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Influence of Polishing Parameters on Chemical Mechanical Polishing Processes of $LiTaO_3$ Wafer

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Abstract. Lithium tantalite ($LiTaO_3$) possesses a combination of unique electro-optical, acoustic, piezoelectric, pyroelectric and non-linear optical properties, making it a suitable material for applications in high frequency, broad width-band SAW and BAW components, filters in television receivers, etc. The surface quality of $LiTaO_3$ wafers decides the performances of the devices. In this paper, the technique of chemical mechanical polishing (CMP) was used to polish $LiTaO_3$ wafers. The influences of the polishing parameters on the CMP processes of $LiTaO_3$ wafers were analyzed in detail based on the measurement of the material removal rate, surface roughness and topograph of the polished wafers in different polishing conditions.

Introduction

Lithium tantalite single crystal $LiTaO_3$ possesses a combination of unique electro-optical, acoustic, piezoelectric, pyroelectric and non-linear optical properties [1]. It has been widely used in high frequency, broad width-band SAW components, filters in television receivers, etc.

It is difficult to obtain high-quality polished surface of $LiTaO_3$ crystal because the crystal is very brittle and soft (Moh hardness 5.5). The polished surfaces usually are observed with digs, scratches, dislocations, microcracks and even cleavages, which would influence greatly the performances of the components. $LiTaO_3$ wafers are polished currently by chemical mechanical polishing (CMP) mostly. CMP technique has been widely used in planarizing semiconductor wafers and attracted more and more attention from the researchers [2-4]. The success of CMP operations depends on the material removal rate and the polished surface quality. The polishing parameters have a complicated influence on the material removal rate and the polished surface quality of CMP operations. Few researches on the polishing process of $LiTaO_3$ crystal wafers have been reported.

Experiment

The CMP experiments were conducted on a polishing machine equipped with correction rings. Woolen clothes and specially treated fabric clothes were used as polishing pad. The slurry was prepared mainly with abrasives, oxidant, suspending agent and alkali (KOH in this paper) to adjust pH value. Al_2O_3, SiO_2 and diamond grains were used as abrasives in the CMP processes. The polishing pressures of 3.63, 7.25 and 10.88kPa were applied, and the rotating speed n_p for the pad was 40, 50, 60, 70 and 80rpm. The weight of the wafer was measured with an electronic scale before and after polishing to assess the material removal rate. The surface roughness of the polished wafer was measured with surface roughness instrument SE-30C.

The $LiTaO_3$ wafers used in the scratching and CMP processes were 36° Y-cut with diameter of ϕ50.8mm and thickness of 0.5-0.8mm. The properties of $LiTaO_3$ crystal are listed in Table 1.

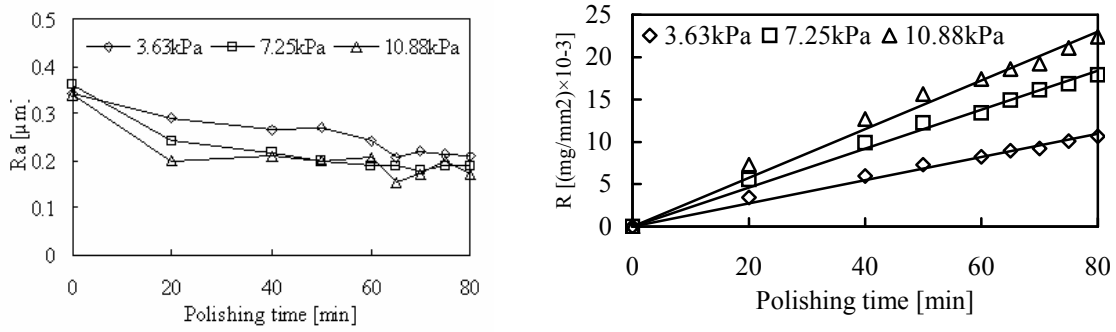
Table 1 Typical properties of $LiTaO_3$ crystal

Crystal structure	Rhombohedral space group 3M
Lattice Constant	(Hex) a = 5.154 Å c = 13.783 Å
Melting Point [^oC]	1650
Density [g /cm^3]	7.45
Hardness [Moh]	5.5
Thermal Expansion [$\times 10^{-6}$ / k]	a_a = 1.61 a_c = 4.1

Results and Discussion

The Effects of Polishing Pressure on the CMP Processes. As shown in Fig.1(a), the higher the pressure, the larger will be the decrement of the surface roughness of the polished wafers in the early polishing stage. It may be explained that the indentation of the abrasive particles becomes large because of small practical contact area between the wafer and the abrasive particles when the wafer surface is rough. With the progress of the polishing process, the decrement of the surface roughness goes small, and the surface roughness becomes relatively stable finally.

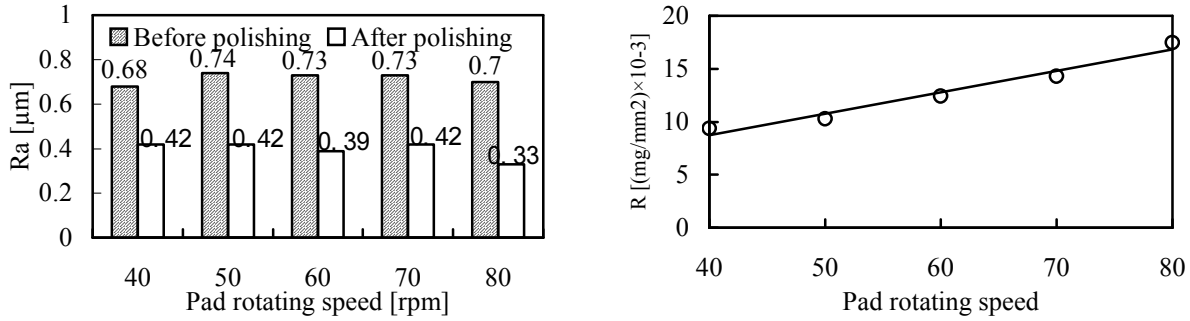
According to the Preston's equation [6], the material removal rate is directly proportional to both the applied pressure and the velocity of the polishing pad. In this study, the material removal rate increases with the increase of the pressure, which is consistent with Preston's equation, as shown in Fig.1(b).Based on the results in Fig.1, the pressure of 7.25kPa is the best one in this research for increasing material removal rate while improving surface roughness.



(a) Surface roughness (b) Material removal rate

(Polishing pad: woolen clothes; pad rotating speed: 60rpm; slurry: Al_2O_3 (W1.0): water: suspend agent = 5: 20: 1 (wt.); pH=10)

Fig.1 The effects of polishing pressure on the surface roughness Ra and Material removal rate R



(a) Surface roughness (b) Material removal rate

(Polishing pad: woolen clothes; polishing pressure: 7.25kPa; polishing time: 60min; slurry: Al_2O_3 (W1.0): water: suspend agent = 5: 20: 1 (wt.); oxidant 0.3%; pH=10)

Fig.2 The effects of pad rotating speed on the surface roughness Ra and Material removal rate R

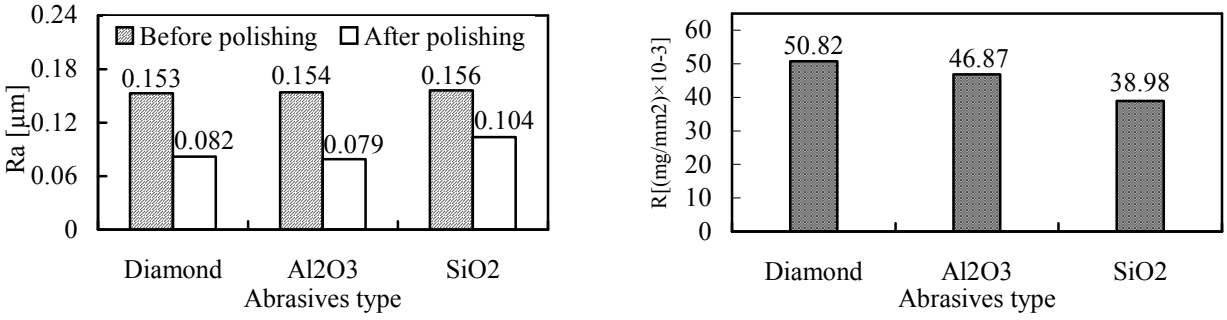
The Effects of Pad Rotating Speed on the CMP Processes. The relation between the material removal rate and the polishing speed is also consistent with Preston's equation, as shown in Fig.2(b). As for the surface roughness of the polished wafers, its decrement increases slightly when increasing the polishing speed, as shown in Fig.2(a). But the polishing machine vibrates when the rotating speed is 70rpm, which affects the surface roughness of the wafer.

With increasing polishing speed, the contact times among the wafer, abrasive and polishing pad increase, resulting in more friction and higher temperature in the contact area. As a result, the chemical reaction on the wafer surface becomes more active and the reactants are removed quickly, so that the material removal rate increases whiling the surface roughness of the wafer is improved.

The Effects of Abrasive Type on the CMP Processes. Different types of abrasive shows different influences on the CMP processes of $LiTaO_3$ wafers. The diamond abrasives have high hardness and sharp cutting edges. When Al_2O_3 abrasives are used in the CMP processes, the best surface roughness is obtained (in Fig.3(a)).There exists the highest material removal rate in the CMP processes with diamond abrasives, as shown in Fig.3(b). The surface roughness of the wafer decreases very slowly, and the material removal rate is the smallest among these with the types of SiO_2 abrasives used. The properties, such as hardness and brittleness, and the shape of the abrasives affect the cutting performances of the abrasives, and so the polishing results.

The Effects of Abrasive Size on the CMP Processes. In general, the surface roughness and the material removal rate increase with the increasing of the abrasive size, as shown in Fig.4. But the removal rate in the process with the abrasives of Al_2O_3 W0.05 is slightly higher than that with the abrasives of Al_2O_3 W1.0.

These results may be explained by the two mechanisms, namely, contact area mechanism and indentation – based mechanism mentioned in reference [7]. When using small abrasives, the contact area mechanism is predominated, and the indentation – based mechanism becomes more important as the slurry abrasive size increased. According to the contact area mechanism, the material removal rate is proportional to the total contact area between the abrasives and the wafer surface, and this mechanism is thought to enhance the chemical activity on the wafer surface. The indentation – based mechanism explains the material removal as a result of indentation created by the abrasive particles. The total indent volume is higher when larger particles are used [7].

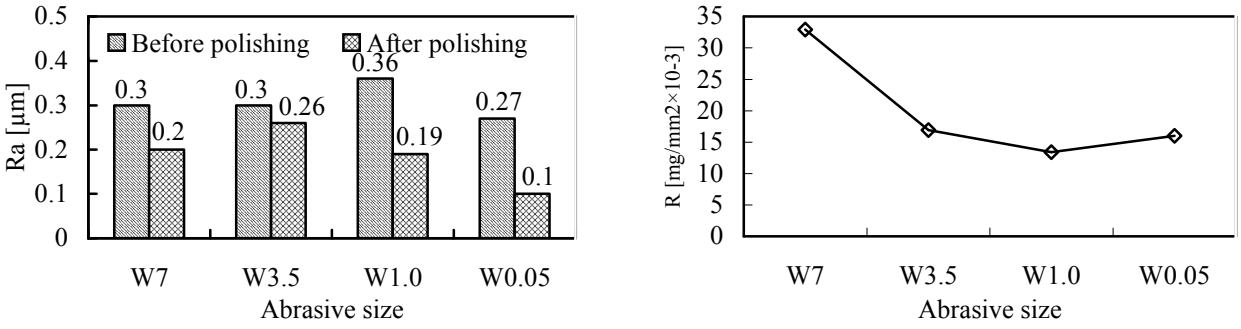


(a) Surface roughness (b) Material removal rate

(Polishing pad: specially treated fabric clothes; polishing pressure: 7.25kPa; pad rotating speed: 60rpm; pH=10; abrasive size: W0.5; polishing time: 120min.)

Fig.3 The effects of abrasive type on the surface roughness Ra and material removal rate R

The total contact area will increase with decreasing abrasive size. So, when the small size abrasives are used in the CMP processes, the polished wafer surface would be improved while a higher material removal rate may be expected because of the contact area mechanism. When the larger abrasives are used, the material may be removed mostly by the indentation – based mechanism, or mechanical mechanism. The lagers the size of the abrasive, the greater will be the material removal rate and the worse the polished wafer surface.



(a) Surface roughness (b) Material removal rate

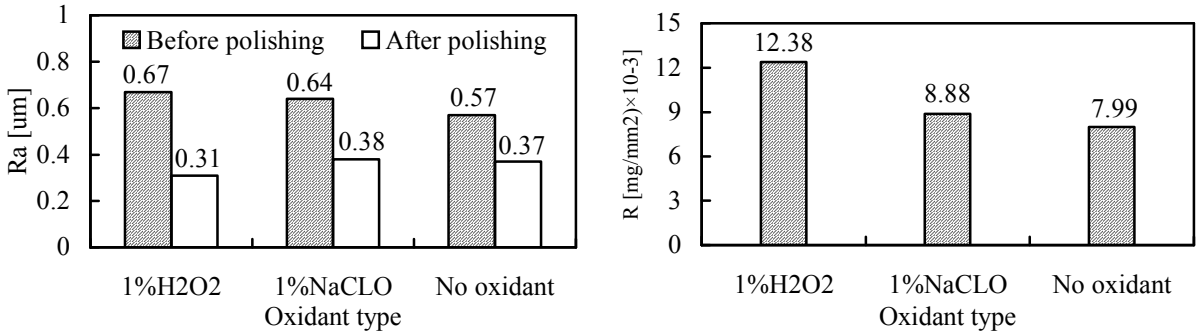
(Polishing pad: woolen clothes; polishing pressure: 7.25kPa; pad rotating speed: 60rpm; slurry: Al_2O_3 (W1.0): water: suspend agent = 5: 20: 1 (wt.); pH=10; polishing time: 60min.)

Fig.4 The effects of abrasive size on the surface roughness Ra and Material removal rate R

The Effects of Oxidant on the CMP Processes. The surface roughness of the wafers is improved and the material removal rate increases greatly when the oxidant H_2O_2 and NaClO are added into the slurry. H_2O_2 has much better effects on the CMP processes than NaClO, as shown in Fig.5.

The chemical reaction and polishing mechanism in the CMP processes of $LiTaO_3$ crystal wafers have been recently studied by our group[8]. It has been discussed that the oxidant in the slurry reacts with $LiTaO_3$ wafer surface, and then the reactants with the weakly bonded molecular are easily removed sequentially by mechanical action of the abrasives. As a result, the removal rate increases while the surface roughness is improved.

The properties and surface structure of the polishing pad play an important role in the CMP processes of $LiTaO_3$ wafers. The research results in this area will be reported in the near future.



(a) Surface roughness (b) Material removal rate

(Polishing pad: woolen clothes; polishing pressure: 7.25kPa; pad rotating speed: 60rpm; slurry: Al_2O_3 (W1.0): water: suspend agent = 5: 20: 1 (wt.); pH=10; polishing time: 60min.)

Fig.5 The effects of oxidant on the surface roughness Ra and Material removal rate R

Conclusions

The effects of pressure and polishing speed on the material removal rate are consistent with Preston's equation in the CMP processes of $LiTaO_3$ wafers.

In the early polishing stage, the higher the pressure, the larger will be the decrement of the surface roughness of the polished wafers. The decrement of the polished wafer surface roughness increases slightly when increasing the polishing speed.

There exist the highest material removal rate with diamond abrasives and the best surface roughness when using Al_2O_3 abrasives in the CMP processes.

In general, the surface roughness and the material removal rate increase with the increasing of

the abrasive size except that with the abrasives of Al_2O_3 W0.05.

Adding H_2O_2 into the slurry can improve the CMP results of $LiTaO_3$ wafers greatly.

Acknowledgements

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References

[1] *http: //www.mt-berlin.com/frames_cryst/descriptions/lnb_lta.htm*

[2] H. Lei, J. B. Luo and J. J. Ma: Lubrication Engineering, (2002) No.4, pp.74.

[3] Y.W. Zhao, L. Chang and S.H. Kim: Wear, Vol.254 (2003), pp.332.

[4] Y.W. Zhao and J.J. Liu: Tribology, Vol.24 (2004) No.3, pp.283.

[5] Z.R. Xia, C.Z. Li and K. Cui: Journal of Synthetic Crystals, Vol.30 (2001) No.4, pp.419.

[6] F.W. Preston: J. Soc. Glass Tech. Vol.XI (1927), pp.214.

[7] G.B. Basim, J.J. Adler, U. Mahajan, R.K. Singh and B.M. Moudgil: Journal of The Electrochemical Society, Vol.147 (2000) No.9, pp.3523.

[8] X. Wei, H. Yuan, H.W. Du, W. Xiong and R.W. Huang: Key Engineering Materials, (2005) (Received, to be pressed)