Technical Data
Pressing & Forming
for Low Tg Optical Glasses

Ver. 9.1 – 1/28/2022

OHARA

Revision history

Ver.	Publication date	Subject
2.0	2007/04/01	Revised edition published
2.1	2008/08/01	Revised edition published
2.2	2009/04/10	Revised edition published
3.0	2010/04/06	Ver.3.0 issued by molding evaluation retest due to renewal of evaluation molding machine
3.1	2011/12/15	Revised due to revision of the scope of preform support
3.2	2012/04/18	Revision due to addition of new glass type (L-BBH2) and revision of preform support range
3.3	2012/12/11	New glass type added (L-BAL43)
3.4	2012/12/18	L-BBH2Revised coefficient of thermal expansion of glass near molding temperature（P.25）
4.0	2013/04/19	New glass type added（S-FPM3）
		L-BAL42プリフォーム対応範囲の拡大（P.30）
		L-PHL1 - Delete
4.1	2013/06/27	2.2Evaluation result for the compatibility of the mold coating with OHARA's glass types（P.8）
		5.2 Mold Press Reference Data List L-LAL 67 - Delete (P.28)
4.2	2013/11/01	5.2 Corrected the supply form of our low Tg optical glass mold press reference data list for glass mold (RP product, round bar cutting product, spherical polishing preform added), Corrected L-BAL43 post-press Nd value（P.28）
		5.3 List of Low Tg Optical Glass（P.29）
5.0	2014/04/11	New glass type added（L-LAH90，L-LAH91）
		L-BBH2，L-LAH81，L-LAH83，L-LAH85，L-LAH87，L-LAM72，L-NBH54，L-PHL2，L-TIH53 - Delete
6.0	2015/01/14	New glass type added（S-FPL55）
		FG (Fine Gob) removed from supply form
		L-BAL42and Carbon-based Molded Thin Films (Molded Product: △⇒◎) (P.9)
		5.3 Added our lineup of low Tg optical glass refractive index for glass molds (P.28)
6.1	2015/11/12	L-BBH1, L-TIM28, L-LAH53, L-LAH84Refractive index, change Abbe number
		Changed Abbe Number to 2 digits
7.0	2016/02/24	New glass type added（L-LAH94）
8.0	2016/06/08	New glass type added（L-LAL15） 5.5 Add low Tg optical glass Nd-Vd map for our glass mold(P.31)
8.1	2016/09/23	3.3 Cooling rate and refractive index after molding for each glass type Correction of Nd data of S-FSL5 (P.13, P.17, P.28) Corrected the contact information of OHARA GmbH (P.32)

8.2	2017/09/01	L-BBH1, L-LAL12 - Delete
8.3	2018/06/05	5.3 List of Low Tg Optical Glass (P.28) L-LAH84P - Delete
8.4	2019/06/06	L-LAH86 - Delete
9.0	2019/12/01	New glass type added (S-FPM4) Update Catalog Value of Wear Level (P.27)
9.1	2022/01/28	New glass type added (S-FPM5) Update of expansion coefficient of glass near molding temperature (P.26, P.27) PF morphology map deleted

1. Glass mold forming (pressing)

1.1 The fundamental concept of glass mold forming (pressing)

The process of glass mold forming(pressing) is as follows:

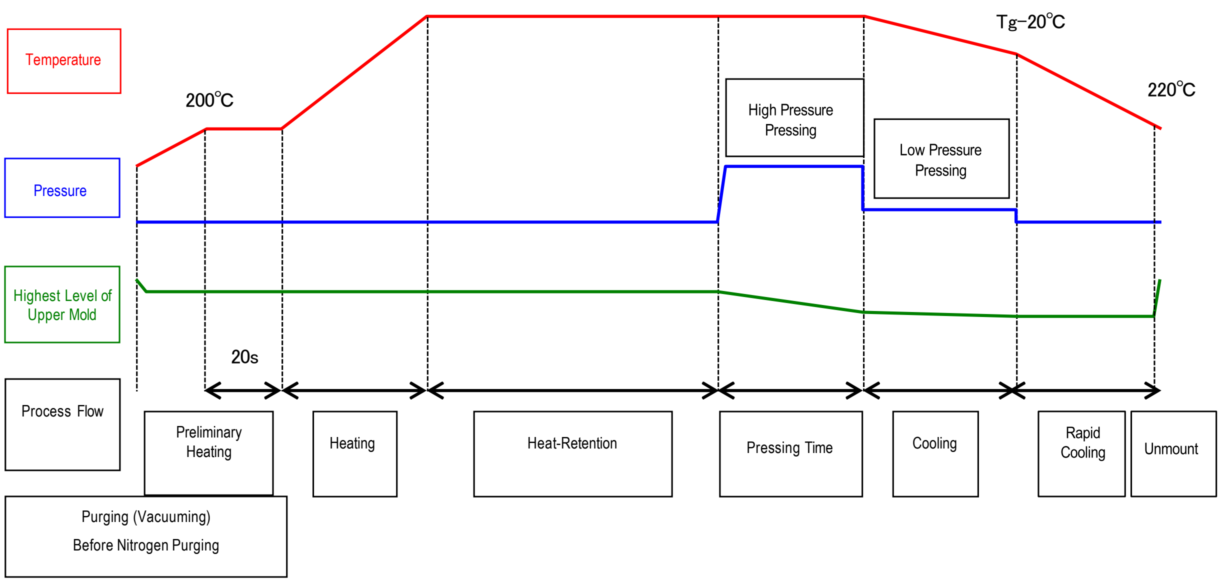
1. The glass(preform) is placed between the upper mold and the lower mold.
   Those molds are specular surface processed in high accuracy, and the surface is coated to prevent the glass from sticking in the mold.
2. The glass is heated up to a temperature that can be transformed.
3. The shape of the upper and lower mold is transcribed in the glass by pressurizing (press).
4. The pressured molds are cooled down to the temperature of Tg or less without taking out the glass while controlling the cooling rate.
5. The glass is taken out from the molds.

In general, the heating temperature for press forming is between at (Yield temp) – SP (Softening Point). The higher temperature (closer to SP) makes the pressing time shorter. However, a higher temperature will cause the molding to shrink more when cooling, resulting in surface recesses. Additionally, under a higher temperature some glass types will cause an out-gassing effect resulting in staining of the surface. Therefore, we recommend forming the glass under low temperature.
In addition, the surface recesses caused by pressure will be limited when forming under low temperature.

1.2 Evaluation tests: basic molding pattern of press molding at OHARA

The data in this brochure was obtained utilizing the molding conditions shown in the following graph.

The information shown illustrates OHARA's test forming and molding conditions.
Please use this data for reference purposes only.
This is not the conditions of forming and molding OHARA recommends.



1.3 Basic condition of press forming at OHARA

Glass Type	Condition of Press Forming					
	Heat-Retention		High Pressure Pressurizing		Cooling & Low-Pressure Pressurizing	
	(°C) Temperature	(s) Time (Sec.)	(N) Pressure	(N/s) Pressurizing inclination	(N) Pressure	(°C) Ending Temperature
S-FPL51	514	60	1000	100	100	438
S-FPL53	478	60	1000	100	100	406
S-FPL55	480	60	1000	100	100	415
S-FPM2	613	70	1000	100	100	535
S-FPM3	554	60	1000	100	100	479
S-FPM4	530	60	1000	100	100	468
New! S-FPM5	525	60	1000	100	100	454
S-FSL5	600	60	1000	100	100	480
L-BAL35	587	60	1000	100	100	507
L-BAL42	564	60	1000	100	100	486
L-BAL43	559	60	1000	100	100	473
L-BSL7	573	60	1000	100	100	478
L-LAL13	594	70	1000	100	100	514
L-LAL15	582	60	1000	100	100	505
L-LAM60	603	60	1000	100	100	521
L-LAM69	552	60	1000	100	100	477
L-LAH53	625	70	1000	100	100	554
L-LAH84	593	60	1000	100	100	507
L-LAH85V	672	80	1000	100	100	593
L-LAH90	670	60	1000	100	100	592
L-LAH91	669	60	1000	100	100	591
L-LAH94	648	70	1000	100	100	573
L-TIM28	550	60	1000	100	100	484

- Pressing Machine: GMP-0204V (TOSHIBA)
- Information of Preform: φ 7.24 (0.20cc) Polished Ball
- Shape of Pressing: R20 convex on both sides, center thickness 3.3mm
- Pressing Time with Pressure: 45 sec.

The information shown is OHARA's test forming and molding conditions. Please use this data for reference purposes only.
This is not the conditions of forming and molding OHARA recommends.

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2. Compatibility of the mold coating with the glass

2.1 Evaluation points for the compatibility of the mold coating with the glass

We evaluated the following points to check the compatibility of the thin mold coatings and the glass elements.

① Evaluation of the lens appearance

Surface inspection of the molding tools using a microscope and visual check for damages such as coating peel-off or coating degradation.

② Evaluation of surface of thin coating

Surface inspection of the molding tools using a microscope and visual check for damages such as coating peel-off or coating degradation.

2.2 Compatibility evaluation result of the thin mold coatings and OHARA's glass types

Since many different elements are contained in the compositions of our L glass types, the molded glass lenses may adhere to the mold or become hazy (an indication of a rough surface). This may depend on the forming conditions, including the materials used in the thin mold coatings. We conducted various tests to evaluate the compatibility of typical thin mold coatings and our Low TG glasses. Please use this information for reference purposes only.We are not recommending a thin mold coating material or guaranteeing certain results using any thin mold coating material. Actual compatibility results will vary due to the molding machines and molding conditions used.

Criterion for compatibility evaluation of the thin coatings of mold with OHARA glass

Mark	Evaluation Result ／Judge
◎	Good
○	Some deterioration
△	Minor defects
×	Major Defects

Compatibility evaluation result of the thin mold coatings under Ohara test conditions.

Glass Type	Type of Thin Mold Coat	Number of shots	Appearance			Judge
			Glass Lens	Thin Mold Coating	Type of Defect	
S-FPL51	Carbon	10	◎	◎		◎
	Transition Metal	4	×	×	Adhesion	×
	Precious Metal	10	◎	◎		◎
S-FPL53	Carbon	10	○	◎	Very Slightly Hazy	○
	Transition Metal	10	○	◎	Very Slightly Hazy	○
	Precious Metal	10	◎	◎		◎
S-FPL55	Carbon	10	△	◎	Slightly Hazy	△
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎
S-FPM2	Carbon	10	◎	◎		◎
	Transition Metal	1	×	×	Adhesion	×
	Precious Metal	1	×	×	Adhesion	×
S-FPM3	Carbon	10	◎	◎		◎
	Transition Metal	10	○	◎	Very Slightly Hazy	○
	Precious Metal	5	○	◎	Very Slightly Hazy	○
S-FPM4	Carbon	10	◎	◎		◎
	Transition Metal	10	◎	◎		◎
	Precious Metal	4	×	×	Adhesion	×
New! S-FPM5	Carbon	10	◎	◎		◎
	Transition Metal	1	×	×	Adhesion	×
	Precious Metal	1	×	×	Adhesion	×
S-FSL5	Carbon	10	◎	◎		◎
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎
L-BAL35	Carbon	10	△	◎	Slightly Hazy	△
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎
L-BAL42	Carbon	10	◎	◎		◎
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎
L-BAL43	Carbon	10	◎	◎		◎
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎
L-BSL7	Carbon	10	◎	◎		◎
	Transition Metal	10	◎	◎		◎
	Precious Metal	10	◎	◎		◎

We are not recommending a thin mold coating material or guaranteeing certain results using any thin mold coating material. Actual compatibility results will vary based on molding conditions. Also, the "haze" level is judged according to the Ohara standard. Your acceptance level may be different.

Compatibility evaluation result of the thin mold coatings under Ohara test conditions.

硝種 Glass Type	薄膜種別 Type of Thin Mold Coat	ショット数 Number of shot	外観 Appearance 成形品 Glass Lens	金型膜 Thin Mold Coating	不良内容 Type of Defect	判定 Judge
L-LAL13	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	8	×	◎	ワレ/Broken	×
	貴金属系/Precious Metal	10	◎	◎		◎
L-LAL15	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	10	△	×	融着/Adhesion	×
	貴金属系/Precious Metal	10	◎	◎		◎
L-LAM60	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	9	×	×	融着/Adhesion	×
	貴金属系/Precious Metal	10	△	◎	薄クモリ/Slightly Hazy	△
L-LAM69	炭素系/Carbon	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	遷移金属系/Transition Metal	10	◎	◎		◎
	貴金属系/Precious Metal	10	◎	◎		◎
L-LAH53	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	10	◎	◎		◎
	貴金属系/Precious Metal	10	◎	◎		◎
L-LAH84	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	10	◎	◎		◎
	貴金属系/Precious Metal	10	◎	◎		◎
L-LAH85V	炭素系/Carbon	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	遷移金属系/Transition Metal	10	△	◎	薄クモリ/Slightly Hazy	△
	貴金属系/Precious Metal	10	×	×	クモリ/Hazy	×
L-LAH90	炭素系/Carbon	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	遷移金属系/Transition Metal	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	貴金属系/Precious Metal	10	○	×	クモリ/Hazy	×
L-LAH91	炭素系/Carbon	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	遷移金属系/Transition Metal	10	○	△	薄クモリ/Slightly Hazy	△
	貴金属系/Precious Metal	10	△	×	融着/Adhesion	×
L-LAH94	炭素系/Carbon	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	遷移金属系/Transition Metal	10	○	×	クモリ/Hazy	×
	貴金属系/Precious Metal	10	△	×	融着/Adhesion	×
L-TIM28	炭素系/Carbon	10	◎	◎		◎
	遷移金属系/Transition Metal	10	○	◎	極薄クモリ/Very Slightly Hazy	○
	貴金属系/Precious Metal	10	◎	◎		◎

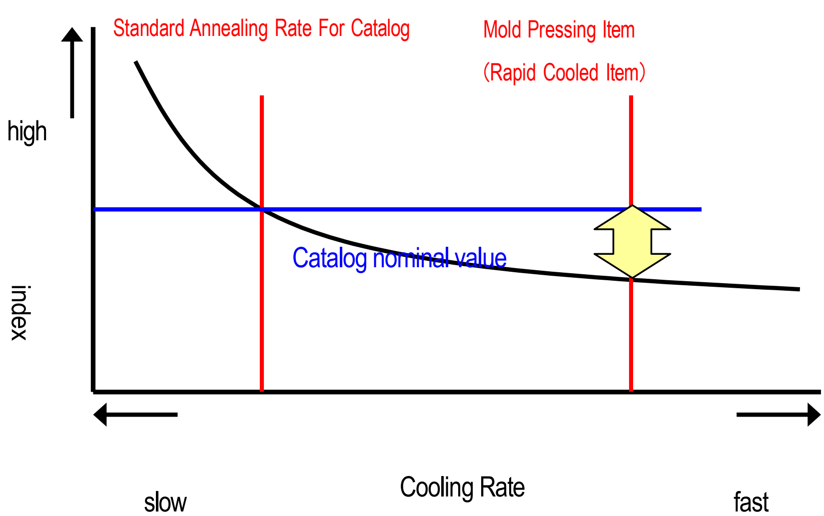
We are not recommending a thin mold coating material or guaranteeing certain results using any thin mold coating material. Actual compatibility results will vary based on molding conditions. Also, the “haze” level is judged according to the Ohara standard. Your acceptance level may be different.

3. Cooling rate during annealing and refractive index

3.1 Relationship between the annealing cooling rate and refractive index

The refractive index of the glass is adjusted by the rate of cooling during the annealing process. The figure below shows the relationship between the refractive index and the cooling rate.

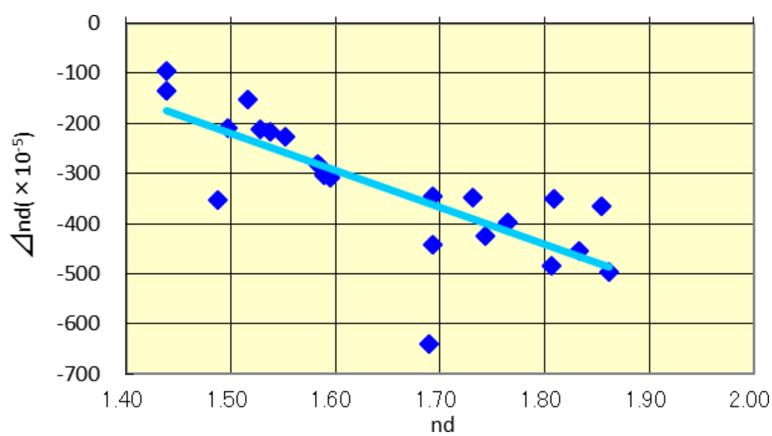
Since mold pressed lenses are cooled rapidly, the final refractive index would be lower than catalog value. In order to achieve catalog value, it is necessary to anneal using the suggested cooling rate after molding.



3.2 Relationship between refractive index and refractive index variation

The refractive index of L glass types will be affected by the cooling ra
solidification with low refractive index. The index change will v
types, the higher refractive index glass types have a
variation is shown in the figure below.

⊿nd shows variation of the refractive index at a cooling rate of 1°C/sec. We have plotted all low Tg Glass types in this figure.



3.3 Refractive index data at various

Under our test condition, the graphs below illustrate the relationship between cooling speed and refractive index of each glass type. Abscissa of axis and ordinate shows cooling speed and refractive index respectively. After the molding process, as the actual cooling speed of molding depends on the molding machine, molding condition, mold tool, lens shape, and measuring point, the data should be considered as a reference only.

Information of Preform: ϕ 7.24 (0.20cc) Polished Ball
Shape of pressing: R20 convex on both sides, center thickness is 3.3

Glass Type	Condition	(Pressing→220℃) Cooling Rate (℃/s)	nC	nd	ne	nF	ng	νd
S-FPL51	Before Pressing	0.0009	1.49514	1.49700	1.49845	1.50123	1.50451	81.54
	After Pressing	0.5	1.49327	1.49509	1.49649	1.49935	1.50261	81.4
		1.0	1.49310	1.49491	1.49632	1.49918	1.50244	81.4
		1.5	1.49298	1.49481	1.49621	1.49907	1.50232	81.3
		2.0	1.49288	1.49471	1.49611	1.49897	1.50222	81.3
S-FPL53	Before Pressing	0.0009	1.43733	1.43875	1.43985	1.44195	1.44442	94.93
	After Pressing	0.5	1.43608	1.43752	1.43862	1.44072	1.44316	94.6
		1.0	1.43596	1.43739	1.43849	1.44059	1.44303	94.8
		1.5	1.43584	1.43727	1.43838	1.44048	1.44292	94.7
		2.0	1.43578	1.43722	1.43832	1.44042	1.44286	94.6
S-FPL55	Before Pressing	0.0009	1.43733	1.43875	1.43986	1.44196	1.44444	94.66
	After Pressing	0.5	1.43649	1.43791	1.43903	1.44113	1.44360	94.4
		1.0	1.43637	1.43779	1.43891	1.44100	1.44348	94.5
		1.5	1.43626	1.43769	1.43880	1.44090	1.44338	94.4
		2.0	1.43620	1.43762	1.43874	1.44083	1.44331	94.4
S-FPM2	Before Pressing	0.0009	1.59255	1.59522	1.59732	1.60134	1.60612	67.74
	After Pressing	0.5	1.58957	1.59222	1.59431	1.59833	1.60310	67.6
		1.0	1.58925	1.59191	1.59399	1.59801	1.60281	67.5
		1.5	1.58907	1.59171	1.59381	1.59782	1.60261	67.6
		2.0	1.58894	1.59158	1.59368	1.59768	1.60247	67.6
S-FPM3	Before Pressing	0.0009	1.53555	1.53775	1.53947	1.54275	1.54664	74.70
	After Pressing	0.5	1.53361	1.53582	1.53754	1.54083	1.54470	74.3
		1.0	1.53339	1.53559	1.53730	1.54059	1.54446	74.4
		1.5	1.53324	1.53545	1.53716	1.54045	1.54431	74.3
		2.0	1.53314	1.53535	1.53705	1.54034	1.54421	74.4
S-FPM4	Before Pressing	0.0009	1.52630	1.52841	1.53006	1.53321	1.53694	76.46
	After Pressing	0.5	1.52435	1.52645	1.52811	1.53127	1.53498	76.1
		1.0	1.52419	1.52630	1.52796	1.53112	1.53483	76.1
		1.5	1.52410	1.52620	1.52786	1.53102	1.53473	76.1
		2.0	1.52400	1.52611	1.52777	1.53093	1.53464	76.0
New! S-FPM5	Before Pressing	0.0009	1.54963	1.55200	1.55386	1.55743	1.56167	70.70
	After Pressing	0.5	1.54754	1.54991	1.55178	1.55534	1.55957	70.2
		1.0	1.54736	1.54973	1.55160	1.55516	1.55939	70.2
		1.5	1.54726	1.54962	1.55149	1.55505	1.55929	70.2
		2.0	1.54717	1.54956	1.55141	1.55497	1.55920	70.2

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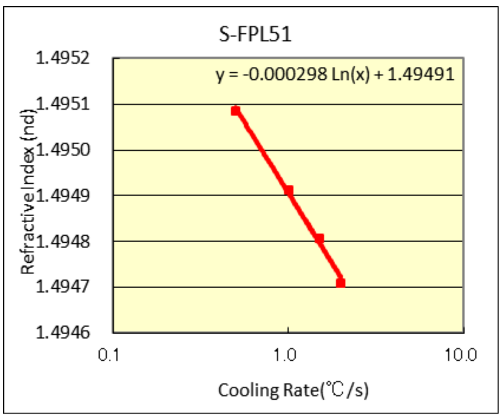
Glass Type	Condition	(Pressing→220℃) Cooling Rate (℃/s)	n_C	n_d	n_e	n_F	n_g	ν_d
S-FSL5	Before Pressing	0.0009	1.48534	1.48749	1.48915	1.49228	1.49596	70.23
	After Pressing	0.5	1.48224	1.48432	1.48603	1.48919	1.49283	70.1
		1.0	1.48188	1.48397	1.48568	1.48883	1.49247	70.0
		1.5	1.48168	1.48376	1.48547	1.48863	1.49227	70.0
		2.0	1.48152	1.48360	1.48532	1.48847	1.49211	69.9
L-BAL35	Before Pressing	0.0023	1.58618	1.58913	1.59143	1.59581	1.60100	61.15
	After Pressing	0.5	1.58353	1.58648	1.58877	1.59314	1.59831	61.1
		1.0	1.58316	1.58611	1.58840	1.59277	1.59793	61.0
		1.5	1.58293	1.58588	1.58816	1.59254	1.59770	61.0
		2.0	1.58275	1.58570	1.58799	1.59237	1.59753	60.9
L-BAL42	Before Pressing	0.0023	1.58013	1.58313	1.58547	1.58995	1.59528	59.38
	After Pressing	0.5	1.57762	1.58062	1.58297	1.58743	1.59275	59.2
		1.0	1.57733	1.58033	1.58267	1.58714	1.59246	59.2
		1.5	1.57712	1.58011	1.58246	1.58693	1.59227	59.1
		2.0	1.57697	1.57996	1.58231	1.58678	1.59211	59.2
L-BAL43	Before Pressing	0.0023	1.58274	1.58573	1.58807	1.59255	1.59786	59.70
	After Pressing	0.5	1.58022	1.58321	1.58554	1.59002	1.59534	59.6
		1.0	1.57987	1.58286	1.58520	1.58968	1.59500	59.5
		1.5	1.57969	1.58267	1.58502	1.58950	1.59482	59.4
		2.0	1.57954	1.58253	1.58487	1.58934	1.59468	59.4
L-BSL7	Before Pressing	0.0023	1.51385	1.51633	1.51825	1.52191	1.52620	64.06
	After Pressing	0.5	1.51251	1.51499	1.51693	1.52058	1.52487	63.8
		1.0	1.51232	1.51480	1.51673	1.52039	1.52469	63.9
		1.5	1.51217	1.51465	1.51658	1.52025	1.52454	63.7
		2.0	1.51206	1.51455	1.51648	1.52013	1.52444	63.8
L-LAL13	Before Pressing	0.0023	1.68955	1.69350	1.69661	1.70259	1.70974	53.18
	After Pressing	0.5	1.68650	1.69045	1.69356	1.69953	1.70667	53.0
		1.0	1.68609	1.69004	1.69315	1.69912	1.70628	53.0
		1.5	1.68582	1.68977	1.69288	1.69883	1.70599	53.0
		2.0	1.68564	1.68958	1.69270	1.69866	1.70581	53.0
L-LAL15	Before Pressing	0.0023	1.68906	1.69304	1.69616	1.70216	1.70932	52.9
	After Pressing	0.5	1.68515	1.68912	1.69225	1.69826	1.70542	52.5
		1.0	1.68465	1.68863	1.69178	1.69778	1.70494	52.4
		1.5	1.68447	1.68845	1.69156	1.69756	1.70472	52.6
		2.0	1.68421	1.68818	1.69130	1.69730	1.70447	52.5
L-LAM60	Before Pressing	0.0023	1.73866	1.74320	1.74679	1.75373	1.76207	49.29
	After Pressing	0.5	1.73485	1.73940	1.74298	1.74993	1.75824	49.0
		1.0	1.73441	1.73894	1.74254	1.74949	1.75783	49.0
		1.5	1.73413	1.73867	1.74226	1.74922	1.75755	48.9
		2.0	1.73395	1.73848	1.74208	1.74904	1.75737	48.9

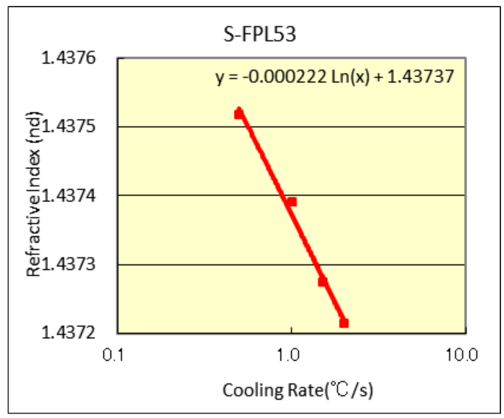
Glass Type	Condition	(Pressing→220℃) Cooling Rate (℃/s)	n_C	n_d	n_e	n_F	n_g	$ν_d$
L-LAM69	Before Pressing	0.0023	1.72542	1.73077	1.73505	1.74346	1.75379	40.51
	After Pressing	0.5	1.72237	1.72769	1.73196	1.74034	1.75060	40.5
		1.0	1.72196	1.72728	1.73154	1.73991	1.75018	40.5
		1.5	1.72169	1.72701	1.73127	1.73963	1.74990	40.5
		2.0	1.72150	1.72682	1.73108	1.73944	1.74970	40.5
L-LAH53	Before Pressing	0.0023	1.80039	1.80625	1.81093	1.82010	1.83132	40.91
	After Pressing	0.5	1.79605	1.80189	1.80655	1.81570	1.82686	40.8
		1.0	1.79558	1.80141	1.80607	1.81521	1.82637	40.8
		1.5	1.79524	1.80107	1.80573	1.81488	1.82604	40.8
		2.0	1.79501	1.80085	1.80551	1.81466	1.82580	40.8
L-LAH84	Before Pressing	0.0023	1.80243	1.80835	1.81309	1.82237	1.83372	40.55
	After Pressing	0.5	1.79934	1.80527	1.81000	1.81932	1.83065	40.3
		1.0	1.79893	1.80484	1.80957	1.81888	1.83022	40.3
		1.5	1.79862	1.80454	1.80927	1.81858	1.82990	40.3
		2.0	1.79838	1.80430	1.80902	1.81833	1.82968	40.3
L-LAH85V	Before Pressing	0.0023	1.84772	1.85400	1.85903	1.86887	1.88090	40.38
	After Pressing	0.5	1.84442	1.85070	1.85569	1.86551	1.87751	40.3
		1.0	1.84410	1.85035	1.85521	1.86520	1.87718	40.3
		1.5	1.84365	1.84992	1.85493	1.86475	1.87674	40.3
		2.0	1.84339	1.84966	1.85465	1.86449	1.87646	40.3
L-LAH90	Before Pressing	0.0023	1.82605	1.83220	1.83713	1.84680	1.85866	40.10
	After Pressing	0.5	1.82209	1.82822	1.83312	1.84277	1.85459	40.0
		1.0	1.82155	1.82768	1.83258	1.84223	1.85404	40.0
		1.5	1.82124	1.82737	1.83227	1.84191	1.85371	40.0
		2.0	1.82105	1.82718	1.83207	1.84171	1.85351	40.0
L-LAH91	Before Pressing	0.0023	1.75981	1.76450	1.76821	1.77538	1.78399	49.09
	After Pressing	0.5	1.75638	1.76107	1.76474	1.77193	1.78053	48.9
		1.0	1.75592	1.76060	1.76427	1.77146	1.78007	48.9
		1.5	1.75565	1.76034	1.76400	1.77119	1.77980	48.9
		2.0	1.75544	1.76013	1.76379	1.77098	1.77959	48.8
L-LAH94	Before Pressing	0.0023	1.85416	1.86100	1.86650	1.87737	1.89080	37.10
	After Pressing	0.5	1.84978	1.85660	1.86209	1.87290	1.88625	37.1
		1.0	1.84921	1.85603	1.86151	1.87231	1.88565	37.0
		1.5	1.84896	1.85577	1.86125	1.87205	1.88538	37.0
		2.0	1.84872	1.85552	1.86099	1.87180	1.88513	37.1
L-TIM28	Before Pressing	0.0023	1.68303	1.68948	1.69473	1.70525	1.71856	31.02
	After Pressing	0.5	1.67726	1.68361	1.68865	1.69902	1.71196	31.4
		1.0	1.67675	1.68308	1.68822	1.69851	1.71147	31.4
		1.5	1.67632	1.68264	1.68778	1.69808	1.71099	31.4
		2.0	1.67609	1.68239	1.68752	1.69778	1.71073	31.5

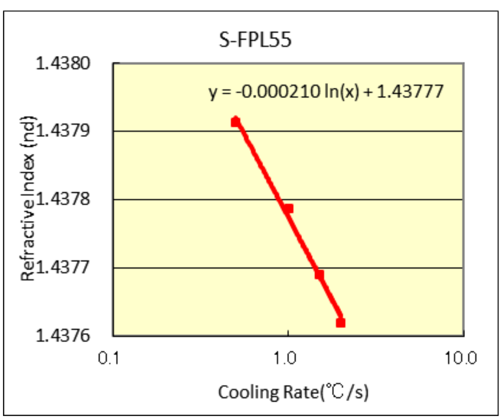
3.4 Cooling speed and refractive index (graph) after forming process

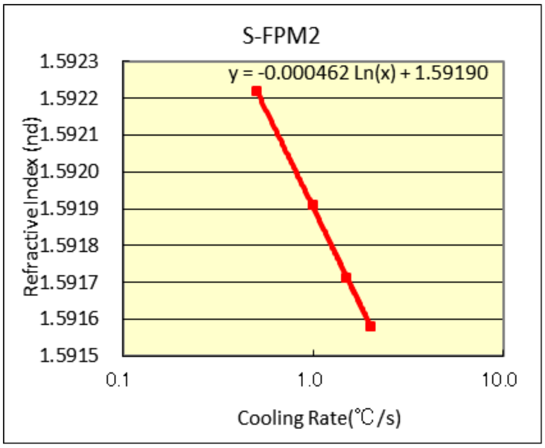
Under our test condition, the graphs below illustrate the relationship between cooling speed and refractive index of each glass type. Abscissa of axis and ordinate shows cooling speed and refractive index respectively. After the molding process, as the actual cooling speed of molding depends on the molding machine, molding condition, mold tool, lens shape, and measuring point, the data should be considered as a reference only.

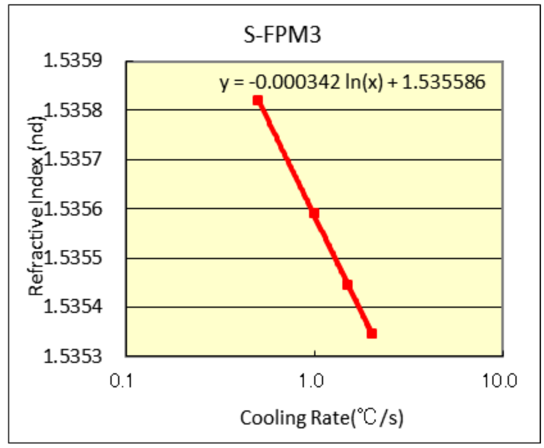
Information of Preform: ϕ 7.24 (0.20cc) Polished Ball
Shape of pressing: R20 convex on both sides, center thickness is 3.3

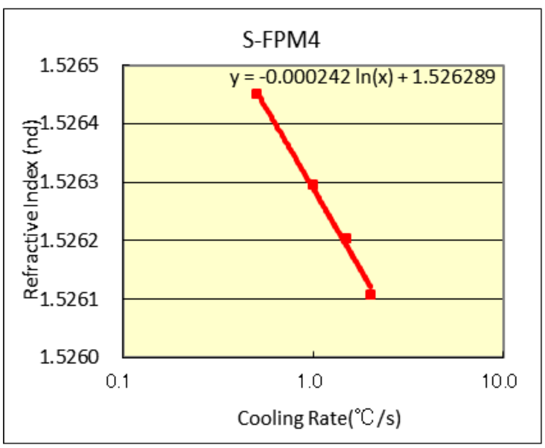


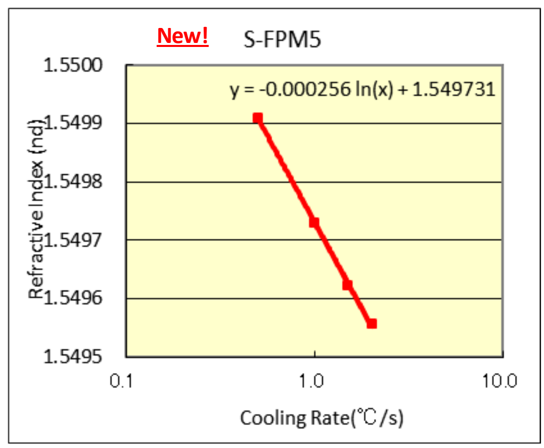


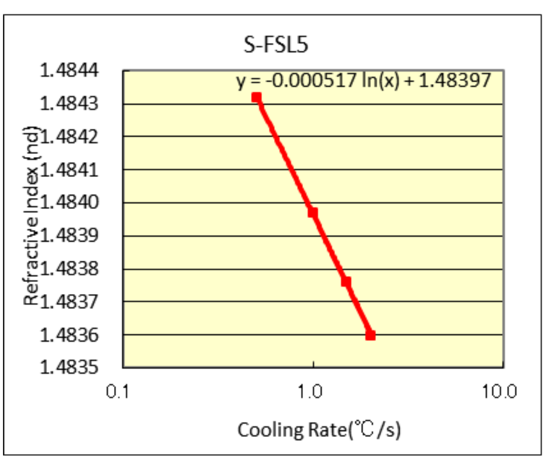


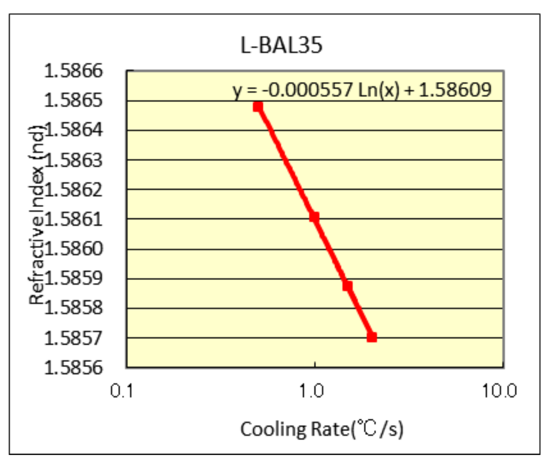

S-FPM2
y = -0.000462 Ln(x) + 1.59190
Refractive Index (nd)
1.5923
1.5922
1.5921
1.5920
1.5919
1.5918
1.5917
1.5916
1.5915
0.1
1.0
10.0
Cooling Rate(℃/s)

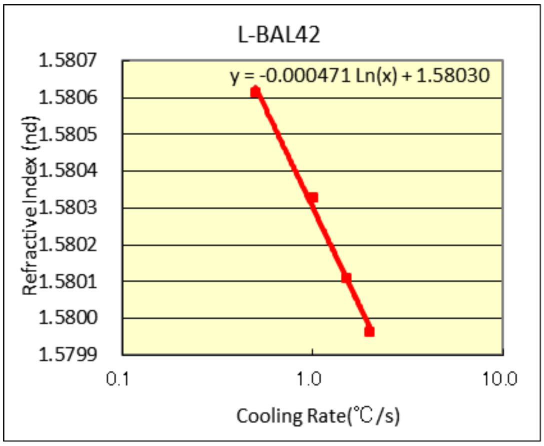

S-FPM3
y = -0.000342 ln(x) + 1.535586
Refractive Index (nd)
1.5359
1.5358
1.5357
1.5356
1.5355
1.5354
1.5353
0.1
1.0
10.0
Cooling Rate(℃/s)

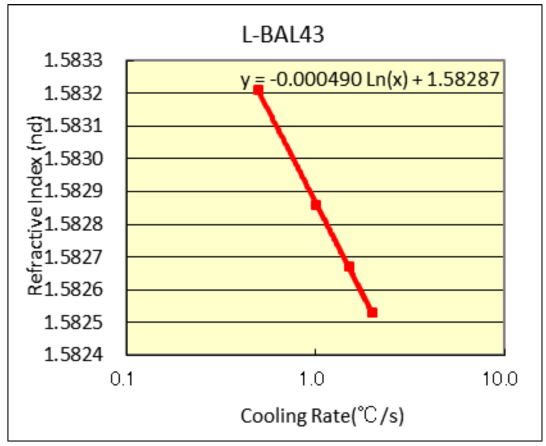

S-FPM4
y = -0.000242 ln(x) + 1.526289
Refractive Index (nd)
1.5265
1.5264
1.5263
1.5262
1.5261
1.5260
0.1
1.0
10.0
Cooling Rate(℃/s)

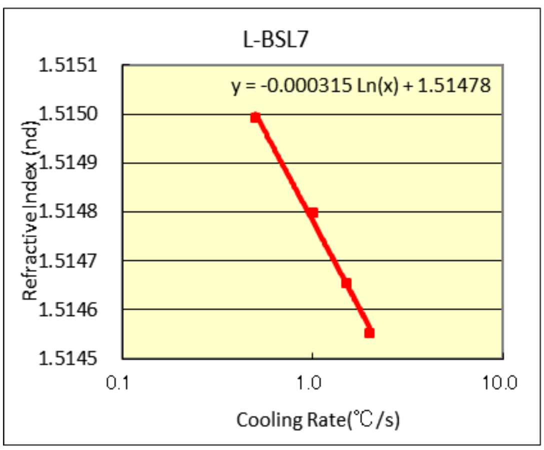

New!
S-FPM5
y = -0.000256 ln(x) + 1.549731
Refractive Index (nd)
1.5500
1.5499
1.5498
1.5497
1.5496
1.5495
0.1
1.0
10.0
Cooling Rate(℃/s)

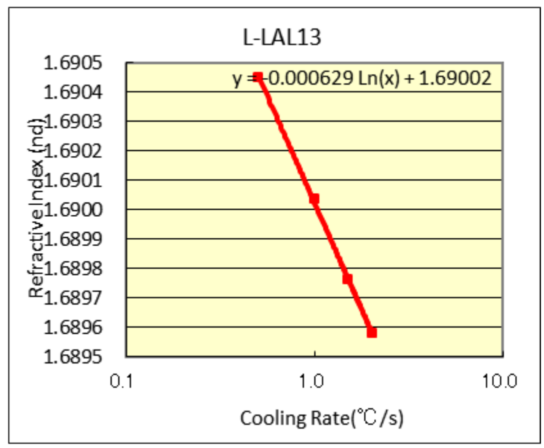

S-FSL5
y = -0.000517 ln(x) + 1.48397
Refractive Index (nd)
1.4844
1.4843
1.4842
1.4841
1.4840
1.4839
1.4838
1.4837
1.4836
1.4835
0.1
1.0
10.0
Cooling Rate(℃/s)

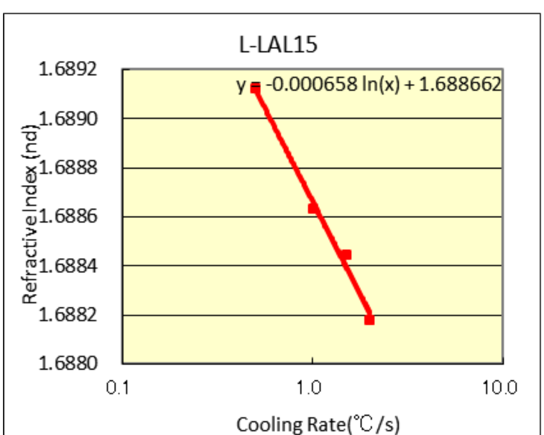

L-BAL35
y = -0.000557 Ln(x) + 1.58609
Refractive Index (nd)
1.5866
1.5865
1.5864
1.5863
1.5862
1.5861
1.5860
1.5859
1.5858
1.5857
1.5856
0.1
1.0
10.0
Cooling Rate(℃/s)

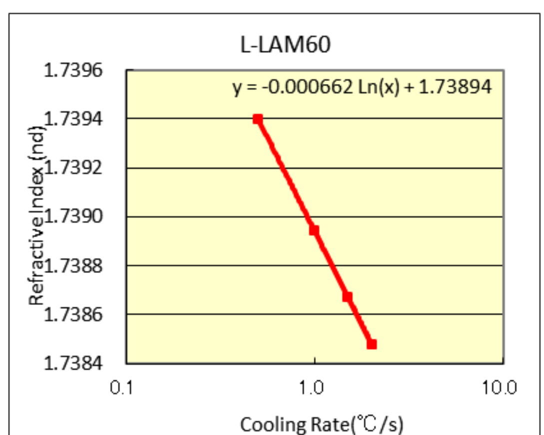

L-BAL42
y = -0.000471 Ln(x) + 1.58030
1.5807
1.5806
1.5805
1.5804
1.5803
1.5802
1.5801
1.5800
1.5799
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

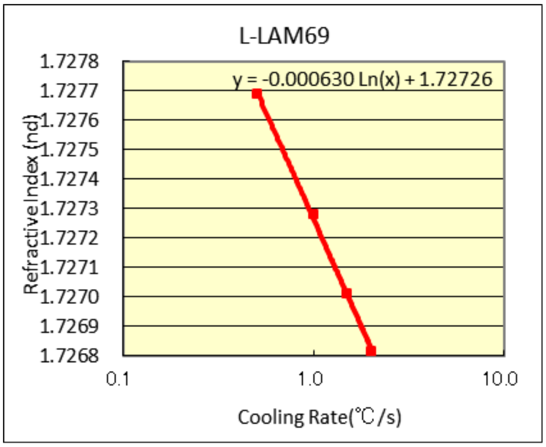

L-BAL43
y = -0.000490 Ln(x) + 1.58287
1.5833
1.5832
1.5831
1.5830
1.5829
1.5828
1.5827
1.5826
1.5825
1.5824
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

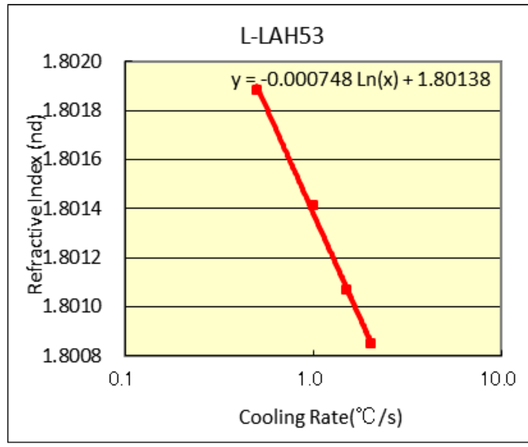

L-BSL7
y = -0.000315 Ln(x) + 1.51478
1.5151
1.5150
1.5149
1.5148
1.5147
1.5146
1.5145
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

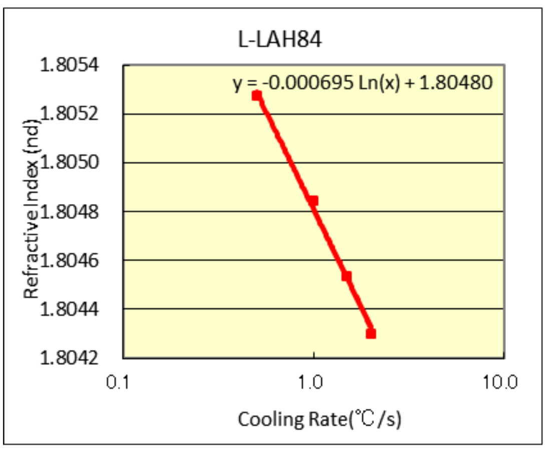

L-LAL13
y = -0.000629 Ln(x) + 1.69002
1.6905
1.6904
1.6903
1.6902
1.6901
1.6900
1.6899
1.6898
1.6897
1.6896
1.6895
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

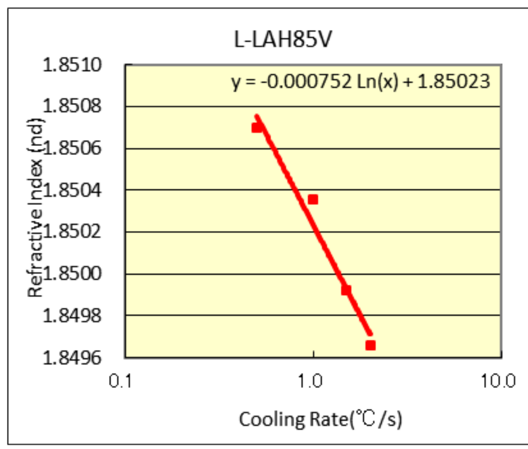

L-LAL15
y = -0.000658 ln(x) + 1.688662
1.6892
1.6890
1.6888
1.6886
1.6884
1.6882
1.6880
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

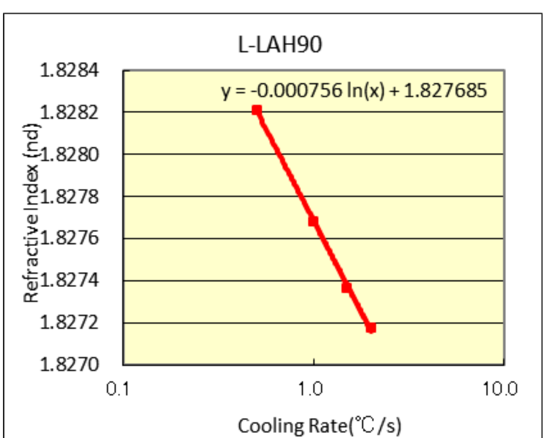

L-LAM60
y = -0.000662 Ln(x) + 1.73894
1.7396
1.7394
1.7392
1.7390
1.7388
1.7386
1.7384
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

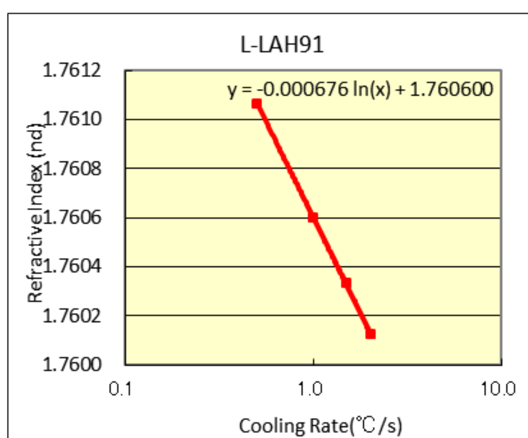

L-LAM69
y = -0.000630 Ln(x) + 1.72726
Refractive Index (nd)
1.7278
1.7277
1.7276
1.7275
1.7274
1.7273
1.7272
1.7271
1.7270
1.7269
1.7268
0.1
1.0
10.0
Cooling Rate(℃/s)

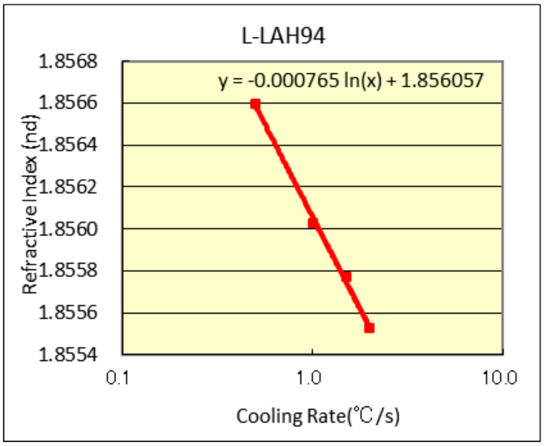

L-LAH53
y = -0.000748 Ln(x) + 1.80138
Refractive Index (nd)
1.8020
1.8018
1.8016
1.8014
1.8012
1.8010
1.8008
0.1
1.0
10.0
Cooling Rate(℃/s)

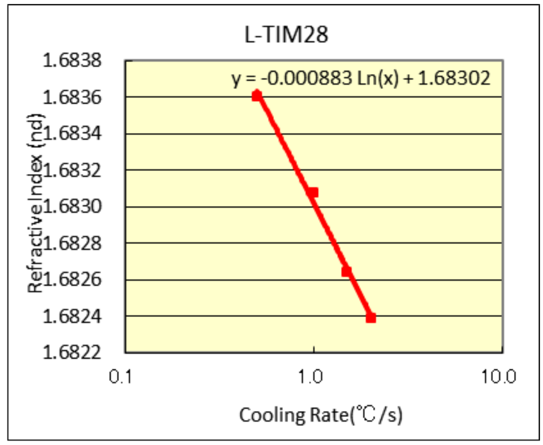

L-LAH84
y = -0.000695 Ln(x) + 1.80480
Refractive Index (nd)
1.8054
1.8052
1.8050
1.8048
1.8046
1.8044
1.8042
0.1
1.0
10.0
Cooling Rate(℃/s)


L-LAH85V
y = -0.000752 Ln(x) + 1.85023
Refractive Index (nd)
1.8510
1.8508
1.8506
1.8504
1.8502
1.8500
1.8498
1.8496
0.1
1.0
10.0
Cooling Rate(℃/s)


L-LAH90
y = -0.000756 ln(x) + 1.827685
Refractive Index (nd)
1.8284
1.8282
1.8280
1.8278
1.8276
1.8274
1.8272
1.8270
0.1
1.0
10.0
Cooling Rate(℃/s)


L-LAH91
y = -0.000676 ln(x) + 1.760600
Refractive Index (nd)
1.7612
1.7610
1.7608
1.7606
1.7604
1.7602
1.7600
0.1
1.0
10.0
Cooling Rate(℃/s)


L-LAH94
y = -0.000765 ln(x) + 1.856057
1.8568
1.8566
1.8564
1.8562
1.8560
1.8558
1.8556
1.8554
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)


L-TIM28
y = -0.000883 Ln(x) + 1.68302
1.6838
1.6836
1.6834
1.6832
1.6830
1.6828
1.6826
1.6824
1.6822
Refractive Index (nd)
0.1
1.0
10.0
Cooling Rate(℃/s)

4. Glass viscosity and coefficient of thermal expansion near the forming temperature

4.1 Thermal properties of glass

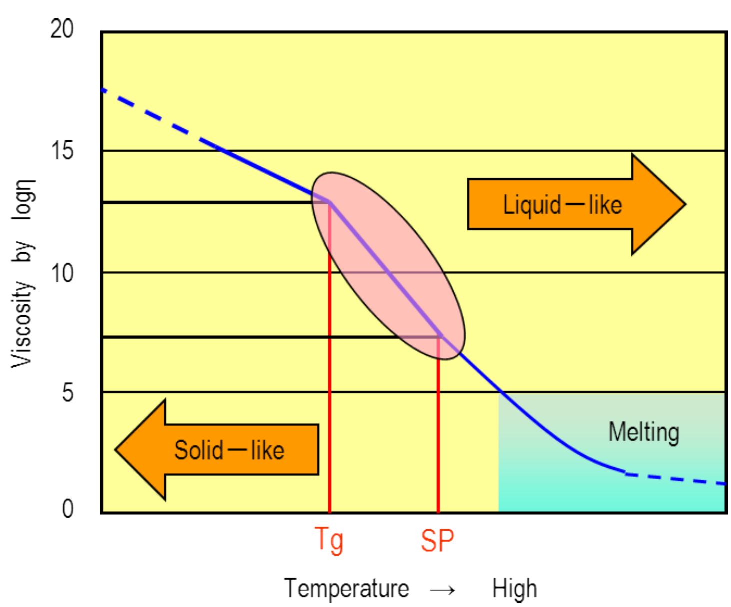
Consideration of the thermal properties is essential to the proper forming and molding of elements using OHARA L glass types. Here are 3 key temperatures which will determine the characteristics of the molded parts.

① Tg ･･･ Transformation Temperature: The temperature at which glass transforms from a solid into a viscous state.
(This corresponds to a temperature of approximately logη = around 13~14)

② At ･･･ Yield point: When viewing OHARA's linear thermal expansion coefficient measurement curve, it is the temperature at which the glass stops expanding and begins to shrink. At is found between Tg and SP.

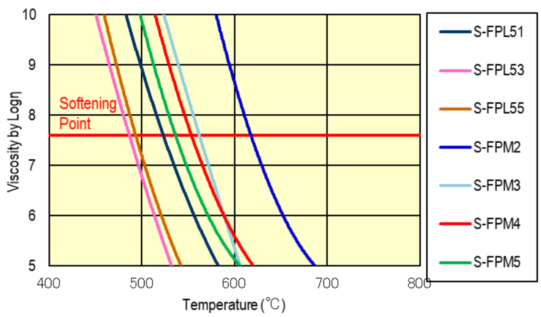
③ SP ･･･ Softening Point: The temperature at which glass is transformed rapidly under its own weight.
(This corresponds to a temperature of approximately logη = 7.6)

The plastic deformation is hardly caused in a temperature range lower than Tg.
On the other hand, at temperature range higher than the SP, the glass approaches a liquid state.

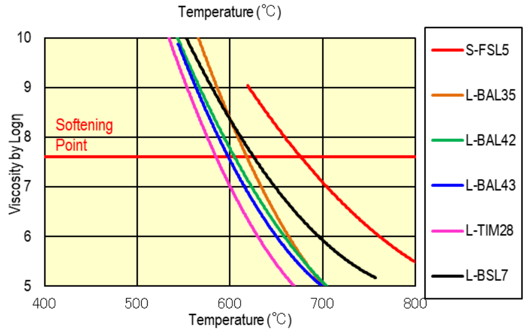


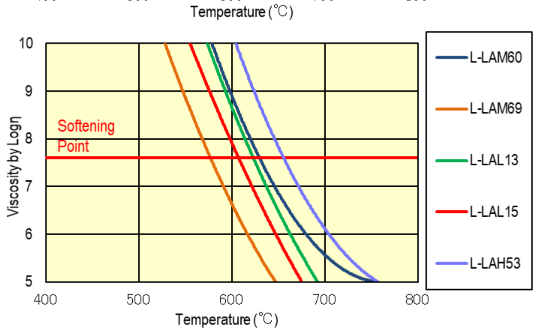
4.2 Glass Viscosity near the forming (pressing) temperature

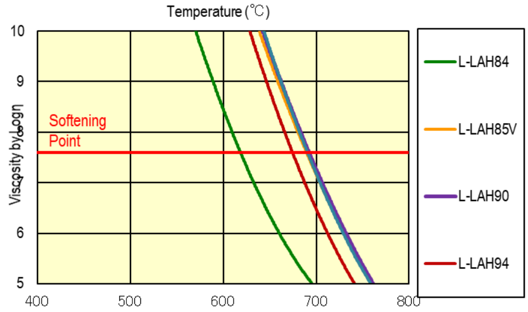
The figures below illustrate the viscosity of each glass type at the temperature of forming (pressing). The horizontal axis illustrates the temperature of the glass, and the vertical line illustrates the viscosity.
The viscosity of the glass (shown in Logη) has a significant influence on the glass molding results (the pressing speed).
Please use this data for comparison purposes.



New!



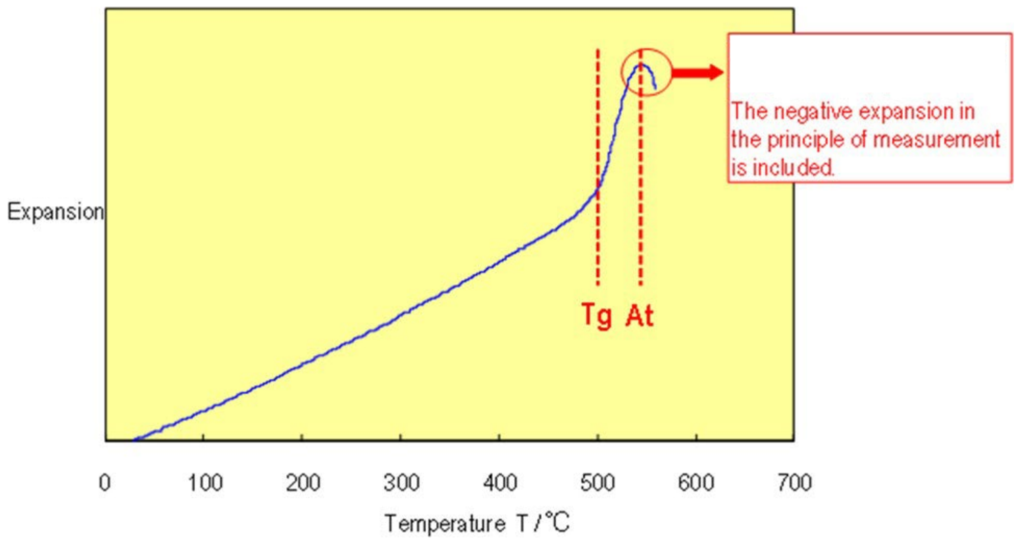




Glass Type	Tg (℃)	At (℃)
S-FPL51	458	489
S-FPL53	426	456
S-FPL55	435	460
S-FPM2	571	596
S-FPM3	496	524
S-FPM4	488	520
New! S-FPM5	474	503
S-FSL5	500	568
L-BAL35	527	567
L-BAL42	506	538
L-BAL43	493	535
L-BSL7	498	549
L-LAL13	534	575
L-LAL15	525	562
L-LAM60	541	581
L-LAM69	497	529
L-LAH53	574	607
L-LAH84	527	568
L-LAH85V	613	653
L-LAH90	607	644
L-LAH91	611	644
L-LAH94	593	628
L-TIM28	504	539

4.3 The coefficient of thermal expansion near the forming temperature

The coefficient of thermal expansion is illustrating the ratio of expansion of the object's length and volume by 1K(℃) caused by an increase in the temperature.



As illustrated above, the glass expands relative to the temperature increase. The expansion curve has two relatively significant changes in direction. The first is the change of coefficient of thermal expansion caused by the change of stiffness to viscosity due to heating. This temperature is called the transformation temperature (Tg). The second is the phenomenon of softening of specimen that the coefficient of thermal expansion looks smaller. This temperature is called yield point (At).

To consider the thermal expansion at the time fo forming (pressing), it is necessary to know the coefficients of the temperature region higher than Tg. However, it is difficult for Ohara to obtain this data due to the measurement device (linear thermal expansion) structure.

Here are the coefficients of thermal expansion in 5 degree C increments.

This is carried out in order to provide the data at a higher temperature range which exceeds the Tg illustrated in the above chart. The coefficient of thermal expansion is much sufficient against dimensions and shape of pressing.

Please make use of the following data for design of lens and pressing tool while considering the coefficient of thermal expansion.

Note: Negative expansion data is included due to the measurement principle. The coefficient of thermal expansion is different from original glass at the range of temperature.

The coefficient of thermal expansion of glass around the forming (pressing) temperature

S-FPL51
Tg : 458℃ At : 489℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	131
100 ～ 300	155
455 ～ 460	435
460 ～ 465	685
465 ～ 470	1110
470 ～ 475	1190
475 ～ 480	875
480 ～ 485	425

S-FPL53
Tg : 426℃ At : 456℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	145
100 ～ 300	169
425 ～ 430	300
430 ～ 435	370
435 ～ 440	530
440 ～ 445	880
445 ～ 450	1170
450 ～ 455	1000
455 ～ 460	735

S-FPL55
Tg : 435℃ At : 460℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	136
100 ～ 300	166
430 ～ 435	360
435 ～ 440	475
440 ～ 445	675
445 ～ 450	790
450 ～ 455	490

S-FPM2
Tg : 571℃ At : 596℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	117
100 ～ 300	135
560 ～ 565	425
565 ～ 570	610
570 ～ 575	970
575 ～ 580	1345
580 ～ 585	1335
585 ～ 590	1040
590 ～ 595	680
595 ～ 600	220

S-FPM3
Tg : 496℃ At : 524℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	115
100 ～ 300	138
495 ～ 500	350
500 ～ 505	517
505 ～ 510	796
510 ～ 515	1165
515 ～ 520	1091
520 ～ 525	835

S-FPM4
Tg : 488℃ At : 520℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	123
100 ～ 300	143
485 ～ 490	575
490 ～ 495	950
495 ～ 500	1265
500 ～ 505	1115
505 ～ 510	845
510 ～ 515	520
515 ～ 520	185

New!

S-FPM5
Tg : 474℃ At : 503℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	109
100 ～ 300	129
470 ～ 475	465
475 ～ 480	800
480 ～ 485	1160
485 ～ 490	1155
490 ～ 495	950
495 ～ 500	665
500 ～ 505	275

S-FSL5
Tg : 500℃ At : 568℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	90
100 ～ 300	95
495 ～ 500	400
500 ～ 505	500
505 ～ 510	625
510 ～ 515	765
515 ～ 520	865
520 ～ 525	905
525 ～ 530	860
530 ～ 535	750
535 ～ 540	635
540 ～ 545	535
545 ～ 550	465

S-FSL5
Tg : 500℃ At : 568℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	90
100 ～ 300	95
550 ～ 555	415
555 ～ 560	380
560 ～ 565	345
565 ～ 570	305

L-BAL35
Tg : 527℃ At : 567℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	66
100 ～ 300	81
525 ～ 530	350
530 ～ 535	510
535 ～ 540	750
540 ～ 545	995
545 ～ 550	1085
550 ～ 555	1010
555 ～ 560	865
560 ～ 565	680
565 ～ 570	495

L-BAL42
Tg : 506℃ At : 538℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	72
100 ～ 300	88
505 ～ 510	590
510 ～ 515	800
515 ～ 520	920
520 ～ 525	885
525 ～ 530	760
530 ～ 535	605
535 ～ 540	455

L-BAL43
Tg : 493℃ At : 535℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	72
100 ～ 300	90
490 ～ 495	225
495 ～ 500	280
500 ～ 505	385
505 ～ 510	565
510 ～ 515	885
515 ～ 520	1260
520 ～ 525	1340
525 ～ 530	1110
530 ～ 535	810
535 ～ 540	550

L-BSL7
Tg : 498℃ At : 549℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	58
100 ～ 300	71
495 ～ 500	260
500 ～ 505	365
505 ～ 510	505
510 ～ 515	675
515 ～ 520	770
520 ～ 525	755
525 ～ 530	675
530 ～ 535	555
535 ～ 540	450
540 ～ 545	360

L-LAL13
Tg : 534℃ At : 575℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	76
100 ～ 300	92
530 ～ 535	315
535 ～ 540	445
540 ～ 545	635
545 ～ 550	875
550 ～ 555	1040
555 ～ 560	1060
560 ～ 565	945
565 ～ 570	795
570 ～ 575	615
575 ～ 580	410

L-LAL15
Tg : 525℃ At : 562℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	54
100 ～ 300	72
525 ～ 530	465
530 ～ 535	810
535 ～ 540	1305
540 ～ 545	1560
545 ～ 550	1405
550 ～ 555	1105
555 ～ 560	770
560 ～ 565	530

The coefficient of thermal expansion of glass around the forming (pressing) temperature

L-LAM60
Tg : 541℃　At : 581℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	74
100 ～ 300	92
540 ～ 545	415
545 ～ 550	575
550 ～ 555	785
555 ～ 560	945
560 ～ 565	985
565 ～ 570	915
570 ～ 575	800
575 ～ 580	635
580 ～ 585	455

L-LAM69
Tg : 497℃　At : 529℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	86
100 ～ 300	105
495 ～ 500	380
500 ～ 505	570
505 ～ 510	905
510 ～ 515	1235
515 ～ 520	1290
520 ～ 525	1085
525 ～ 530	860

L-LAH53
Tg : 574℃　At : 607℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	59
100 ～ 300	72
570 ～ 575	470
575 ～ 580	705
580 ～ 585	935
585 ～ 590	1010
590 ～ 595	970
595 ～ 600	860
600 ～ 605	715
605 ～ 610	525

L-LAH84
Tg : 527℃　At : 568℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	64
100 ～ 300	79
525 ～ 530	240
530 ～ 535	340
535 ～ 540	500
540 ～ 545	775
545 ～ 550	1080
550 ～ 555	1120
555 ～ 560	950
560 ～ 565	745
560 ～ 565	500

L-LAH85V
Tg : 613℃　At : 653℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	62
100 ～ 300	75
610 ～ 615	425
610 ～ 620	660
610 ～ 625	1030
610 ～ 630	1270
610 ～ 635	1175
610 ～ 640	980
640 ～ 645	715
645 ～ 650	430
645 ～ 650	185

L-LAH90
Tg : 607℃　At : 644℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	63
100 ～ 300	74
605 ～ 610	275
610 ～ 615	410
615 ～ 620	725
620 ～ 625	1195
625 ～ 630	1415
630 ～ 635	1260
635 ～ 640	980
640 ～ 645	735

New!

L-LAH91
Tg : 611℃　At : 644℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	57
100 ～ 300	71
610 ～ 615	290
615 ～ 620	470
620 ～ 625	890
625 ～ 630	1485
630 ～ 635	1545
635 ～ 640	1175
640 ～ 645	810

L-LAH94
Tg : 593℃　At : 628℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	62
100 ～ 300	77
590 ～ 595	335
595 ～ 600	520
600 ～ 605	835
605 ～ 610	1135
610 ～ 615	1175
615 ～ 620	1040
620 ～ 625	845
625 ～ 630	610

L-TIM28
Tg : 504℃　At : 539℃

Temp Range (℃)	CTE ($10^{-7}K^{-1}$)
-30 ～ 70	101
100 ～ 300	130
500 ～ 505	640
505 ～ 510	875
510 ～ 515	1100
515 ～ 520	1160
520 ～ 525	1040
525 ～ 530	845
530 ～ 535	600
535 ～ 540	350

5. List of OHARA Low Tg Optical Glasses for Molding

5.1 List of Properties

Glass Type	Optical Properties			Thermal Properties		Physical Properties		Durability		Specific Gravity	Abrasion
	N_d	ν_d	Coloring	Tg (℃)	At (℃)	α (100～300℃) ($10^{-7}K^{-1}$)	K (W/m・K)	W(s)	SR	d	Aa
S-FPL51	1.49700	81.54	340 / 290	458	489	155	0.780	1	52.1	3.62	493
S-FPL53	1.43875	94.93	330 / 280	426	456	169	0.857	3	52.3	3.62	480
S-FPL55	1.43875	94.66	335 / 290	435	460	166	0.876	2	52.1	3.59	470
S-FPM2	1.59522	67.74	365 / 310	571	596	135	0.624	2	51.3	4.17	521
S-FPM3	1.53775	74.70	345 / -	496	524	138	0.805	1	5.1	3.64	418
New! S-FPM4	1.52841	76.46	340 / -	488	520	143	0.746	1	51.3	3.76	506
S-FPM5	1.55200	70.70	345 / -	474	503	129	0.765	1	52.1	3.74	413
S-FSL5	1.48749	70.23	300 / 265	500	568	95	1.007	1～2	3.0	2.46	117
L-BAL35	1.58913	61.15	345 / 295	527	567	81	1.126	3	52.2	2.82	100
L-BAL42	1.58313	59.38	340 / 285	506	538	88	1.028	1～2	5.2	3.05	117
L-BAL43	1.58573	59.70	340 / 285	493	535	90	1.028	3	51.4	3.05	118
L-BSL7	1.51633	64.06	330 / 295	498	549	71	1.169	3	1.0	2.38	72
L-LAL13	1.69350	53.18	360 / 285	534	575	92	0.887	2	53.2	3.69	108
L-LAL15	1.69304	52.93	345/ -	525	562	72	0.923	3	53.0	3.66	82
L-LAM60	1.74320	49.29	370 / 310	541	581	92	0.876	3	51.2	4.20	92
L-LAM69	1.73077	40.51	410 / 340	497	529	105	1.114	2	52.2	3.24	121
L-LAH53	1.80625	40.91	400 / 335	574	607	72	0.862	1	51.2	4.49	83
L-LAH84	1.80835	40.55	400 / 335	527	568	79	0.875	2	51.3	4.62	88
L-LAH85V	1.85400	40.38	(380) / 340	613	653	77	0.819	4	3.2	5.25	65
L-LAH90	1.83220	40.10	415 / 340	607	644	74	0.839	2	5.2	4.65	80
L-LAH91	1.76450	49.09	365 / 275	611	644	71	0.841	2	52.2	4.29	68
L-LAH94	1.86100	37.10	(390)/350	593	628	77	0.817	3	51.2	4.89	81

The coloring values with "( )" is the value at λ_{70}

5.3 List of Reference Data from OHARA'S analysis

Glass Type	Thermal Properties		Glass Type				Compatibility of Thin Mold coating		
	N_d	At (℃)	Catalog Value		(Pressing→220℃) Cooling Rate (℃/s)		Carbon	Transition Metal	Precious Metal
			N_d	v_d	N_d	v_d			
S-FPL51	458	489	1.49700	81.54	1.49491	81.4	◎	×	◎
S-FPL53	426	456	1.43875	94.93	1.43739	94.8	○	○	◎
S-FPL55	435	460	1.43875	94.66	1.43779	94.5	△	◎	◎
S-FPM2	571	596	1.59522	67.74	1.59191	67.5	◎	×	×
S-FPM3	496	524	1.53775	74.70	1.53559	74.4	◎	○	○
S-FPM4	488	520	1.52841	76.46	1.52630	76.1	◎	◎	×
New! S-FPM5	474	503	1.55200	70.70	1.54973	70.2	◎	×	×
S-FSL5	500	568	1.48749	70.23	1.48397	70.0	◎	◎	◎
L-BAL35	527	567	1.58913	61.15	1.58611	61.0	△	◎	◎
L-BAL42	506	538	1.58313	59.38	1.58033	59.2	◎	◎	◎
L-BAL43	493	535	1.58573	59.70	1.58286	59.5	◎	◎	◎
L-BSL7	498	549	1.51633	64.06	1.51480	63.9	◎	◎	◎
L-LAL13	534	575	1.69350	53.18	1.69004	53.0	◎	×	◎
L-LAL15	525	562	1.69304	52.93	1.68863	52.4	◎	×	◎
L-LAM60	541	581	1.74320	49.29	1.73894	49.0	◎	×	△
L-LAM69	497	529	1.73077	40.51	1.72728	40.5	○	◎	◎
L-LAH53	574	607	1.80625	40.91	1.80141	40.8	◎	◎	◎
L-LAH84	527	568	1.80835	40.55	1.80484	40.3	◎	◎	◎
L-LAH85V	615	656	1.85400	40.38	1.85035	40.3	○	△	×
L-LAH90	607	644	1.83220	40.10	1.82768	40.0	○	○	×
L-LAH91	611	644	1.76450	49.09	1.76060	48.9	○	△	×
L-LAH94	593	628	1.86100	37.10	1.85603	37.0	○	×	×
L-TIM28	504	539	1.68948	31.02	1.68308	31.4	◎	○	◎

Criterion for compatibility evaluation of the thin coatings of mold with OHARA glass

Mark	Evaluation Result ／Judge
◎	Good
○	Some deterioration
△	Minor defects
×	Major Defects

5.3 The list of Low Tg Optical Glass

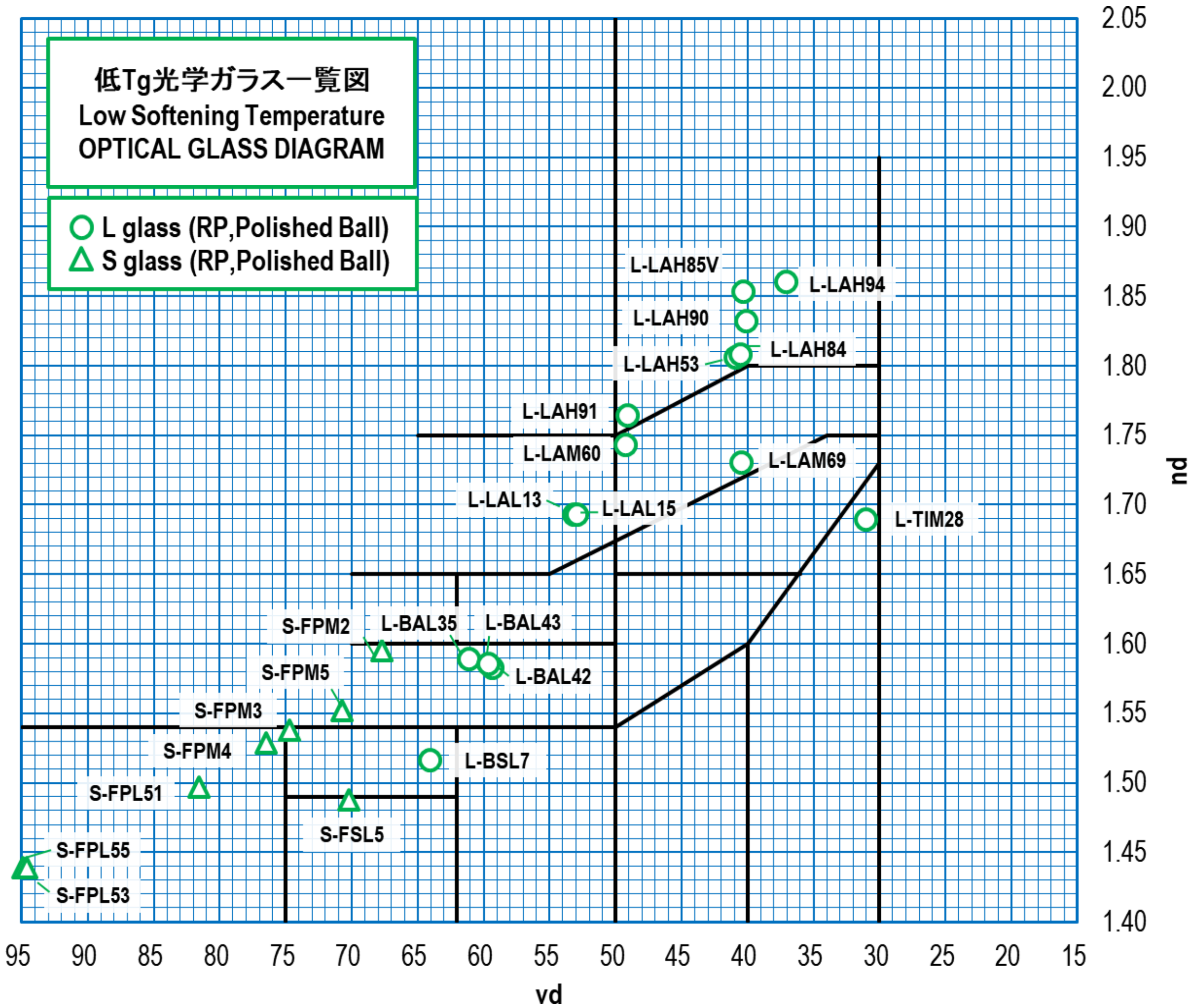
For wider variations of the glass choices, we have increased our line up of Low Tg Optical Glass for Glass Mold Lens.

Glass Type	Catalog value		Controlled value	After molding	Difference in refractive index between before molding and after molding.
	n_d	ν_d	n_d	n_d	Δn_d
L-BAL35	1.58913	61.15	1.58868	1.58611	0.00257
L-BAL35P	1.59208	61.00	1.59163	1.58906	0.00257
L-BAL42	1.58313	59.38	1.58263	1.58033	0.00230
L-BAL42P	1.58593	59.24	1.58543	1.58313	0.00230
L-BAL43	1.58573	59.70	1.58523	1.58286	0.00237
L-BSL7	1.51633	64.06	1.51603	1.51480	0.00123
L-LAH53	1.80625	40.91	1.80540	1.80141	0.00399
L-LAH84	1.80835	40.55	1.80770	1.80484	0.00286
L-LAH85V	1.85400	40.38	1.85330	1.85035	0.00295
L-LAH90	1.83220	40.10	1.83145	1.82768	0.00377
L-LAH91	1.76450	49.09	1.76385	1.76060	0.00325
L-LAH94	1.86100	37.10	1.86020	1.85603	0.00417
L-LAL13	1.69350	53.18	1.69280	1.69004	0.00276
L-LAL15	1.69304	52.93	1.69234	1.68863	0.00371
L-LAM60	1.74320	49.29	1.74260	1.73894	0.00366
L-LAM69	1.73077	40.51	1.73017	1.72728	0.00289
L-TIM28	1.68948	31.02	1.68848	1.68308	0.00540
L-TIM28P	1.69453	30.66	1.69353	1.68813	0.00540

1 : Controlled value: The refractive index is controlled by annealing with cooling rate -600 °C/day.

2 : The refractive index values depend on our molding conditions.

5.4 Low Softening Temperature OPTICAL GLASS DIAGRAM



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