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Chemical mechanical planarization of $Ge_2Sb_2Te_5$ using IC1010 and Politex reg pads in acidic slurry*

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In the paper, chemical mechanical planarization (CMP) of $Ge_2Sb_2Te_5$ (GST) is investigated using IC1010 and Politex reg pads in acidic slurry. For the CMP with blank wafer, it is found that the removal rate (RR) of GST increases with the increase of pressure for both pads, but the RR of GST polished using IC1010 is far more than that of Politex reg. To check the surface defects, GST film is observed with an optical microscope (OM) and scanning electron microscope (SEM). For the CMP with Politex reg, many spots are observed on the surface of the blank wafer with OM, but no obvious spots are observed with SEM. With regard to the patterned wafer, a few stains are observed on the GST cell, but many residues are found on other area with OM. However, from SEM results, a few residues are observed on the GST cell, more dielectric loss is revealed about the trench structure. For the CMP with IC1010, the surface of the polished blank wafer suffers serious scratches found with both OM and SEM, which may result from a low hardness of GST, compared with those of IC1010 and abrasives. With regard to the patterned wafer, it can achieve a clean surface and almost no scratches are observed with OM, which may result from the high-hardness SiO_2 film on the surface, not from the soft GST film across the whole wafer. From the SEM results, a clean interface and no residues are observed on the GST surface, and less dielectric loss is revealed. Compared with Politex reg, the patterned wafer can achieve a good performance after CMP using IC1010.

Keywords: $Ge_2Sb_2Te_5$, CMP, polishing pad

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1. Introduction

Phase change memory (PCM) which uses $Ge_2Sb_2Te_5$ (GST) material has attracted much attention because it is non-volatile with fast random programming, and has high endurance and thus is one of the most promising candidates for storage class memory and will replace DRAM or Flash.[1–3] Originally the planar cell structure of PCM was fabricated in the IC industry, however, it not only suffers from large thermal cross-talk between cells but also requires a high reset current. Recently, a confined structure of the cell which can improve these shortcomings has been developed to replace the planar cell structure.[4] The chemical mechanical planarization (CMP) and dry etch process have been used for fabricating the confined cell structures, separately. However, the application of the CMP process can not only achieve a smooth surface but also avoid the peeling trouble between chalcogenide material and the dielectric underneath, compared with the dry etch process.[5] What is more, with critical dimensions shrinking, it is very hard to meet the integration requirement using GST etch, especially below 30 nm. Therefore, GST CMP is a central point in the integration process of PCM.

Recently, GST CMP has been reported. The abrasives, surfactant, oxidant, and other additives which come from the alkaline or acidic slurry were investigated in the GST CMP.[5–10] However, there are few reports about the effect of a polishing pad on the GST performance. As is well known, the CMP is a process used in the silicon wafer fabrication industry to achieve the planarity that is necessary and material removal is generally carried out by chemical reaction and mechanical abrasion during the CMP process.[11] The polishing pad is very important, because it contributes to the transferal of the slurry and executes the polishing action for material removal.[12]

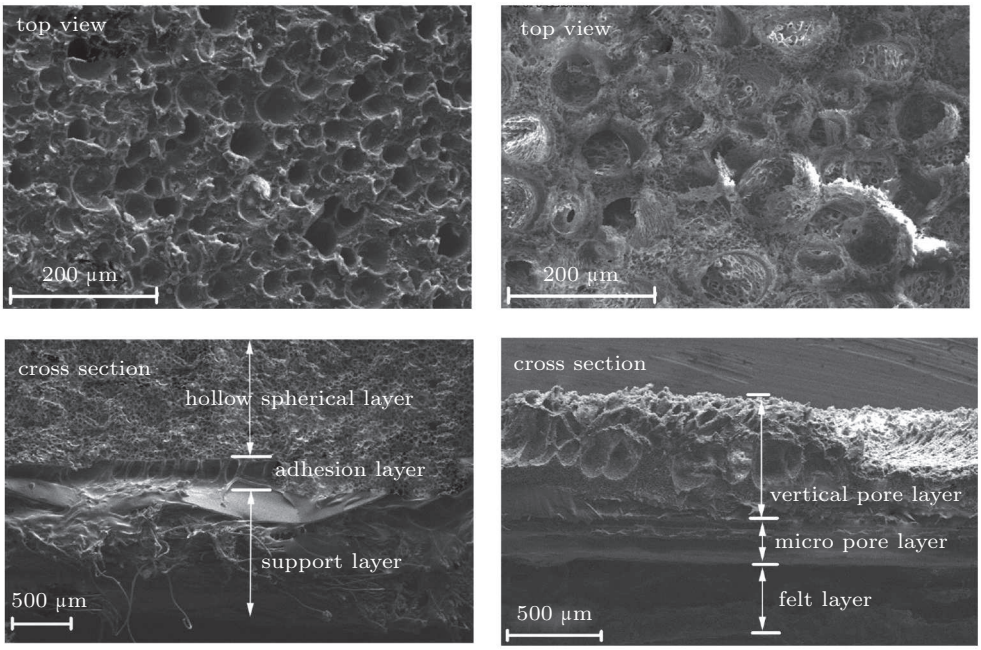
The characteristics of the polishing pads have a great influence on and plays an important role in the optimization of the GST CMP process. Generally, IC-series pads and Politex pads are widely used in the various CMP processes, such as metal CMP, shallow trench isolation (STI) CMP, inner

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metal dielectric (IMD) CMP. IC-series pads are filled or blown with composite urethanes, having surface structures made up of hemispherical depressions derived from exposed hollow spherical elements or incorporated gas bubbles (Fig. 1(a)), and politex pads are made from microporous urethane, which have a surface morphology resulting from the ends of columnar void structures in bulk urethane and are grown on a urethane felt base (Fig. 1(b)).[13–15] In the paper, GST CMP is investigated using IC1010 and Politex reg pads in the acidic slurry, separately.



(a) IC1010 (b) Politex reg

Fig. 1. Surface morphology images and cross section images of polishing pads.

2. Experiment

For the experiment with a blank wafer, a 400-nm-thick GST film was used and which had been deposited on the surface of a 12-inch (1 inch = 2.54 cm) wafer which had a substrate of SiO_2/Si, with physical vapor deposition (PVD) (Oerlikon, CLN300 II). With regard to the patterned wafer test, a tested trench structure which is composed of an array of line-spacing structures with approximate 60-nm linewidth was employed.

CMP-polishing experiments were performed on a 300-mm CMP tool (Reflexion LK 300 mm, Applied Material) using IC1010 (hard pad) and Politex reg (soft pad), which came from Dow, and the images of surface morphology and cross section for both of pads are shown in Fig. 1, respectively. The endpoint system was used with optical signal for the patterned polished wafer.[16] The self-made acidic slurry was used in the acidic condition (pH 2.5), which includes the fumed silica abrasive (80 nm–160 nm size) and H_2O_2. The flow rate of slurry was 500 ml/min, the rotation speeds of the plate and head were 53 rpm and 50 rpm, respectively. The polishing pressure ranged from 0.5 psi (1 psi = 6.89476×10^3 Pa) to 2.0 psi. After CMP, the surface morphology of GST was observed with a scanning electron microscope (SEM) and optical microscope (OM). The removal rate (RR) of GST was calculated using the thickness difference between pre- and post-CMP with 9 points.

In order to check the variations of Ge, Sb, and Te elements, the surface compositions of GST were scanned linearly using an energy dispersive spectroscope (EDS). All experiments were conducted at room temperature.

3. Results and discussion

Figure 2 shows that the variations of RR of GST with pressure calculated using both IC1010 pads and Politex reg pads, respectively. The RR of GST increases with the increase of pressure for both pads. However, the RR of GST, calculated using the IC1010 pad is far more than that using Politex reg, which may be due to the different fundamental mechanisms for the pressure dependence of RR between the hard- and soft-pad in the CMP process.[17] For a CMP process with a hard pad, the increase in the applied force causes the increase in the indentation depth of abrasive particles into the wafer which contributes to film removal,[18,19] but for a soft pad, the increase in the applied force to the wafer can increase the number of particles in contact with the wafer but not markedly increase the indentation depth of abrasive particles into the wafer.[20–22] For the polishing pad, the hardness values of IC1010 and Politex reg are Shore D 57 and Shore

D 13, respectively. GST material is a soft metal and its hardness value is 2.03 GPa. However, the hardness value of SiO_2 is larger than 5 GPa, which is far more than that of GST. IC1010, due to its high hardness, has a stronger mechanical action and makes the removal of soft GST alloy easy during CMP, and the increased pressure causes the indentation depth of abrasive particles into the wafer which promotes an increase of RR. For the Politex reg, the increase of pressure just increases the number of particles in contact with the wafer and contact area between wafer and pad, which also leads to the increase of RR, but the action is far less than that of IC1010.

Figure 3 shows the surface morphologies of blank wafers polished using IC1010 and Politex reg pads in the acidic slurry with OM, respectively. For the CMP with Politex reg, many spots are found on the GST surface, but few scratches are observed from 0.5 psi to 2.0 psi as shown in Fig. 3(a), a worse surface is gained at the low (0.5 psi) or high pressure (2.0 psi) as shown in Figs. 3(a) and 3(c). However, for the CMP with IC1010, the GST surface suffers serious scratches, but no spots are revealed (Fig. 3(b)). High pressure can result in more serious scratches due to the increase of indentation depth of abrasives into the wafer (Fig. 3(f)). In order to check the surface defect further, the surface morphology of GST is observed with SEM as shown in Fig. 4. It is found that no obvious spots are found in the GST surface using Politex reg (Fig. 4(a)), which is different from using OM. However, serious scratches are also found in the surface using IC1010 (Fig. 4(b)), which match well with the results obtained with OM. Compared with Politex reg, IC1010 has a strong mechanical action which causes serious scratches with the help of abrasives due to its high hardness. Politex reg, due to its low hardness and large asperities, has a mild mechanical action and abrasives of the slurry embed into the pad, not the wafer during GST CMP using Politex reg, therefore scratch formation could be avoided.

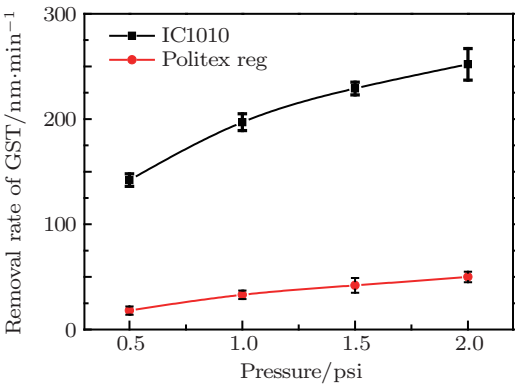


Fig. 2. (color online) Variations of the removal rate of GST with pressure, calculated using IC1010 and Politex reg pads, respectively.

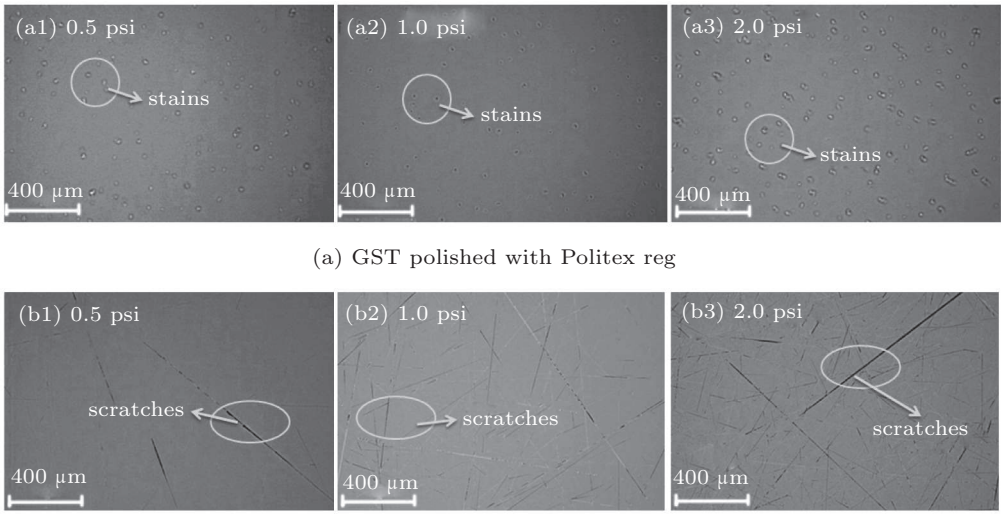


Fig. 3. Surface morphologies of blank GSTs polished using Politex reg and IC1010 pads with OM, respectively.

As is well known, Ge, Te, and Sb elements have different reactive capacities due to different standard reduction potentials of the elements.[23,24] It may lead to the selective corrosion of Ge, Sb, and Te, causing a stoichiometric change of $Ge_2Sb_2Te_5$ at a-GST film surface. Therefore, the surface composition of polished GST was scanned linearly to analyze the variations of Ge, Sb, and Te as shown in Fig. 5. The curves of Ge, Sb, and Te for as-deposited GST keep stable and have few fluctuations (Fig. 5(g)). For the chemical mechanical planarization with Politex reg, there are a few variations of surface compositions about Ge, Sb, and Te from 0.5 psi to 2.0 psi compared with as-deposited GST. The curves of Ge, Sb, and Te each have a serious fluctuation in the 2.0-psi condition (Fig. 5(c)), it seems to be a wise choice for better GST performance at low pressure. For the chemical mechanical planarization with IC1010, the curves of Ge, Sb, and Te elements below 1.0 pressure (Figs. 5(d) and 5(e)) are nearly comparable to the as-deposited, but it has a serious fluctuation in the 2.0-psi condition (Fig. 5(f)). Therefore, high pressure is not beneficial to surface performance during GST CMP with IC1010.

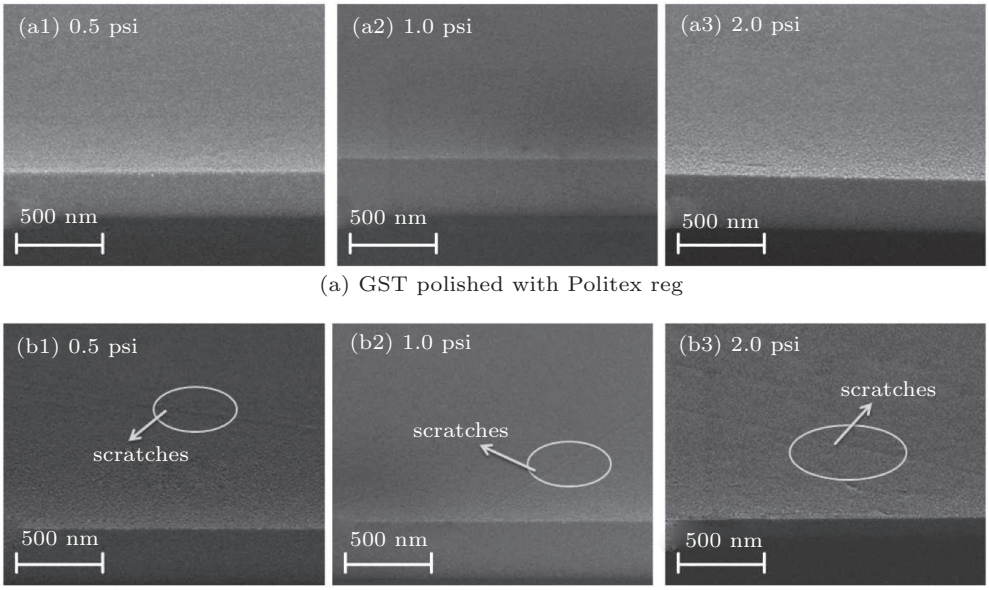


Fig. 4. Surface morphologies of blank GSTs polished using Politex reg and IC1010 pads with SEM, respectively.

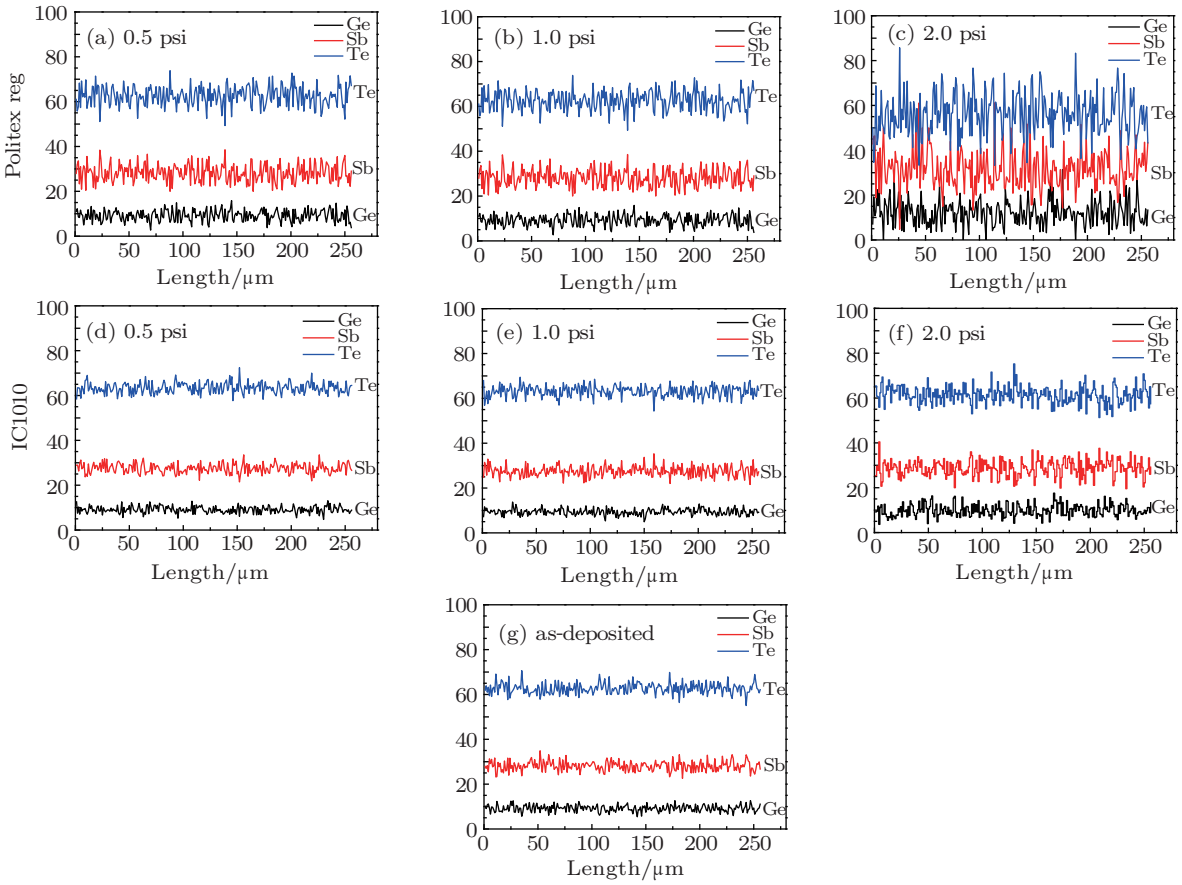
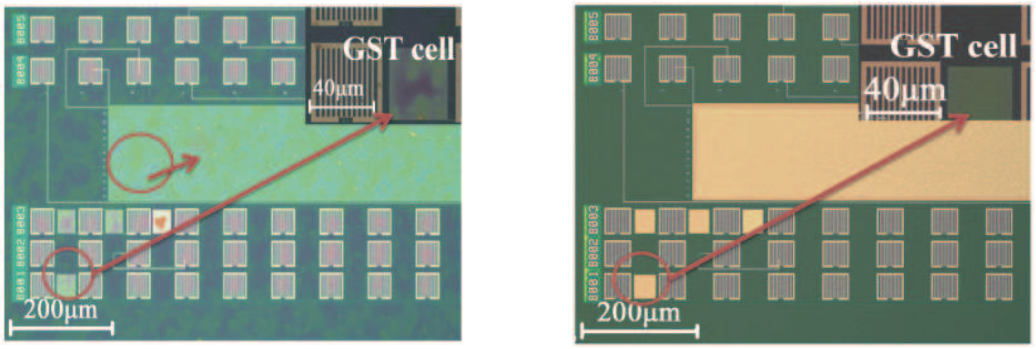


Fig. 5. (color online) Surface compositions of Ge, Sb, and Te elements for blank GST polished with linear scanning.

According to the results of the blank wafer, the polishing condition is optimized in consideration of RR, the selectivity of RR (GST/oxide) and the surface defects, which seems to be a better choice for patterned wafer polished with 1 psi pressure. Figure 6 shows the surface morphologies of patterned GST polished using IC1010 and Politex reg in the acidic slurry with OM, respectively. For CMP with Politex reg, it is shown that a few stains of GST cell are obtained, but many GST residues are found on other locations (Fig. 6(a)). However, for CMP with IC1010, a clean surface is achievable, and almost

no scratches are observed (Fig. 6(b)), which is different from the blank wafer. The scratch disappearance may result from the high-hardness SiO_2 film on the surface, instead of soft GST across the whole wafer. Therefore, it is preferable for the patterned wafer to be polished using IC1010. The surface morphology and cross section are analyzed to check the GST



(a) Politex reg (b) IC1010

Fig. 6. (color online) Surface morphologies of patterned GST wafer polished using Politex reg and IC1010 pads, obtained with OM.

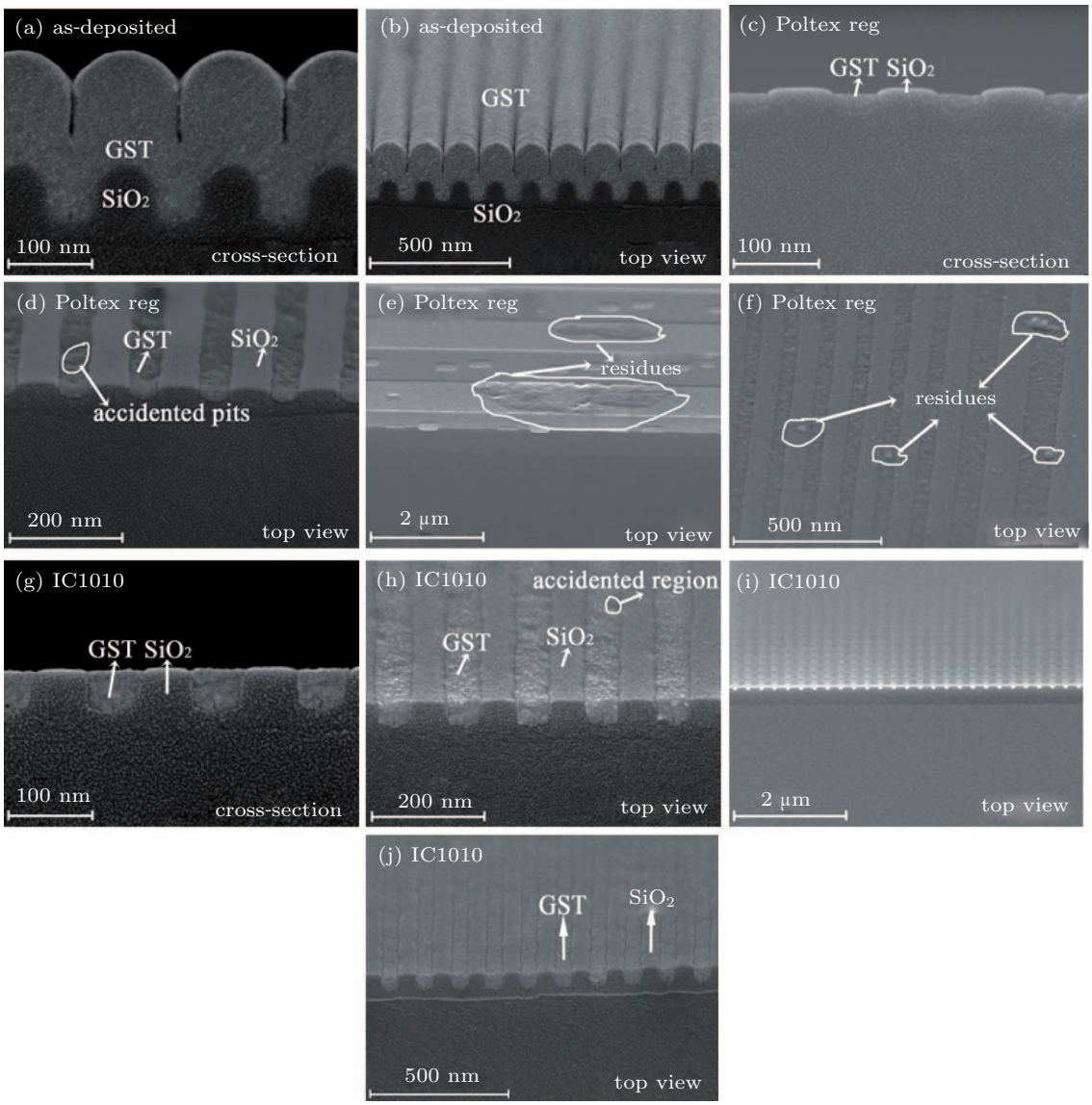


Fig. 7. Images of the surface morphology and cross section of the patterned wafer polished using Politex reg and IC1010 pads with SEM, respectively.

performance in detail as shown in Fig. 7. For the CMP with IC1010, a clean surface and no residues are observed on the GST line and space with about a 60-nm-wide damascene trench as shown in Figs. 7(g)–7(j). A few accidented regions occur on the GST line (Fig. 7(h)), the dielectric loss is less than 12 nm although there is much overpolishing. Less dielectric loss may result from the high selectivity of RR (>100) during CMP with IC1010. However, for the CMP with Politex reg, a few residues are observed on the GST cell (Fig. 7(f)), more residues or byproducts are present on other locations (Fig. 7(e)), more than 45-nm dielectric loss and serious dishing (8 nm) locations are revealed (Fig. 7(c)). What is more, serious accidented regions occur on the GST line (Fig. 7(d)). Politex reg, due to high compressibility and large asperities, makes it easy to deform and cause higher local pressure on the high density array of the GST cell. Therefore, the GST cell is polished more quickly than other areas, few residues of GST cell can be achieved, whereas many GST byproducts and residues still adhere to other locations across the wafer. These residues and byproducts can be wiped off by increasing the amount of overpolishing, which however causes serious dielectric losses. Compared with Politex reg, a GST patterned wafer polished with IC1010 can achieve a better performance and seems to be a better choice for the fabrication of PCM.

4. Conclusions

In the paper, GST CMP is investigated using IC1010 and Politex reg pads in acidic slurry. For the CMP with a blank wafer, it is found that the RR of GST increases with the increase of pressure for both pads, but the RR of GST polished using IC1010 is far higher than that of Politex reg. To check for surface defects, the polished GST surface is observed by OM and SEM separately. It is shown that many spots on the GST surface using Politex reg and little scratches can be found with OM, but no obvious spots are observed with SEM. However, the polished GST surface using IC1010 suffers serious scratches observed with both OM and SEM, which may result from a low hardness of GST compared with those of IC1010 and the abrasives. The surface scan of GST with EDS shows that better surface performance can be achieved at low pressure due to a few variations in the surface composition of Ge, Sb, and Te elements. For a patterned wafer with Politex reg, a few stains of GST cell are observed, but many GST residues are found at other locations, observed with OM. SEM results show that a few residues of GST cell occur, whereas more GST byproducts and residues are found at other locations across the wafer, and more oxide losses are revealed. However, for CMP with IC1010, a clean surface can be achieved, and almost no scratches are observed with OM, which may result from the high-hardness SiO_2 film on the surface, not the soft GST film across the whole wafer. The clean surface with no residues is observed on the GST line and space, and less oxide loss which may result from the high selectivity of RR is obtained although with much overpolishing. Compared with Politex reg, GST patterned wafer polished with IC1010 can achieve a better performance and seems to be a better choice for the fabrication of PCM.

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