



**BILLES EN:
VERRE – RUBIS – SAPHIR - CERAMIQUE
& TOUS MATERIAUX**

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QUALITY CONTROL:

A.F.B.M.A. * GRADE TOLERANCES AND TERMINOLOGY

GRADE TOLERANCE CHART:

A.F.B.M.A. Grade	Diameter Tolerance per Ball Sphericity	Diameter Tolerance per Unit Container	Basic Diameter Tolerance	Marking Increments
	Inch	Inch	Inch	Inch
3	.000003	.000005	± .00003	.000003
5	.000005	.00001	± .00005	.000005
10	.000010	.00002	± .0001	.000010
15	.000015	.00003	± .0001	.000015
25	.000025	.00005	± .0001	.000025
50	.00005	.0001	± .0002	.00005
100	.0001	.0002	± .0005	.0001
200	.0002	.0004	± .0010	.0002

BASIC DIAMETER: The size ordered which is the basis to which the basic diameter tolerances apply. The Basic Diameter is specified by a fraction plus a decimal or a decimal only to the sixth place, e.g. $1/4'' + .0002''$, or $.2502''$; $15/64'' + .0003''$, or $.234675''$.

BASIC DIAMETER TOLERANCE: The maximum allowable deviation of any ball diameter from the basic diameter, in any shipments to fill orders for that basic diameter.

DIAMETER TOLERANCE PER BALL: The permissible difference between the largest diameter and the smallest diameter measurable on one ball.

DIAMETER TOLERANCE PER UNIT CONTAINER: The permissible range of the average diameters of the individual balls within any one unit container.

GRADE: The numerical value of the Diameter Tolerance Per Ball expressed in millionths of an inch.

MARKING INCREMENTS: The standard unit steps in millionths of an inch used to express the Specific Diameter.



TALYROND 61 Taylor-Hobson, guarantees a measuring tolerance on roundness, (sphericity), of 0,00005 mm, 2 millionths of an Inch.

Diameter checked on electronic dial indicators calibrated by gauges, at times supplied by the customer.

TALYSURF Taylor-Hobson, used for measuring of surface roughness.

Visual inspection with binocular microscope at 15x.

STANDARD STOCK SIZES OF SAPPHIRE-, RUBY-, GLASS- & CERAMIC TYPE A99 BALLS FOR INDUSTRIAL APPLICATIONS

SAPPHIRE + RUBY		GLASS		CERAMIC-A99	
Ø INCH	Ø MM	Ø INCH	Ø MM	Ø INCH	Ø MM
.005			1.00		1.50
	0.15	3/64"		1/16"	
	0.20		1.20		
	0.25		1.25		2.00
	0.30		1.50	3/32"	
	0.40	1/16"			2.50
	0.50-1.00		1.75		3.00
3/64"			2.00	1/8"	
	1.20	3/32"			3.50
	1.25		2.50		
	1.50		3.00	5/32"	
1/16"		1/8"			4.00
	1.75		3.50		4.50
	2.00	5/32"		3/16"	
3/32"			4.50		5.00
	2.50	3/16"		7/32"	
	3.00		5.00		
1/8"		7/32"			6.00
	3.50		6.00	1/4"	
5/32"		1/4"			6.50
	4.00		6.50		7.00
	4.50		7.00	5/16"	
3/16		9/32"			8.00
	5.00		7.50	11/32"	
7/32		5/16"			9.00
	6.00		8.00		9.50
1/4"			8.50	3/8"	
	6.50	11/32"			10.00
	7.00		9.00		11.00
9/32"			9.50	7/16"	
	7.50	3/8"			12.00
5/16			10.00	1/2"	
	8.00		11.00		13.00
	8.50	7/16"			14.00
	9.00		12.00	9/16"	
	9.50	1/2"			15.00
3/8"				5/8"	
	10.00				16.00
	11.00				17.00
7/16"					18.00
	12.00				19.00
1/2"				3/4"	
					20.00
					25.00
				1"	
					30.00
				1.25"	

Maximum diameters for: RUBY .590"
SAPPHIRE 20 mm
GLASS .500"
CERAMIC A99 2"

For special glass spheres see page 5.

SPECIFICATIONS: SANDOZ GLASS BALLS

	Black	Crystal & pyrex	Red
Specific Gravity (Density)*	3.17 + -.09	3.2 & 2.23	2.56 + -.1
Hardness	537 Vickers	545 Vickers	586 Vickers
Compressive Strenght	7910 kg/cm ²	7910 kg/cm ²	9327 kg/cm ²
Module of Elasticity	5.85 10 ⁵ kg/cm ²	5.9 10 ⁵ kg/cm ²	6.7 10 ⁵ kg/cm ²
Temp. Expansion Coefficient	10.75·10 ⁻⁵ /°C	10.8 10 ⁻⁶ /°C	10.0 10 ⁻⁶ /°C
Max. Temp. Utilization	261°C	258°C	280°C

* Other densities upon request.



CERAMIC SPHERES:

Material	Aluminium oxid	Zirconium oxid	Silicone nitride
Color	White	White	Black
Chemical Composition	Al_2O_3	ZrO_2, Y_2O_3	Si_3N_4
Purety%	99		
Apparent Porosity (%)	< 1	0	
Density g/cm ³	3,85	6,05	3,22
Flexual Strength (MPa) at 20 °C	350	1200	1000
at 1000 °C	250		
Compressive Strength (MPa)at 20 °C	2500	4000	3800
Hardness, Vickers (kg/mm ²)	1800	1100	1600
Coefficient of linear Thermal Expansion (10 ⁻⁶ /°C)	8,1	9,2	3,4
Thermal Conductivity (cal/cm s °C)	0,07	0,004	0,03
Thermal Shock Resistance ΔT (°C)	200	360	650
Modulus of Elasticity (Gla)	400	200	310
Kic MPa√m	1~3	4~9	4~7
Average Crystal size in microns	1-3	1-2	1-2

Except type A99, listed ceramic spheres are made to order, involving an eventual tooling charge and minimum order quantity.

We also fabricate spheres to order made from crystals or glass supplied by customer.

PRECISION OPTICAL SPHERES FOR ALL FIBER OPTIC SYSTEMS

Except for ruby and sapphire, (see page 3), crystal and glass spheres are made to order, involving an eventual tooling charge and minimum order quantity. Glass type as per glass producer's specifications selected by the customer. (Eg. Schott or Corning).

Crystal	Sapphire	Rutile	Spinel	Quartz	YAG	Cubic Zirconia	Silicon
	Al_2O_3	TiO_2	$MgO \times Al_2O_3$	SiO_2	$Y_{2.97}Nd_{0.03}Al_5O_{12}$	ZrO_2Si	
	hexagonale rhomboedrique	tétragonale	cubique				
Density	3.99 - 3.98	4.25	3.61	2.2	4.55	5.65	2.33
Fusion temperature	2050 °C	1825 °C	2030 - 2060 °C	1900 °C	1950 °C	2700 °C	1412 °C
Thermal expansion	$5.4 \times 10^{-6}/^{\circ}C$ face perp. axe C $6.2 \times 10^{-6}/^{\circ}C$ face paral. axe C	$9.19 \times 10^{-6}/^{\circ}C$ face perp. axe C $7.14 \times 10^{-6}/^{\circ}C$ face paral. axe C	$5.9 \times 10^{-6}/^{\circ}C$	0.51	6.9×10^{-6} 0-1		2.33
Hardness Mohs Knoop	9 1800 face perp. axe C 2200 face paral. axe C	7 900/950	8 1175/1380	5.5 - 6.5	8.0 - 8.5	8.5	7
Modulus of elasticity	$4.4 \times 10^2 kg/cm^2 \pm 1\%$ Young E			4.41×10^6 a 20°C			
Refractive index n_d	1.760 face perp. axe C 1.769 face paral. axe C	2.903 face perp. axe C 2.616 face paral. axe C	1.1727	1.45	1.823	2.177	3.498 at 1.3 microns
Dispersion factor	0.011	0.205 face perp. axe C 0.155 face paral. axe C	0.012			0.065	