

The Global Market for Ice-Resistant Coatings and Surfaces

Table of contents

1	Introduction	9
1.1	Aims and objectives of the study	9
1.2	Market definition.....	9
2	Research methodology	10
3	Executive summary	11
3.1	High performance coatings	11
3.2	Market drivers and trends	13
3.3	Global market size and opportunity to 2030	15
3.3.1	End user market for ice-resistant coatings	15
3.3.2	Global revenues for ice-resistant coatings 2010-2030	18
3.3.3	Global revenues for ice-resistant coatings, by market.....	19
3.3.3.1	The market in 2017.....	19
3.3.3.2	The market in 2018.....	21
3.3.3.3	The market in 2030.....	22
3.3.4	Global revenues by substrate materials (e.g. plastics, metals, glass, concrete and ceramic).....	24
3.3.5	Regional demand for ice-resistant coatings	25
3.4	Market and technical challenges	26
4	Ice-resistant coatings technical analysis	27
4.1	Properties of ice-resistant coatings.....	28
4.2	Benefits of using ice-resistant coatings	29
4.3	Production and synthesis methods.....	30
4.3.1	Film coatings techniques analysis	31
4.3.2	Superhydrophobic coatings on substrates	33
4.3.3	Electrospray and electrospinning.....	33
4.3.4	Chemical and electrochemical deposition	34
4.3.4.1	Chemical vapor deposition (CVD)	34
4.3.4.2	Physical vapor deposition (PVD)	35
4.3.4.3	Atomic layer deposition (ALD)	36
4.3.4.4	Aerosol coating	37
4.3.4.5	Layer-by-layer Self-assembly (LBL)	37
4.3.4.6	Sol-gel process	38
4.3.4.7	Etching	40
4.4	Hydrophobic coatings and surfaces.....	40
4.4.1	Hydrophilic coatings.....	41
4.4.2	Hydrophobic coatings	41
4.4.2.1	Properties.....	41
4.5	Superhydrophobic coatings and surfaces.....	42
4.5.1	Properties.....	42
4.5.2	Durability issues.....	44

4.5.3	Nanocellulose	44
4.6	Oleophobic and omniphobic coatings and surfaces	45
4.6.1	SLIPS	45
4.6.2	Covalent bonding	46
4.6.3	Step-growth graft polymerization	46
4.6.4	Applications	46
4.7	Phase switching materials	47
5	Ice-resistant coatings market analysis	48
5.1	Market drivers and trends	49
5.2	Types of ice-resistant coatings	52
5.2.1	Advanced coating solutions	53
5.2.1.1	Hydrophobic and superhydrophobic coatings (HSH)	54
5.2.1.2	SLIPS	55
5.2.1.3	Heatable coatings	55
5.2.1.4	Anti-freeze protein coatings	56
5.2.1.5	Graphene coatings	57
5.3	Patent analysis	59
5.4	Global market for ice-resistant coatings-applications, addressable market size and revenues	65
5.4.1	Global revenues 2010-2030	66
5.5	Aviation and aerospace	68
5.5.1	Icing on engine components, rotors, and wings	68
5.5.2	UAVs	69
5.6	Transport	70
5.6.1	Train	70
5.6.2	Automotive	70
5.6.3	Marine	70
5.7	Construction and buildings	72
5.8	Marine	72
5.9	Energy	73
5.9.1	Wind turbines	74
5.9.2	Gas turbine engines	76
5.9.3	Power transmission	76
5.9.4	Heat exchangers	77
5.10	Oil and gas	77
6	Notable research in ice-resistant coatings	79
7	Company profiles	81
7.1	Adaptive Surface Technologies	81
7.2	Advanced NanoTech Lab	82
7.3	Aerospace & Advanced Composites GmbH	82
7.4	Alchemy	83
7.5	Agiltron	83
7.6	Airbus	84
7.7	Ames Corp	84
7.8	Battelle	85
7.9	CAV Ice Protection	85
7.10	CG2 Nanocoatings	86

7.11	Chela.....	86
7.12	Clariant.....	87
7.13	Cryotech Deicing Technology.....	87
7.14	CSIRO.....	87
7.15	Cytonix LLC.....	88
7.16	DowDuPont Inc.....	88
7.17	Ecological Coatings LLC.....	89
7.18	EnviroTech Services Inc.....	89
7.19	Evonik Industries AG.....	90
7.20	Fraunhofer IGB.....	90
7.21	GE Global Research.....	91
7.22	Helicity Technologies.....	92
7.23	Hempel.....	92
7.24	Hydrobead.....	93
7.25	Hygratek, LLC.....	93
7.26	Innovative Dynamics, Inc.....	94
7.27	Jotun.....	94
7.28	Kilfrost Ltd.....	95
7.29	Kiss Polymers LLC.....	95
7.30	LNT Solutions.....	96
7.31	Luna Innovations.....	96
7.32	Nanohmics.....	97
7.33	Nanosonic, Inc.....	97
7.34	Nanovere Technologies, LLC.....	98
7.35	NBD Nanotechnologies.....	99
7.36	NEI Corporation.....	99
7.37	Neverwet.....	100
7.38	Oceanit.....	101
7.39	Opus Materials Technology.....	101
7.40	PEG LLC.....	102
7.41	PPG.....	102
7.42	Provion Functional Chemicals NV.....	102
7.43	Seashell Technology LLC.....	103
7.44	Signet Graphene Technologies, Inc.....	104
7.45	Slips Technology.....	105
7.46	Statoil ASA.....	105
7.47	Surfactis Technologies.....	106
7.48	SurfEllent, Inc.....	106
7.49	Synavax.....	107
7.50	X-Therma, Inc.....	107
8	References.....	109

Tables

Table 1: Properties of ice-resistant coatings.....	12
Table 2. Market drivers and trends in ice-resistant coatings.....	13

Table 3: End user markets for ice-resistant coatings.....	15
Table 4: Global revenues for ice-resistant coatings, 2010-2030, millions USD.....	18
Table 5: Global revenues for ice-resistant coatings, 2017, millions USD, by market.....	19
Table 6: Estimated revenues for ice-resistant coatings, 2018, millions USD, by market.	21
Table 7: Estimated revenues for ice-resistant coatings, 2030, millions USD, by market.	22
Table 8: Global revenues for ice-resistant coatings, 2015-2030.	24
Table 9: Market and technical challenges for ice-resistant coatings.	26
Table 10: Technology for synthesizing ice-resistant coatings agents.	30
Table 11: Film coatings techniques.	31
Table 12: Contact angles of hydrophilic, super hydrophilic, hydrophobic and superhydrophobic surfaces.	41
Table 13: Disadvantages of commonly utilized superhydrophobic coating methods.	43
Table 14: Applications of oleophobic & omniphobic coatings.....	46
Table 15: Ice-resistant coatings-Materials used, principles, properties, applications.....	48
Table 16: Market drivers and trends in Ice-resistant coatings.	49
Table 17: Types of ice-resistant coatings.	52
Table 18: Nanomaterials utilized in anti-icing coatings and benefits thereof.....	57
Table 19: Ice-resistant coatings patent applications 2010-2018.....	59
Table 20: Main ice-resistant coatings patent assignees.	60
Table 21: Location of ice-resistant coatings patent filings 2010-2018.....	61
Table 22: Ice-resistant coatings -Markets, applications and potential addressable markets.	65
Table 23: Revenues for Ice-resistant coatings, 2010-2030, US\$, conservative and optimistic estimates.	66
Table 24. Research in ice-resistant coatings by organization.	79

Figures

Figure 1: Global revenues for ice-resistant coatings, 2010-2030, millions USD.	19
Figure 2: Global market revenues for ice-resistant coatings 2017, millions USD, by market.....	20
Figure 3: Markets for ice-resistant coatings 2017, %.....	21
Figure 4: Estimated market revenues for ice-resistant coatings 2018, millions USD, by market.....	22
Figure 5: Estimated market revenues for ice-resistant coatings 2030, millions USD, by market.....	23
Figure 6: Markets for ice-resistant coatings 2030, %.....	23
Figure 7: Global revenues for ice-resistant coatings, 2015-2030, by substrate materials.....	24

Figure 8: Regional demand for ice-resistant coatings, 2018.	25
Figure 9: Regional demand for ice-resistant coatings, 2030.	26
Figure 10. Ice/snow removal methods-active and passive.	28
Figure 11: Coatings synthesis techniques.	31
Figure 12: Techniques for constructing superhydrophobic coatings on substrates.	33
Figure 13: Electrospray deposition.	34
Figure 14: CVD technique.	35
Figure 15: Schematic of ALD.	37
Figure 16: SEM images of different layers of TiO ₂ nanoparticles in steel surface.	37
Figure 17: The coating system is applied to the surface. The solvent evaporates.	39
Figure 18: A first organization takes place where the silicon-containing bonding component (blue dots in figure 2) bonds covalently with the surface and cross-links with neighbouring molecules to form a strong three-dimensional.	39
Figure 19: During the curing, the compounds or- ganise themselves in a nanoscale monolayer. The fluorine-containing repellent component (red dots in figure 3) on top makes the glass hydro- phobic and oleophobic.	39
Figure 20: (a) Water drops on a lotus leaf.	41
Figure 21: A schematic of (a) water droplet on normal hydrophobic surface with contact angle greater than 90° and (b) water droplet on a superhydrophobic surface with a contact angle > 150°.	42
Figure 22: Contact angle on superhydrophobic coated surface.	43
Figure 23: Self-cleaning nanocellulose dishware.	44
Figure 24: SLIPS repellent coatings.	45
Figure 25: Omniphobic coatings.	47
Figure 26: Nanocoated surface in comparison to existing surfaces.	54
Figure 27: NANOMYTE® SuperAi, a Durable Anti-ice Coating.	55
Figure 28: SLIPS coating schematic.	55
Figure 29: Carbon nanotube based anti-icing/de-icing device.	56
Figure 30: CNT anti-icing nanocoating.	56
Figure 31: Revenues for Ice-resistant coatings 2010-2030, US\$, conservative and optimistic estimates. Conservative estimates in blue, optimistic in red.	67
Figure 32: Self-Cleaning Hydrophobic Coatings on solar panels.	75
Figure 33: Znshine Graphene Series solar coatings.	75
Figure 34: Nanocoating for solar panels.	76