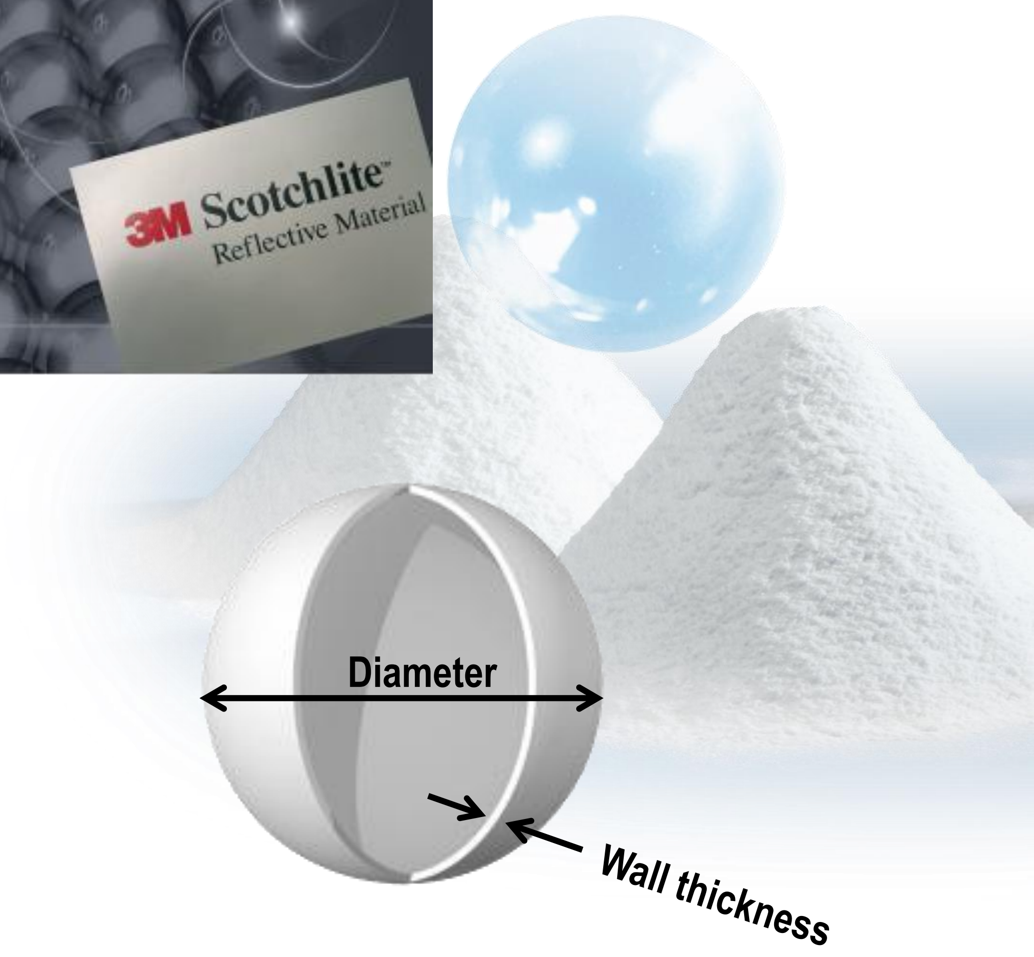
3M Advanced Materials Division

Potential of Hollow Glass Microspheres (3M™ Glass Bubbles) for Thermal Insulation

Dr. Friedrich Wolff

History – From Solid Glass Beads to Glass Bubbles

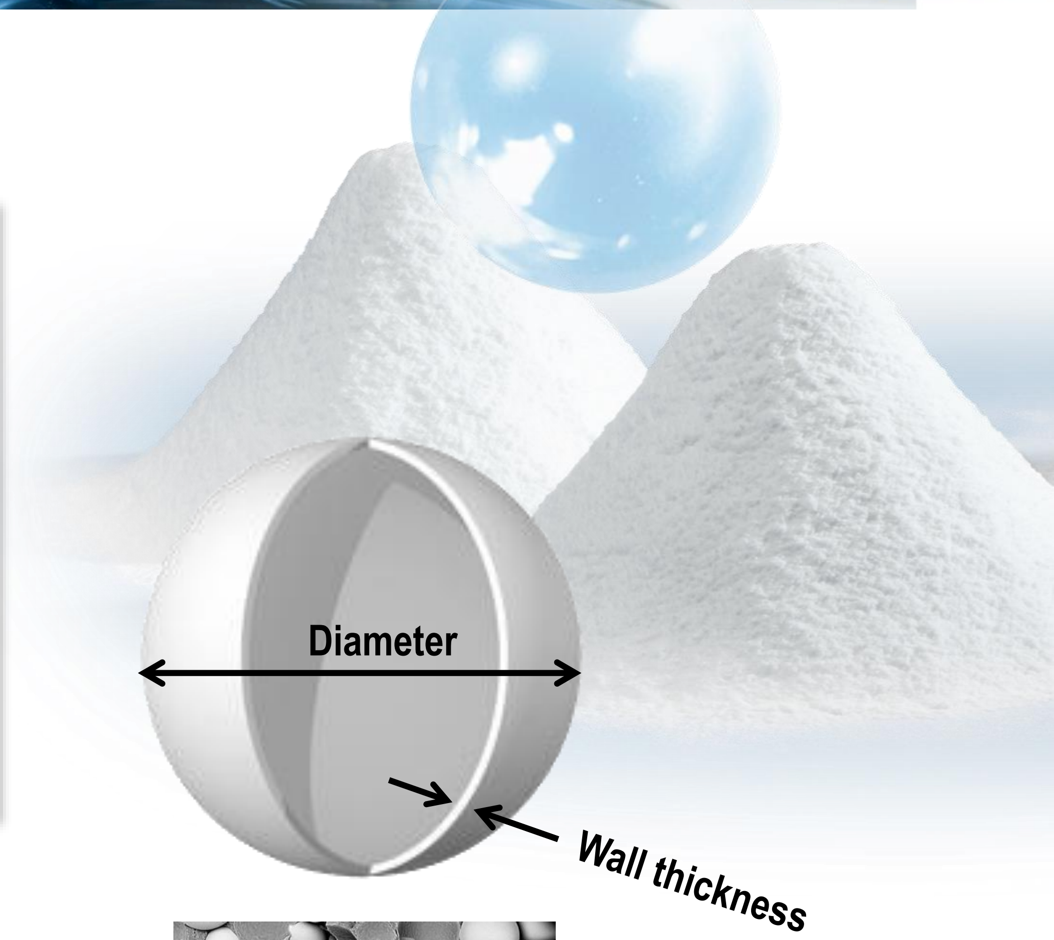
3,365,315
GLASS BUBBLES PREPARED BY REHEATING SOLID GLASS PARTICLES
Warren R. Beck, St. Paul, and Donald L. O'Brien, South St. Paul, Minn., assignors to Minnesota Mining and Manufacturing Company, St. Paul, Minn., a corporation of Delaware
No Drawing. Filed Aug. 23, 1963, Ser. No. 304,221
3 Claims. (Cl. 106—40)

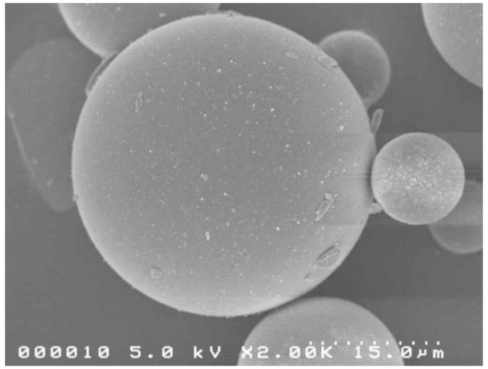


Properties of 3M™ Glass Bubbles

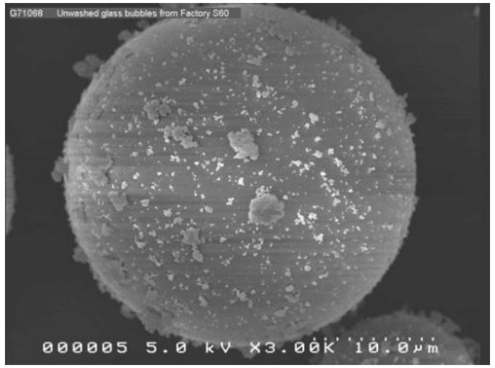
Property	Value
Shape	**Hollow; thin walled; single-cellular spheres**
Composition	**Borosilicate glass, chemical and water resistant**
Color	**White**
Hardness	**Mohs Scale 5**
Softening temperature	**600° C**
Density	**0.12 – 0.6 g/cm^3**
Isostatic collapse strength	**1.7 – 190 MPa (250 – 2800 psi)**
Average particle diameter	**16 – 65 µm**

The named properties are not for specification purpose.

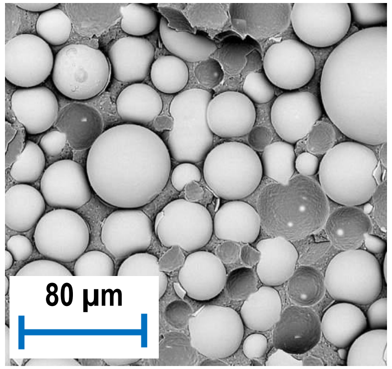




Glass Bubble as manufactured



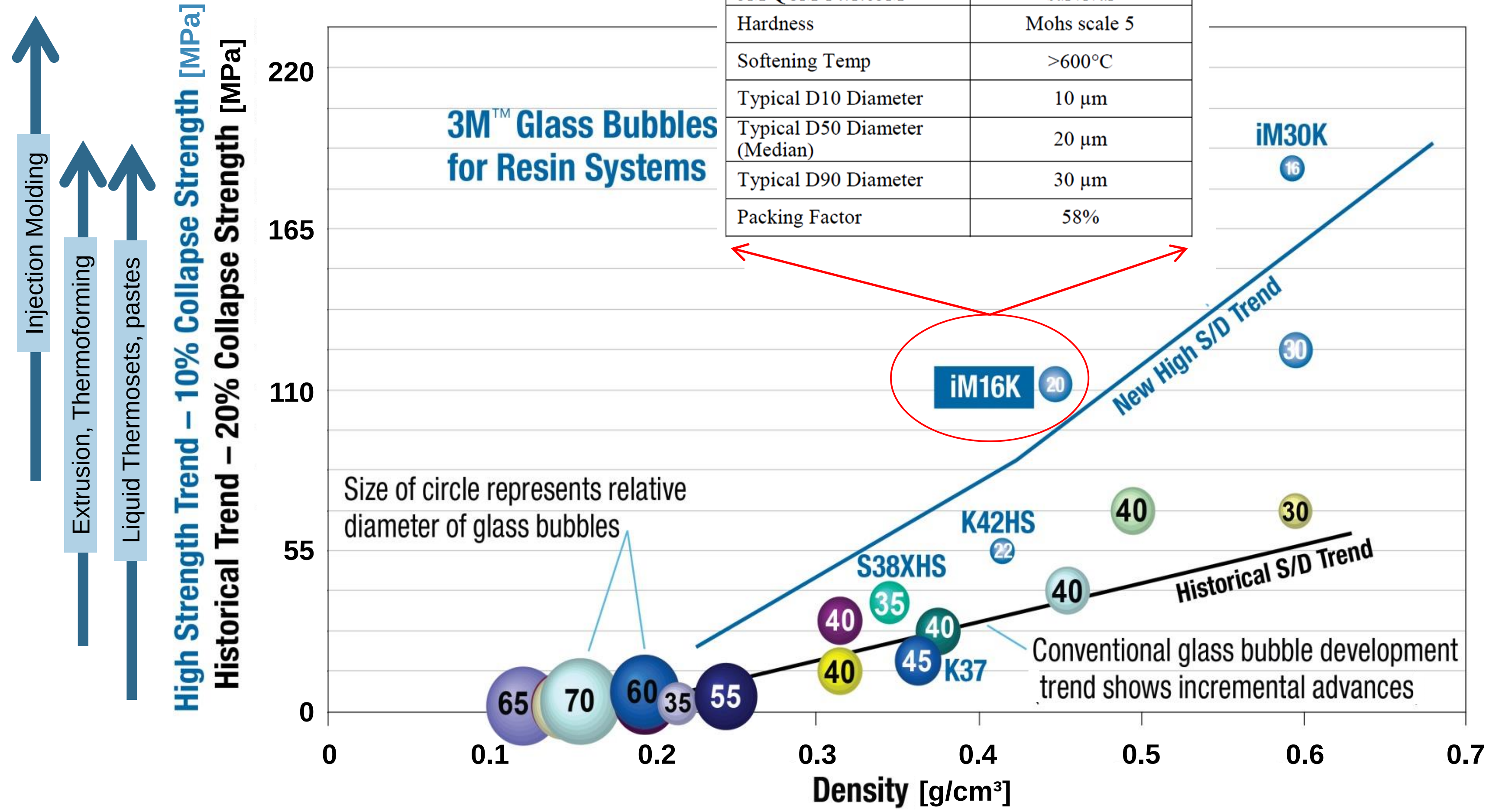
Glass Bubble with amorphous silica anti caking agent

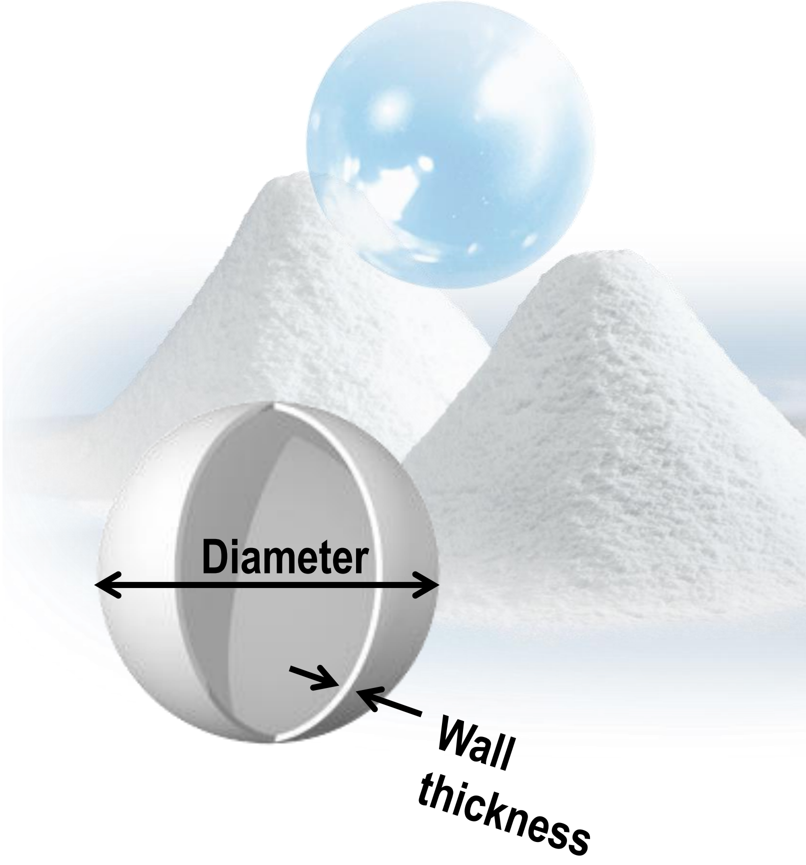


Glass Bubbles Masterbatch (PP)

3M™ Glass Bubbles Isostatic Collapse Strength

True Density	0.46 +/- 0.03 g/cc
Isostatic Crush Strength 3M QCM 14.1.83M	Min 16,000 psi @ 90% survival
Hardness	Mohs scale 5
Softening Temp	>600°C
Typical D10 Diameter	10 µm
Typical D50 Diameter (Median)	20 µm
Typical D90 Diameter	30 µm
Packing Factor	58%

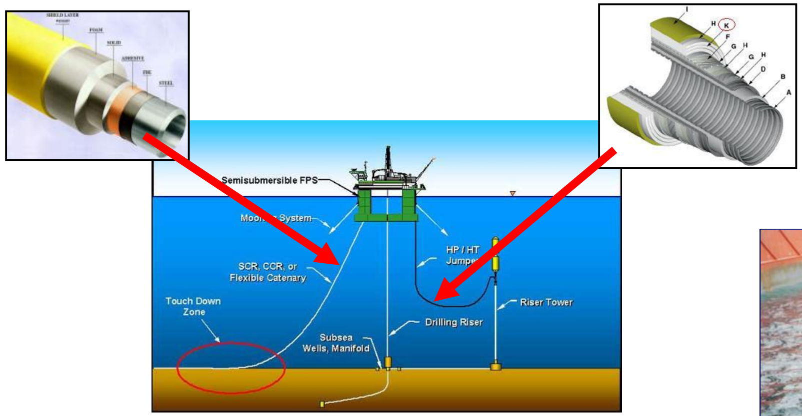




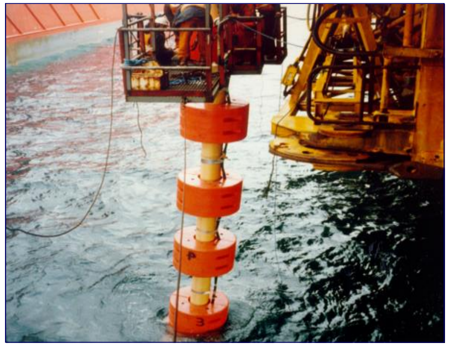
Applications of 3M™ Glass Bubbles

Explosives

Oil well drilling & cementing



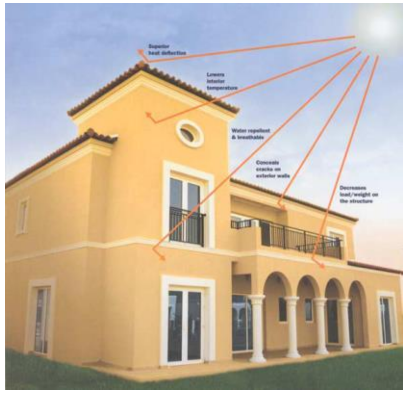
Pipeline thermal insulation



Buoyancy elements

Light weight SMC

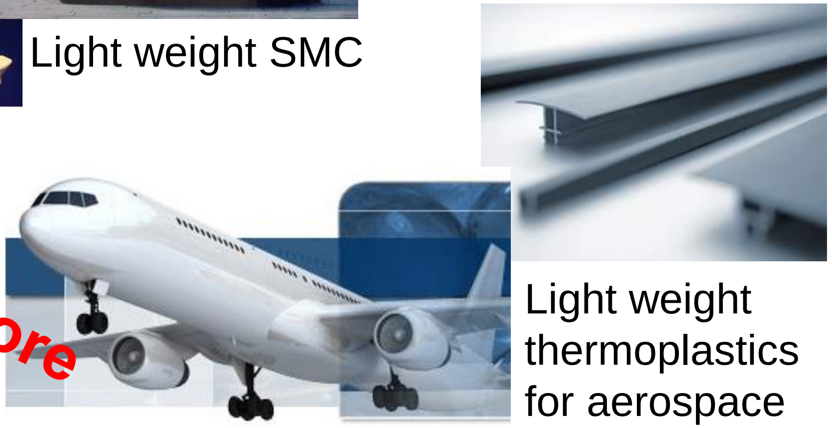
Anti-condensation paints



Solar heat reflective paints & coatings

Wall fillers

…and many more



Light weight thermoplastics for aerospace

Thermal Conductivity of 3M™ Glass Bubbles

Maxwell equation:

$$\lambda_{GB} = \lambda_{glass}\left[\frac{\lambda_{int} + 2\lambda_{glass} + 2V_{int}(\lambda_{int} - \lambda_{glass})}{\lambda_{int} + 2\lambda_{glass} - V_{int}(\lambda_{int} - \lambda_{glass})}\right]$$

λ_{GB}	Thermal conductivity of Glass Bubble
λ_{glass}	Thermal conductivity of glass
λ_{int}	Thermal conductivity of interior medium
$V_{int} = 1 - \frac{\rho_{GB}}{\rho_{glass}}$	Volume fraction of the interior medium
ρ_{GB}	Density of Glass Bubble
ρ_{glass}	Density of glass

Bubble type	Density [g/cm³]	Pressure Strength [bar]	Bubble Void Volume [%]	Calculated Thermal Conductivity of GB [W/m.K]
K1	0.125	17	95.1%	0.044
K15	0.15	21	94.1%	0.051
K20	0.20	34	92.1%	0.065
S22	0.22	28	91.3%	0.071
XLD3000	0.23	210	90.9%	0.074
K25	0.25	52	90.2%	0.080
S32LD	0.29	103	88.6%	0.091
S32	0.32	140	87.4%	0.100
S35	0.35	210	86.2%	0.109
K37	0.37	210	85.4%	0.115
S38HS	0.38	385	85.0%	0.118
S42XHS	0.42	550	83.5%	0.131
K46	0.46	420	81.9%	0.143
iM16K	0.46	1100	81.9%	0.143
iM30K	0.60	1930	76.4%	0.187

Maxwell JC (1892), A treatise on electricity and magnetism. Oxford University Press, London

Thermal Conductivity of Compounds with 3M™ Glass Bubbles

Nielsen equation:

$$\lambda_c = \lambda_m \left[\frac{1 + AB\phi_{GB}}{1 - B\psi\phi_{GB}}\right]$$

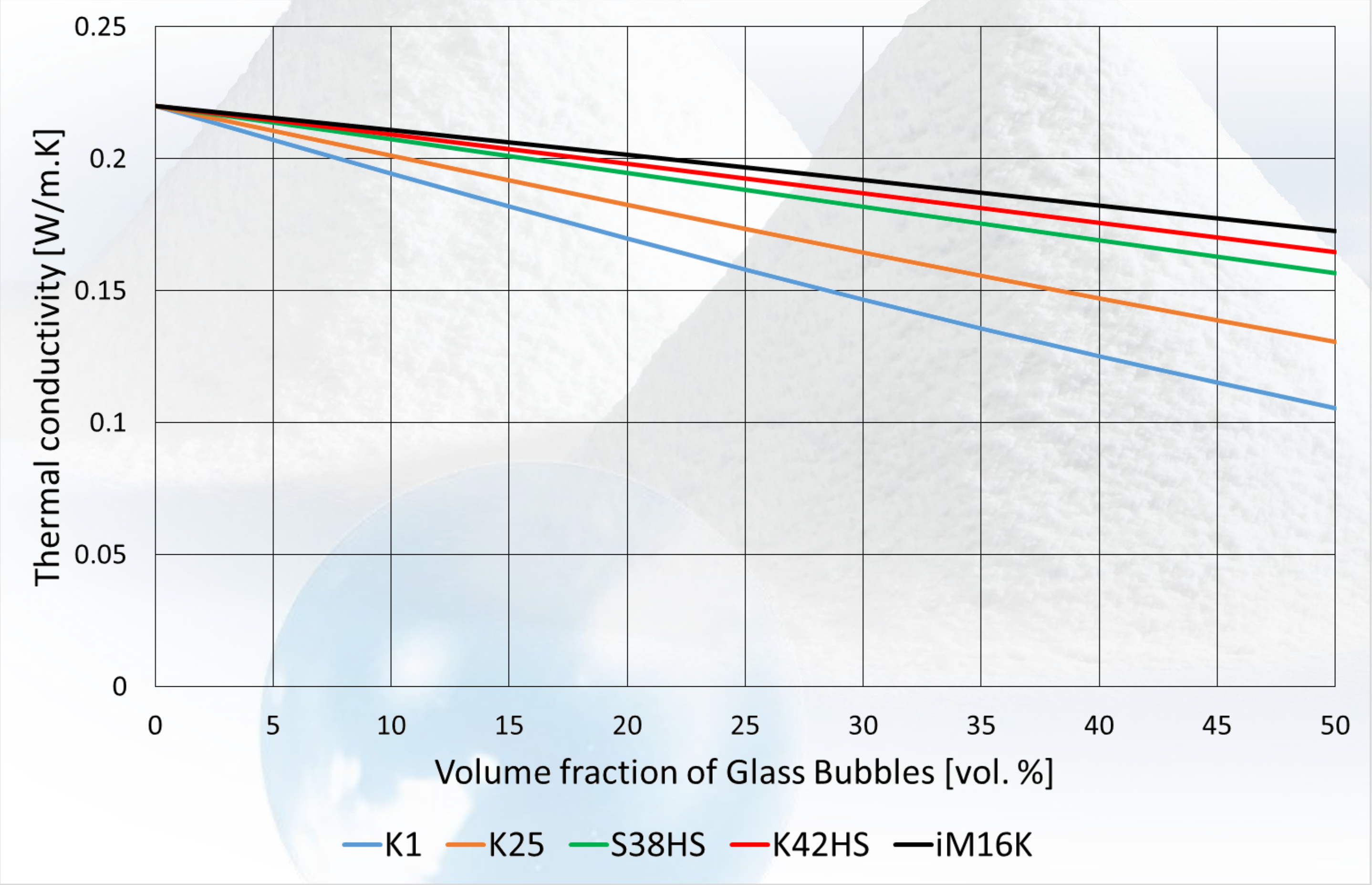
with

$$A = k_e\text{-}1 \qquad B = \frac{\lambda_{GB}/\lambda_m - 1}{\lambda_{GB}/\lambda_m + A}$$

$$\psi = 1 + \left(\frac{1 - \phi_m}{\phi_m^2}\right)\phi_{GB}$$

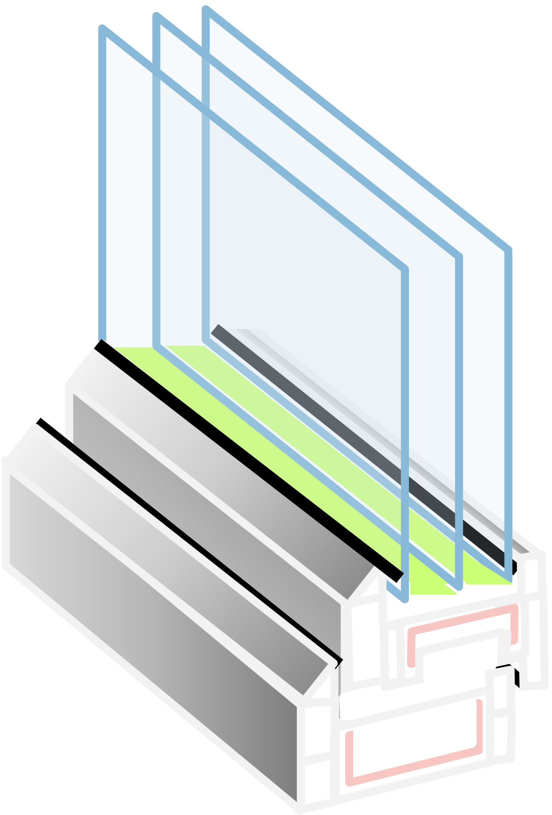
λ_c	Thermal conductivity of compound
λ_m	Thermal conductivity of matrix
λ_{GB}	Thermal conductivity of Glass Bubble
k_e	Einstein coefficient (2.5 for rigid spheres)
ϕ_{GB}	Volume fraction of Glass Bubbles
ϕ_m	Maximum packing fraction of Glass Bubbles (~0.63)

Example: Glass Bubbles in Polypropylene Matrix



Nielsen LE (1974), The thermal and electrical conductivity of two-phase systems, Ind. Eng. Chem. Fundam 13 17-20

Potential Applications for 3M™ Glass Bubbles in Windows



Reduction of thermal conductivity and elimination of thermal bridges

- PVC window frame profiles
- Insulation profiles for metal windows
- Spacer between window panes (“warm edge”)
- Sealings

Acknowledgement

- Jean-Marie Ruckebusch (3M France)
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3M™ Glass Bubbles Plant Tilloy, France

Industrial Park Werk GENDORF, Germany
with 3M™ Specialty Additives Laboratory

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