Glass (SiO_2) CMP using an innovative chamber type polishing machine with high-pressure gasses and manganese oxide slurries

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Motivation of the research

High functional glasses: - applied to display FPD, memory HDD, exposure photo mask, optical fiber, etc.,

High quality, high accuracy and high efficiency finishing

Polishing of glasses and quartz substrates, etc.,

A lot of cerium oxide (CeO_2 ,ceria) is used as slurries

Planarization CMP of oxide films for LSI devices

Application of slurry with ultra-fine ceria abrasives

Cerium (Ce) & cerium oxide (CeO_2)

One of the rare metals, and applied massively to advanced technological fields.

- **Depletion of cerium has become a controversial issue worldwide**
- **Development of resource saving slurry has become essential and urged for the good of this earth**

Objectives of this research

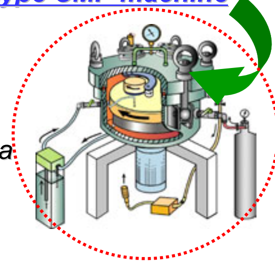
1) Understanding **polishing characteristics of glasses** by ceria slurry
→ reduction of slurry consumption

2) Discussions on the mechanism of glass polishing
→ Search for other abrasives with **oxidization actions** as ceria abrasives
Focused attention on **manganese oxide particles**

Comparison with polishing characteristics between ceria and manganese oxide slurry

3) Introduction of **an atmosphere-controlled, closed type CMP machine**
→ creating radical environment in the polishing area

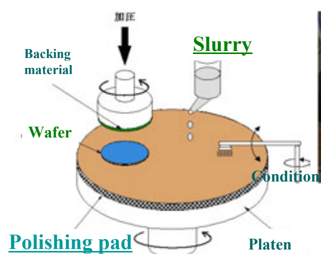
① Conditions to reduce ceria slurry
② Effective polishing methods and conditions of manganese oxide slurry as an alternative for ceria



4) Proposal of **the effective processing conditions** for glass substrates

Experimental Machines & Polishing Conditions

Workpiece	Glass substrates (soda lime glass), ϕ 2"x t1.8mm
Polishing Machine	"Conventional machine": Ring type polishing machine (Lapmaster Co., LM-15) "Bell-jar machine": *Closed atmosphere controlled Bell-Jar shaped CMP machine* (Prototype) Pressure inside the Bell-Jar: -100 ~ +500 kPa (Gauge pressure) Gas : Air, Oxygen, Nitrogen, or in vacuum
Slurry	- CeO_2 slurry (Showa Denko K.K, Shorox-V2104, p.s:0.35 μm) - MnO_2, Mn_2O_3-(a), Mn_2O_3-(b), Mn_3O_4 slurries (prototype, p.s.:0.2 - 0.4 μ)
Pad	Foamed polyurethane (ϕ 320mm) (Nitta-Haas Co., MH-N15A)



"Conventional machine"

"Bell-jar machine"

The processing atmospheres and their pressures should have large influence on the removal rates.

Construction drawing of the bell-jar shaped CMP machine
(Moving-mechanism inside the Bell-jar)

Experimental Machines & Polishing Conditions

Workpiece	Glass substrates (soda lime glass), φ 2"x t1.8mm
Polish Machine	ine: Ring type polishin Closed atmosphere cont polishing machine (Proto Pressure inside the Bell-Jar: -100 ~ +50 (Gauge pressure) Gas : Air, Oxygen, Nitrogen, or in va
Slurry	- CeO_2 slurry (Showa Denko K.K, Shorox V2104, p.s:0.35 μm) - MnO_2, Mn_2O_3-(a), Mn_2O_3-(b), Mn_3O_4 slurries (*prototype*, p.s.:0.2 - 0.4 μm)
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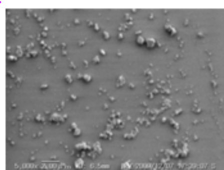
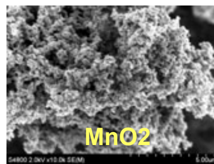
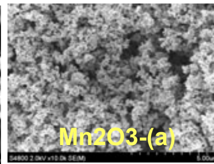
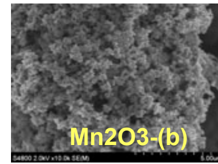
Commercially available ceria slurry

Four different type of manganese oxide slurries

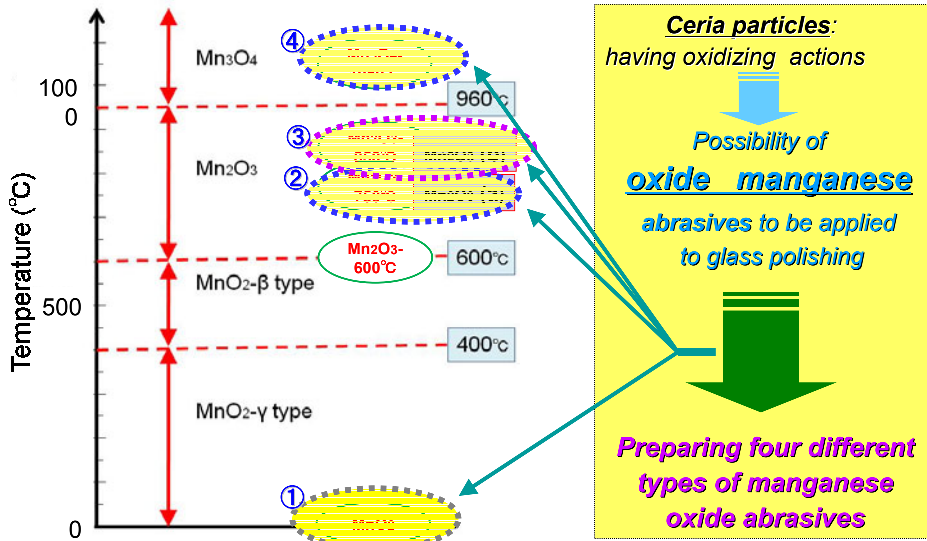








CeO2 prototype manganese oxide 3μm



Change of valence of manganese oxide abrasive with annealing temperature

Experimental Machines & Polishing Conditions

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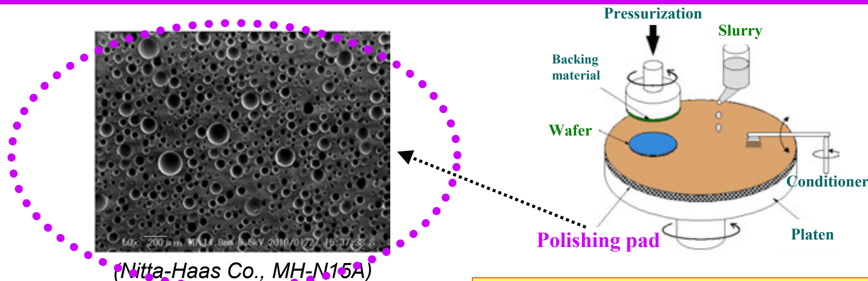

Next Slides ➡ Experimental Results

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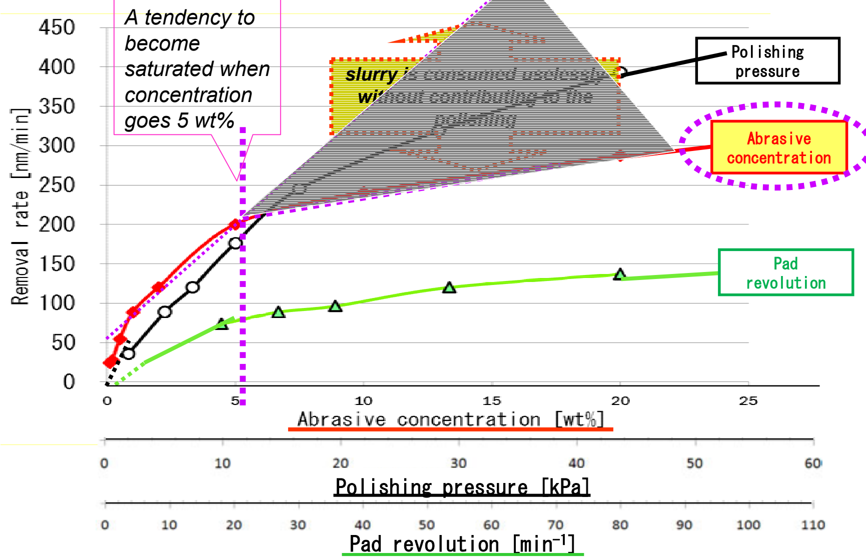

Basic polishing characteristics of glass substrates with ceria slurry by a conventional CMP machine

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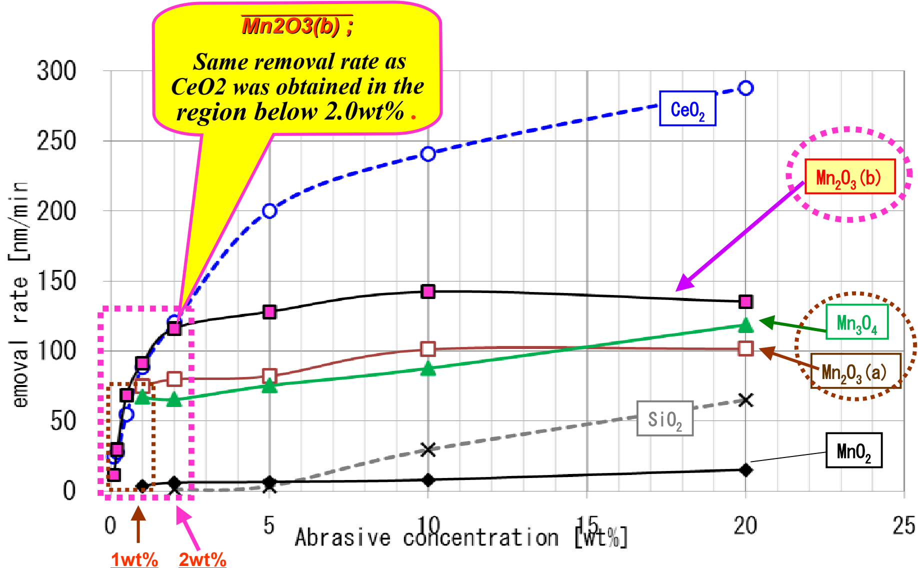
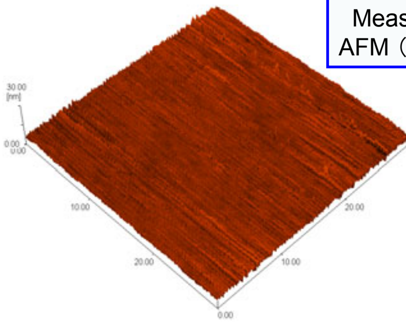
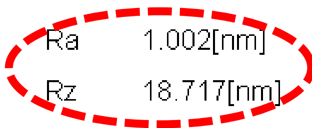


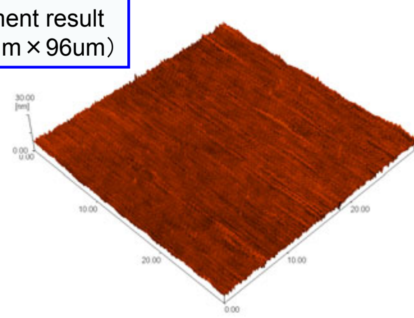
Relations between the removal rates and abrasive concentrations by manganese oxide slurries with a conventional CMP machine

Measurement result
AFM（128um×96um）

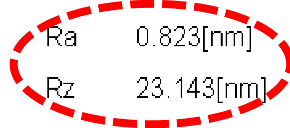


Polished with CeO_2 Slurry





Polished with Mn_2O_3-(b) Slurry



Surfaces roughness of glass substrate polished (AFM)

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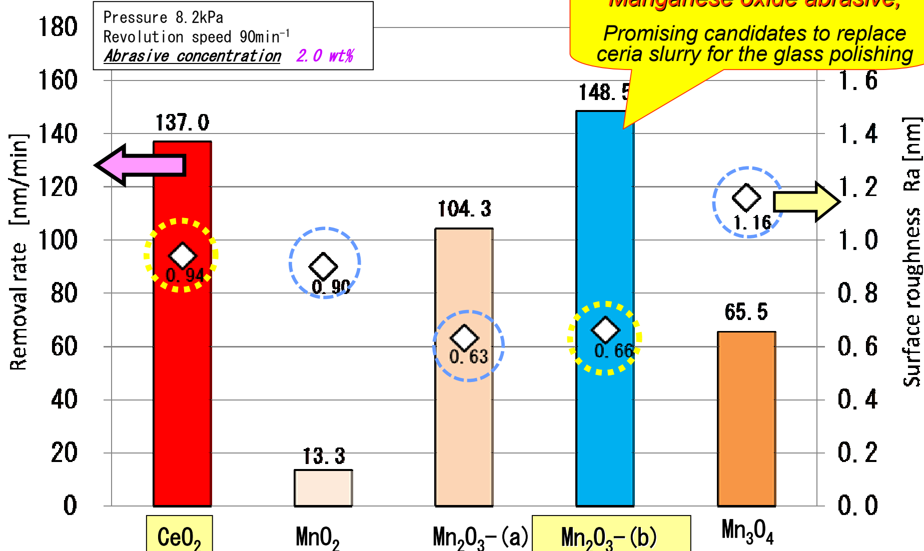
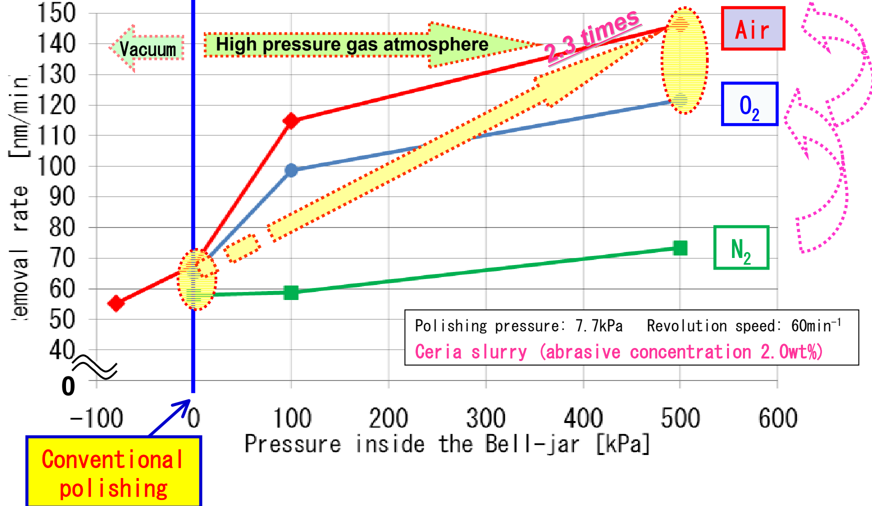
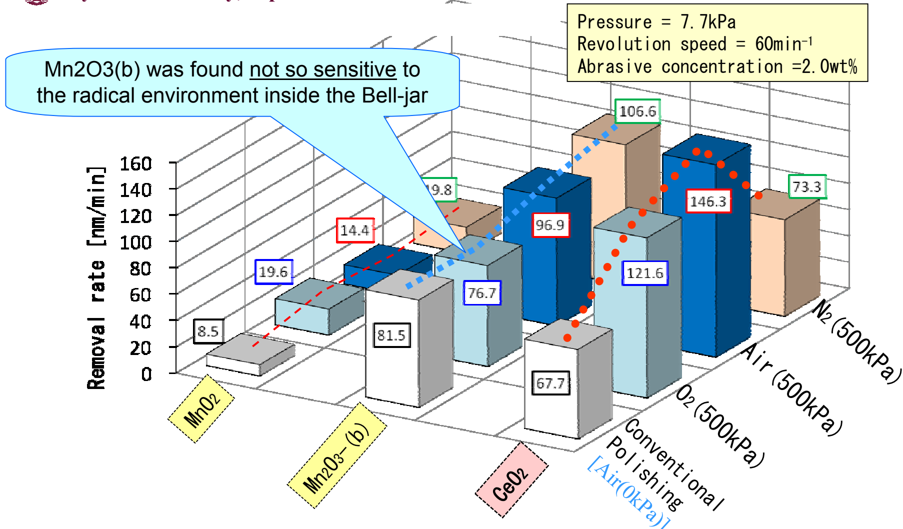


Removal rates and glass surface roughness by type of slurry at 2wt% abrasives by a conventional machine



(Polishing characteristics by applying "Bell-jar CMP machine")

Relation between the removal rates of glass substrate and pressures inside Bell-jar using ceria slurry



Comparison of the increasing ratio of the removal rates with various slurries and gases using a Bell-jar machine

Abrasives having strong oxidization actions are not always good for glass polishing

➡ It is necessary to tailor **the radical environment for each properties of the slurry**

Conclusions

We aimed to reduce the consumption of ceria slurry, and found that manganese oxide slurries give better performance to that of ceria for glass polishing with the conventional CMP machine.

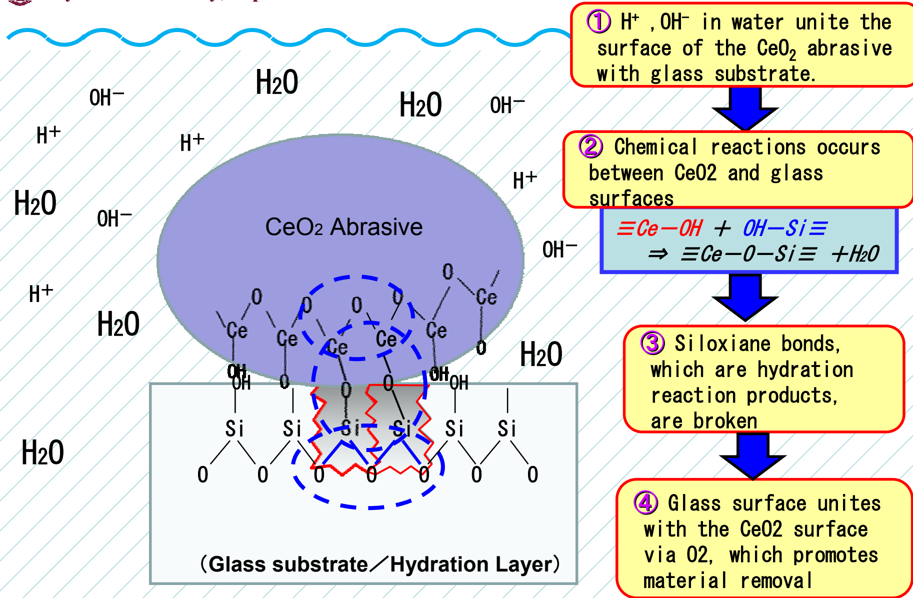
When a new, closed-atmosphere controlled, Bell-jar CMP machine was applied, more effective polishing results were obtained.

Thank you for your attention !

"Bell-jar shaped CMP machine for a next generation polishing technology"

Suggestions for effective processing conditions of glass substrates

Ceria slurry	**Abrasive concentration of 5 wt%**
Manganese oxide slurry	**Mn_2O_3(b) slurry at 5wt%** → Alternative for ceria slurry Removal rate: equal to or better than ceria slurry Surface roughness: better roughness than ceria slurry
Radical polishing environment	***Effective conditions for atmosphere-controlled, closed type CMP machine:*** ***Polishing by ceria slurry;*** → ***high pressure air atmosphere*** *MnO_2 slurry: high pressure N_2 atmosphere (however, removal rate is low)* *Mn_2O_3 slurry: high pressure N_2 atmosphere*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① H+ , OH− in water unite the surface of the CeO2 abrasive with glass substrate.
② Chemical reactions occurs between Ce02 and glass surfaces
≡Ce−OH + OH−Si≡ ⇒ ≡Ce−O−Si≡ +H2O
③ Siloxiane bonds, which are hydration reaction products, are broken
④ Glass surface unites with the Ce02 surface via 02, which promotes material removal
H2O
OH−
H+
CeO2 Abrasive
(Glass substrate／Hydration Layer)
Processing mechanism of glass polishing
Prof. T. Doi
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