, IEEE 1999, p.225, 1999.

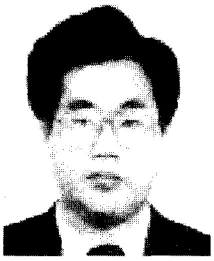
[8] Y. J. Seo, C. B Kim and S.Y Kim, *"A Study of Removal Rate Control of Oxide CMP (Chemical Mechanical Polishing) Process"*, Proc. of CMP-MIC 2001, p.527, 2001.

[9] S. Y. Kim and Y. J. Seo, *"Correlation Analysis Between Pattern and Non-pattern Wafer for Characterization of Shallow Trench Isolation-Chemical Mechanical Polishing (STI-CMP) Process"*, Microelectronic Engineering, Vol. 60, p.357, 2002.

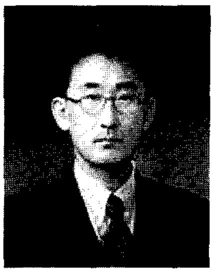


Chang-Jun Park received his B.S degree in Electronic Engineering from DAEBUL University in 2002. Currently, he is working toward his MS degree in Electrical Engineering at DAEBUL University, Chonnam-do, Korea. His research interests are in the area of Si-based optoelectronics and optimization of chemical mechanical polishing (CMP) process for ULSI applications.

Tel: +82-61-469-1260, Fax: +82-61-469-1260
E-mail: pcj@mail.daebul.ac.kr



Sang-Yong Kim was born in Gwang-ju, Korea, in 1961. He received his Ph.D. degree in electronic engineering from Chung-Ang University, in 1999. He joined the Hyundai Electronic Semiconductor R&D Center, Ichen Korea, in 1990. From 1990 to 1994, he was involved in CVD and PVD processing. In 1994, he joined the Non-memory system I.C R&D Center. From 1994 to 1996, he worked for the Chemical Mechanical Planarization (CMP). He moved to the ANAM Semiconductor Co., Buchen Korea. From 1996 to 2002, he managed several generations of advanced non-memory I.C, 0.25um, 0.18um, 0.15um. His interests in the CMP Process during this time were new process architectures such as APC, CLC, next generation device design rule technologies, and development of new CMP consumable parts. he was engaged in the development of CMP processing of 0.13 ㎛ non memory I.C. Now, he is a technical director in CMP processing and he lectures on semiconductors at Chang-Ang University. Also from 1998 to 2001, he became chairman for the Korea CMP user group meeting.



Yong-Jin Seo received his B.S., M.S. and Ph.D. degrees in Electrical Engineering from Chung-Ang University in 1987, 1989 and 1994, respectively. In 1995, he joined the Department of Electrical Engineering at DAEBUL University, Chonnam-do, Korea. From 1999 to 2000, he was a Post-Doctoral Fellow in the Electrical Engineering Department at the University of North Carolina at Charlotte. He was engaged in the development of Multi-layer nanocrystalline Si-O superlattice diode. Since 2002, he has been an Associate Professor in the Electrical Engineering Department of DAEBUL University. His research interests are in the area of Si-based optoelectronics and optimization of chemical mechanical polishing (CMP) process for ULSI applications.

Tel: +82-61-469-1260, Fax: +82-61-469-1260
E-mail: syj@mail.daebul.ac.kr