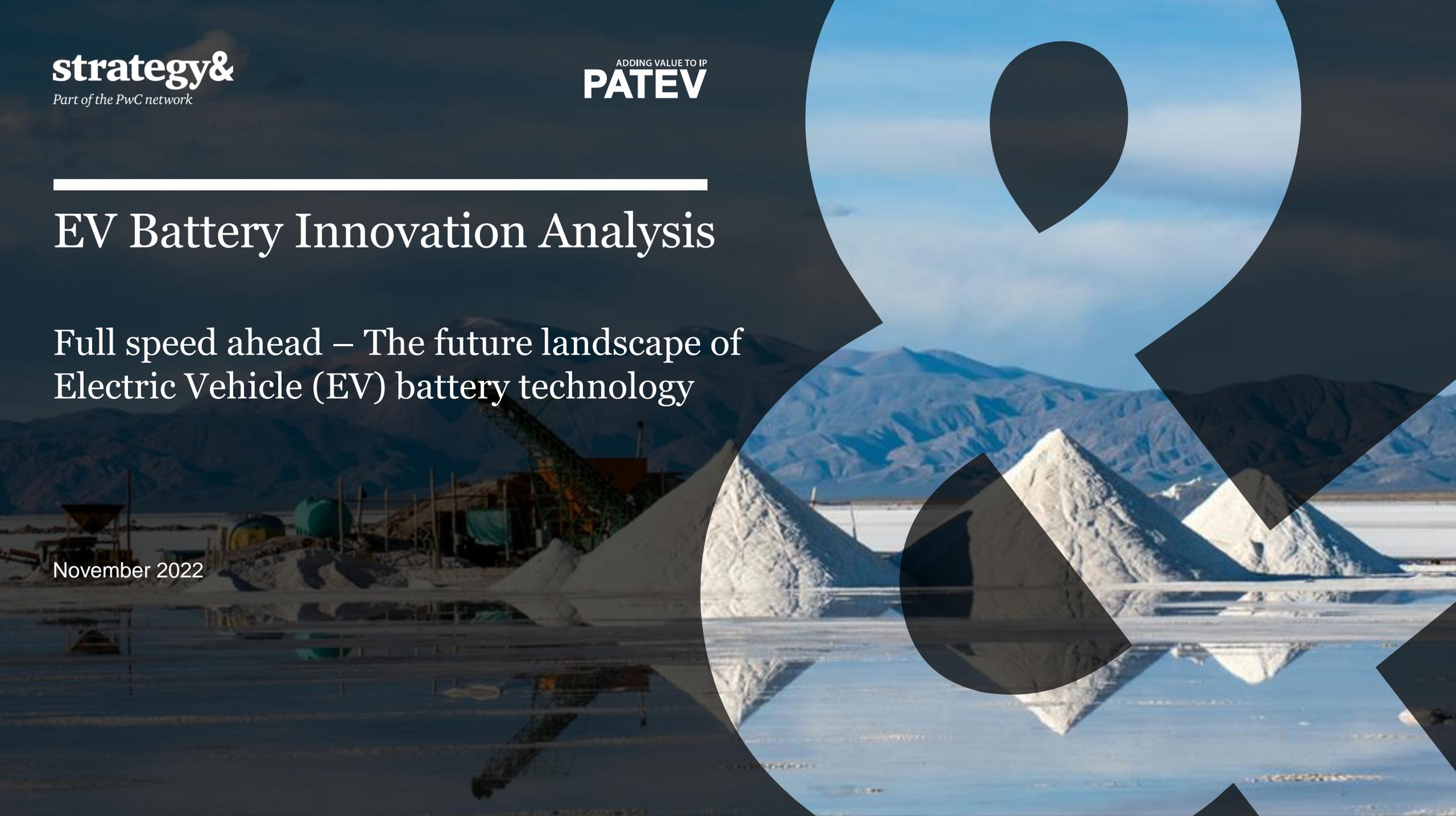

EV Battery Innovation Analysis

Full speed ahead – The future landscape of
Electric Vehicle (EV) battery technology

November 2022



Methodology for this EV Battery Innovation Analysis

For our analysis, we first **selected and structured relevant battery technology areas** for electric vehicles. We **acquired data** on the IP portfolios of the **leading cell suppliers¹** and **automotive OEMs²**, respectively for the relevant battery technology areas (e.g. cell casings, temperature control, electrode materials, manufacturing aspects etc.)

Even though focusing only on the top industry players, our analysis covers **more than 64,000 resulting patent applications** grouped into **almost 25,000 patent families** filed from **2002 to 2020**. Finally, we used the PATEV Innovation Intelligence system to prepare the vast amount of data for **evaluation and interpretation**. With the interactive evaluation, data can be presented from different perspectives, such as **regional trends, dynamics of applicants, and shifts in technology focus**.



¹ by planned capacity (source: Global lithium-ion battery capacity to rise five-fold by 2030; Wood Mackenzie; <https://www.woodmac.com/press-releases/global-lithium-ion-battery-capacity-to-rise-five-fold-by-2030>)

² by revenue (source: Top 10 Biggest Car Manufacturers by Revenue (2021) <https://www.threadinmotion.com/blog/top-10-biggest-car-manufacturers-by-revenue>)

Summary of Hypotheses for Global EV Battery Innovation

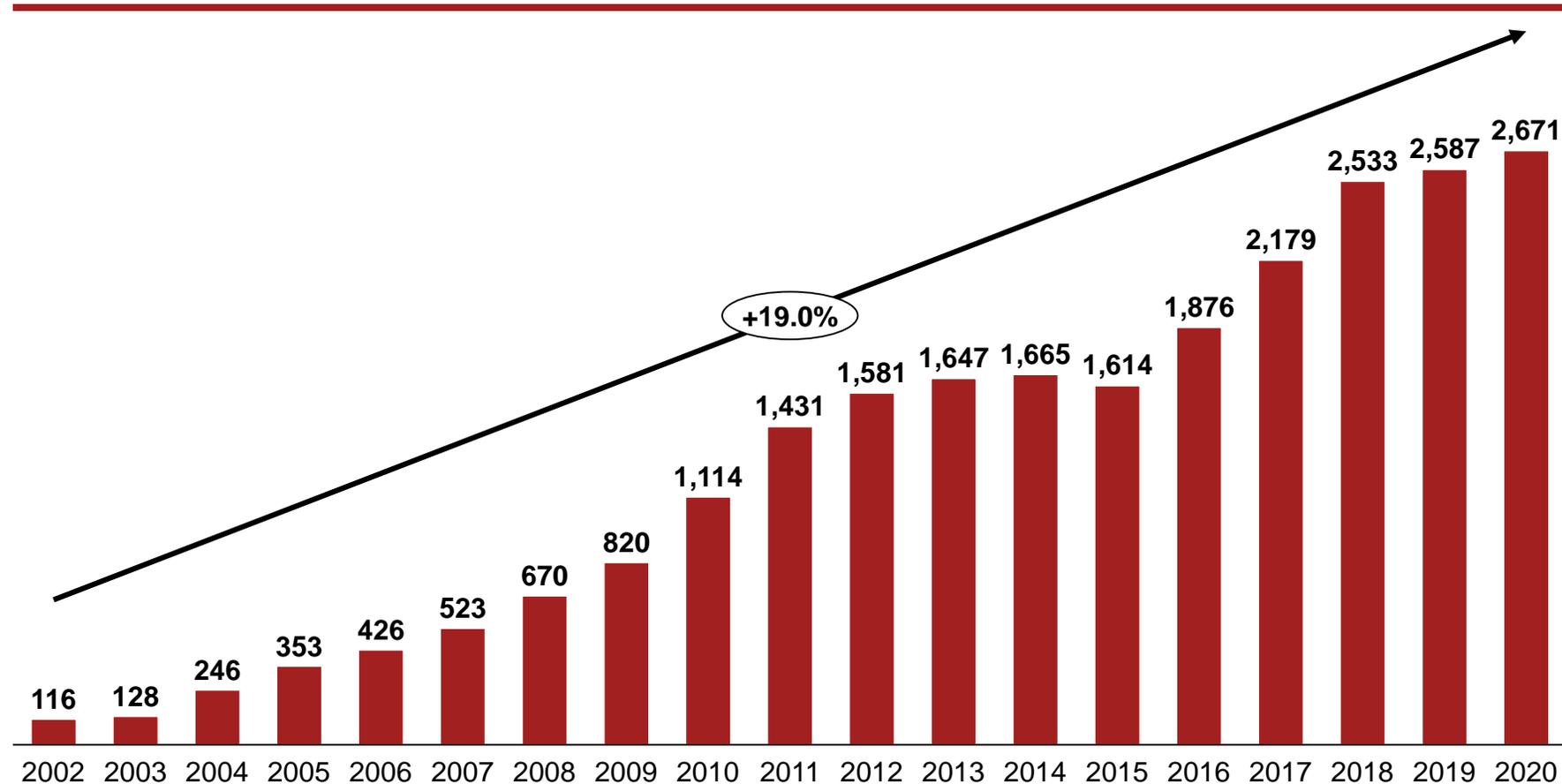
- 1 EV battery innovation just at the beginning**
- 2 Small number of players dominate innovation
- 3 Innovation leadership taken over by new players
- 4 New players with high innovation pace
- 5 Battery system innovation currently with large focus
- 6 OEMs pushing to crack thermal system challenges
- 7 Toyota overall dominates long-term innovation
- 8 Gas escape facilitation as next big innovation focus
- 9 Innovation in silicon electrodes accelerating
- 10 Non-Asian players struggle on joint-innovation ownership



Activity in the analysed EV battery areas grown with a CAGR of ~20 % over the last 20 years – plateau from 2012-2015

1 – Number of battery related patent filings

New patent families (per priority year)



Key takeaways

- Over the last 20 years, battery patent activity for electric vehicles grew constantly (CAGR ~20%)
- Between 2012 and 2015 a plateau in inventions in the selected EV battery areas can be observed, indicating a halt of interest in the field
- From 2015 onwards, the interest in EV battery technology grew again most probably due to the global Dieselgate
- In 2020, more than 2,500 new patents were globally filed in the analysed areas of EV batteries

Small number of players dominate EV battery patent landscape – cell suppliers innovate evenly on cell and system level

2 – Relevant players in battery patent landscape (I/II)

Patent Family Counts (total number of patent families from 2002-2020)

Group	Companies	Battery Cells	Battery System	Total
		Count of Patent families	Count of Patent families	Count of Patent families
OEM	Total (OEMs)	2,829	8,448	10,375
	Toyota	1,828	3,652	5,130
	Daimler	209	1,133	1,162
	HONDA	132	1,013	1,091
	Hyundai	226	778	944
	BMW	233	807	893
	VW	159	561	633
	Stellantis	13	245	246
	SAIC Motor	7	129	136
	Tesla	22	97	107
	GM	0	29	29
	Ford	0	4	4
Cell Supplier	Total (GF)	7,355	10,040	14,534
	LG	3,457	3,467	5,762
	Samsung (SDI)	1,709	2,413	3,204
	Panasonic	658	1,042	1,553
	BYD	257	951	1,077
	CATL	414	635	820
	Svolt	270	597	805
	SK Innovation	361	487	695
	EVE Energy	77	218	270
	CALB	62	100	159
	Envision	72	65	112
	Farasis	16	64	75
Northvolt	2	1	2	
Total		10,184	18,488	24,909

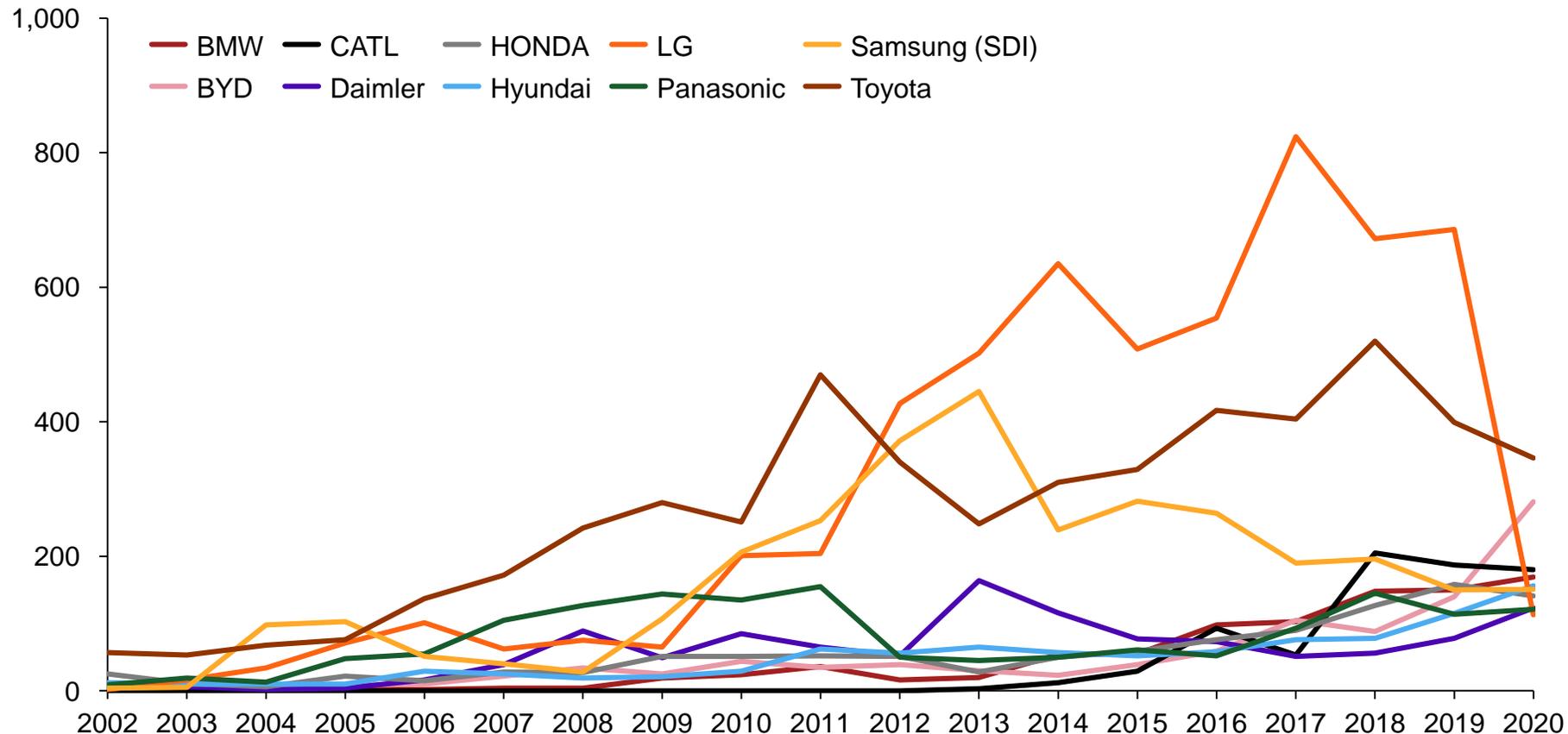
Key takeaways

- Of about 25,000 analysed patent families, about 60% were filed by the Cell Suppliers while about 40% were filed by the automotive OEMs
- Within the TOP players of the field, only a fraction makes up for the majority of filings
- Especially Asian players are EV battery innovation forerunners (especially China, Japan and Korea), while European players are mediocre
- The American players present a rather weak EV battery patent position

LG, Toyota and Samsung are historically the largest battery patent players globally – CATL made it to the top just recently

3 – Relevant players in battery patent landscape (II/II)

New patent families (per priority year)



Key takeaways

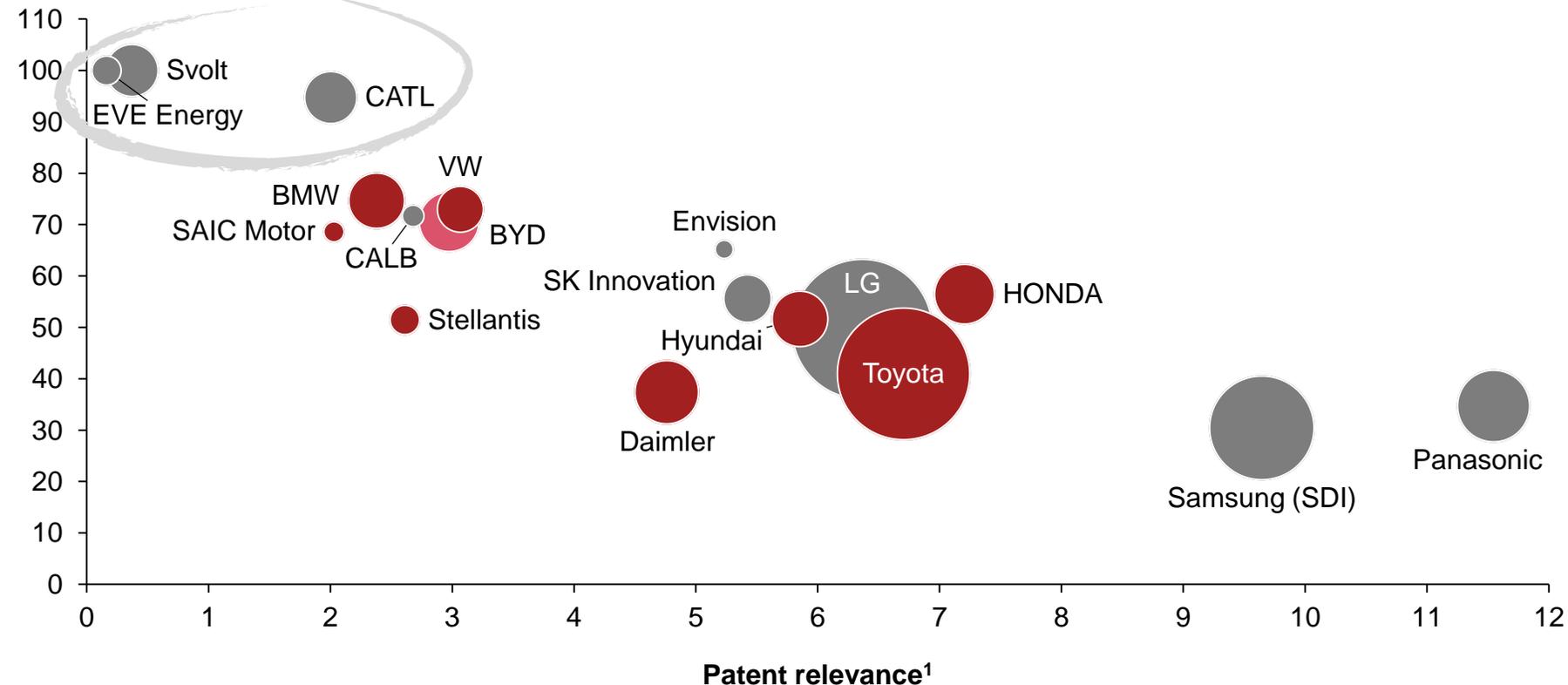
- Among the considered companies, Toyota, LG and Samsung were dominating the last two decades in terms of patent family quantity
- Within the last years, this evident „law of dominance“ is changing
- LG and Samsung significantly reduced their battery patenting activities indicating either a shortening of innovation or new strategies (e.g. due to legal disputes)
- Other emerging players are gaining momentum (e.g. CATL)

Players with long history in EV battery industry with most relevant patents, while new players seem to catch up speed

4 – Patent relevance and innovation speed

Patent relevance and innovation speed (from 2002-2020)

Innovation speed



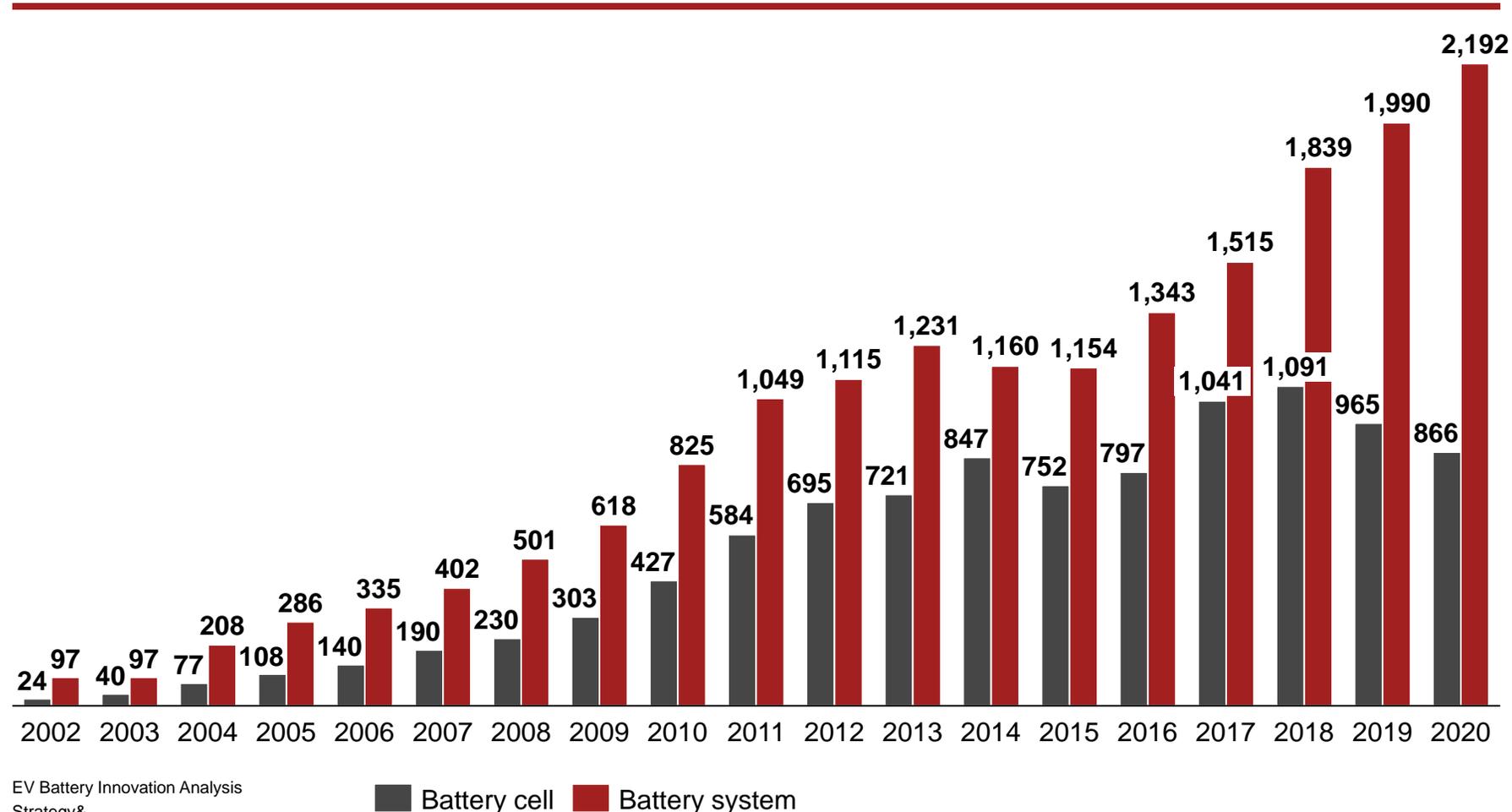
Key takeaways

- With regards to patent relevance, indicated by citation frequencies, Panasonic and Samsung seem to have laid some fundamentals for subsequent EV battery innovations and patents
- Both cell suppliers (red) and automotive OEMs (blue) seem on par with regards to innovation intensity
- New players are catching up with high innovation speed; the relevance of their portfolio is not proven yet

EV battery system related IP with highest growth in recent years – cell level activity seems to plateau since last ten years

5 – Number of identified EV battery related patent filings by cell or system level

New patent families (per priority year)



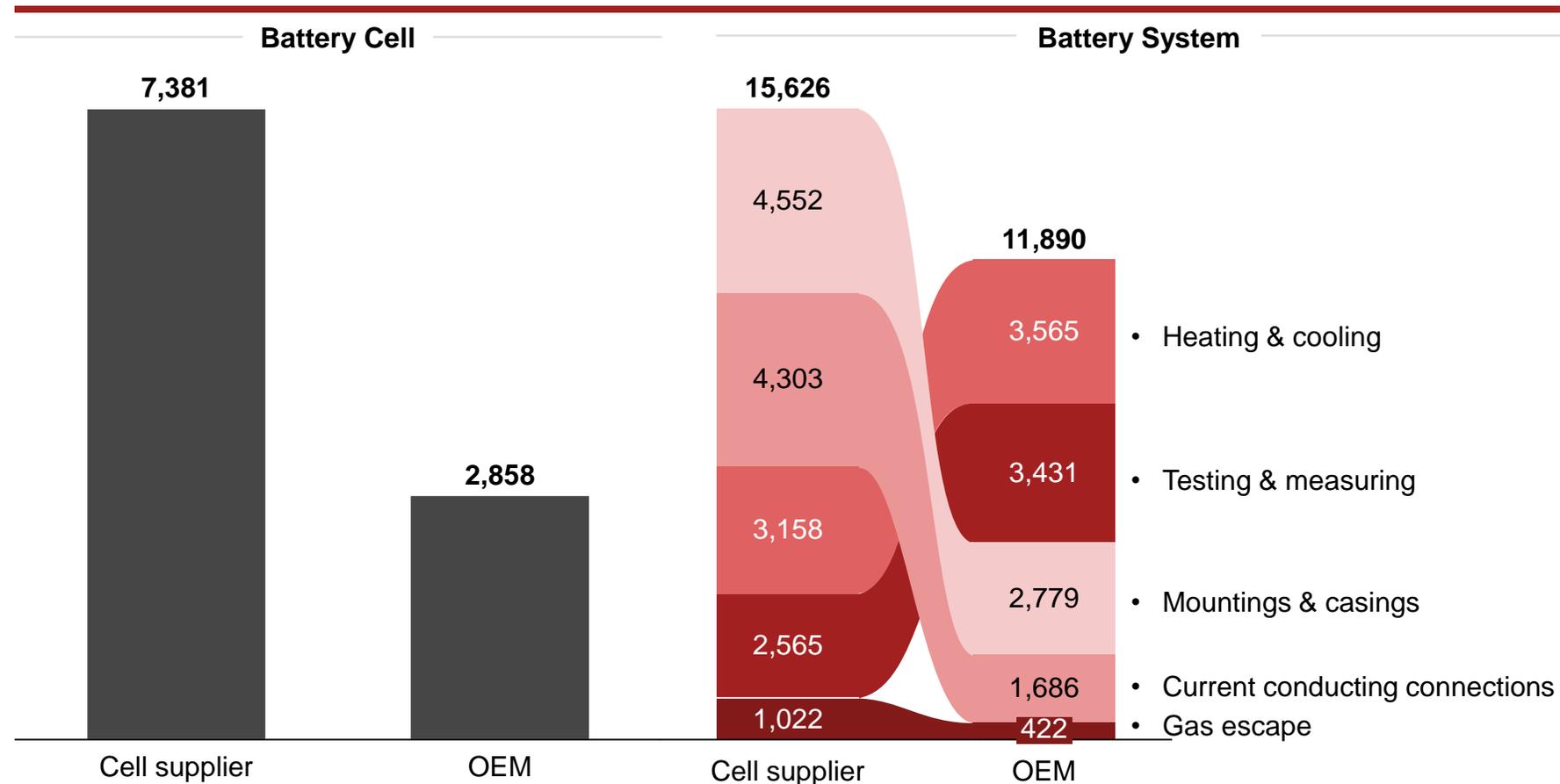
Key takeaways

- Both battery cell and battery system (pack/modul) patent filings grew meaningful over the last 20 years
- While battery cell patenting activity remains stable on a high level since around 2014, battery system patent filings keep growing over time
- Since the 2015 Dieselgate, the patent focus shifted even more to the system level
- With a constant level of battery cell (production) filing activities, an innovation catch up seems possible from a patent perspective

While cell suppliers focus more on casings and current conducting in EV battery systems, OEMs focus on thermal challenges and testing

6 – Patent details: battery system (I/III)

Patent family counts in detail (from 2002-2020)



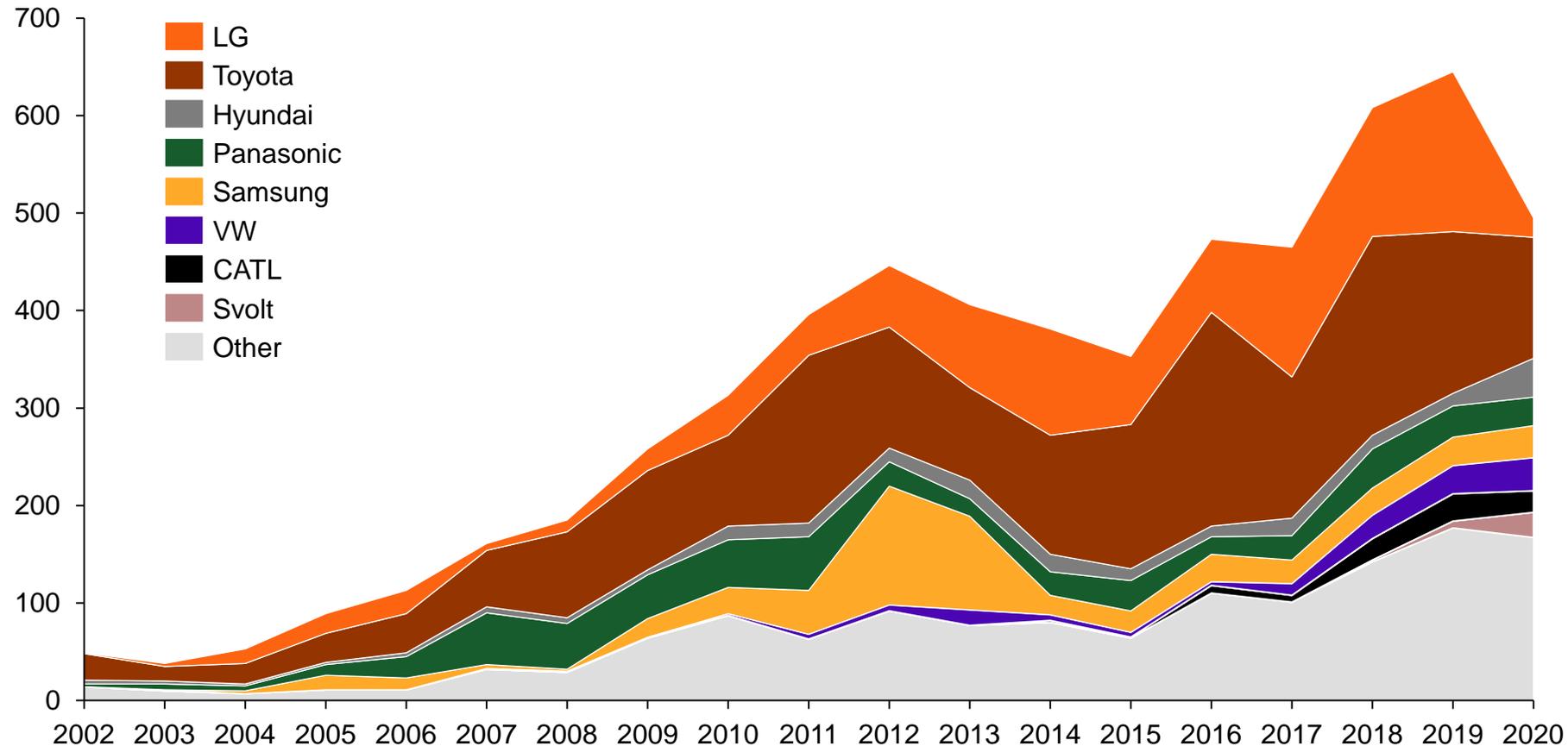
Key takeaways

- Cell suppliers display a balanced patenting approach towards both cell and system level, while OEMs focus comparatively stronger on the system level
- In the field of battery systems, the majority of cell supplier patent filings focus on mountings and casings, while OEMs favor their battery system patent activities on thermo and testing & measuring (incl. sensors)

Toyota emerges as strongest IP player in battery system testing with about a third of the analysed filings over the last 20 years

7 – Patent details: battery system (II/III)

Patent families related to testing/measuring in battery systems by applicants (per priority year)



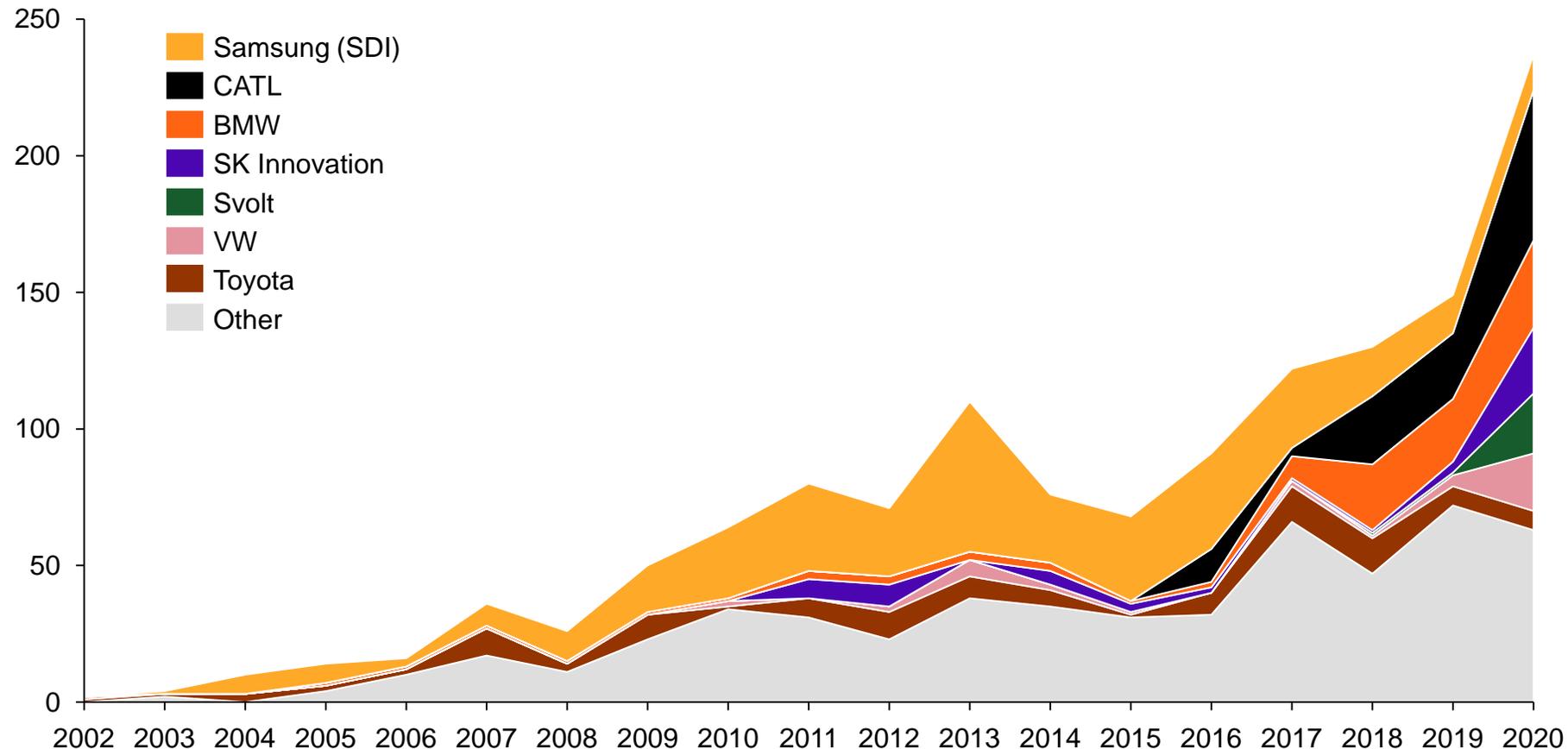
Key takeaways

- Within testing-related innovations for battery systems, Toyota emerges as the strongest player over the last 20 years with almost double the amount of patent filings compared to the global second place (LG)
- Looking at the patent filing trends for battery system testing/measurement in recent years, especially Hyundai, VW, Svolt and CATL are increasing their patenting activity, indicating an innovation focus

Facilitating escape of gases has experienced a major boost just recently across both OEMs as well as cell suppliers

8 – Patent details: battery system (III/III)

Patent families related to gas escape facilitation in battery systems by applicants (per priority year)



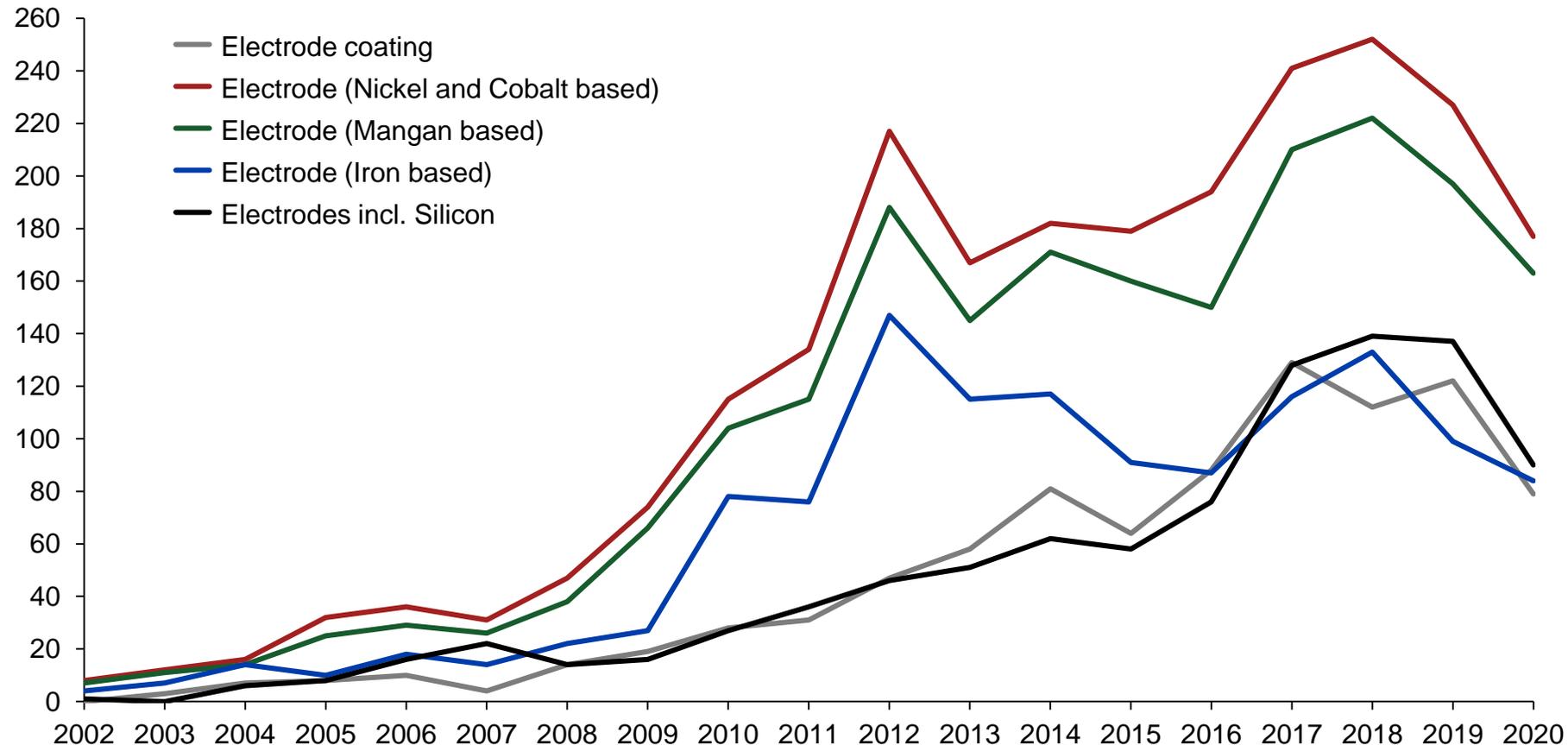
Key takeaways

- Within the last years, a strong trend towards patent filings focusing on gas escape facilitation in EV battery systems emerged, peaking recently
- Especially CATL, BMW, SK Innovation, Svolt and VW filed multiple patents in 2020, with some players making their patenting debut in that area
- The driver of a massive increase of gas escape patenting activity for EV battery systems may be requirements towards thermal propagation of batteries

Hot topic of battery cell patents has been silicon electrodes – with small patent share but increasing dynamics recently

9 – Patent details: battery cell

Battery cell patent families by covered sub-technologies (per priority year)



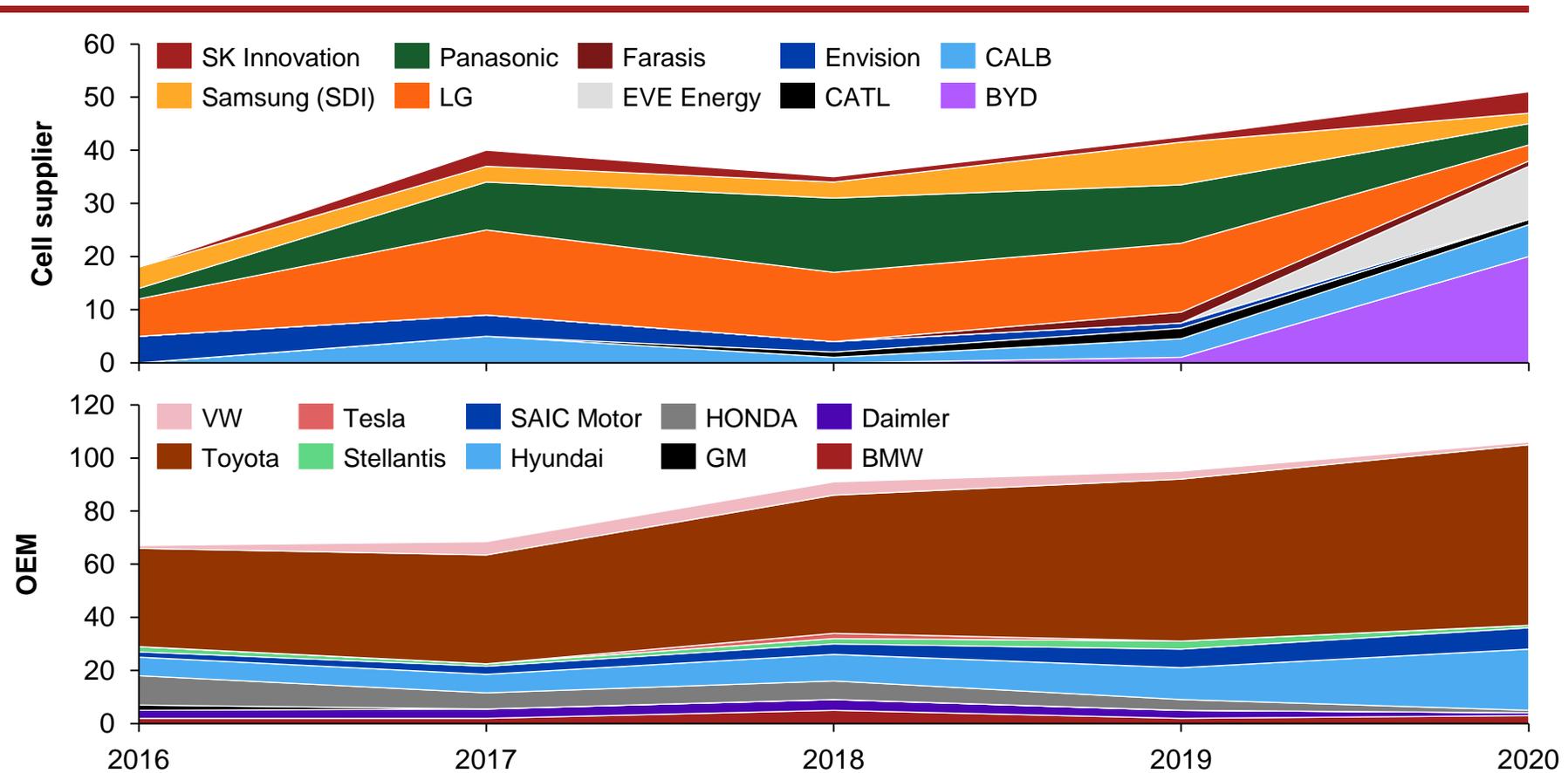
Key takeaways

- Within battery cell patenting, silicon-blended electrodes have emerged as a „hot-topic“ over the last 5 years (most likely due to their capability of increasing battery cell energy density)
- On the other hand, Lithium-Iron-Phosphate (LFP) chemistry cell patenting peaked in 2012, while Nickel-Mangan-Cobalt (NMC) chemistry cell patenting activities grew further

Non-Asian players struggle on joint-innovation ownership on both OEM and cell supplier level

10 – Analysis of patent cooperation

Patent families filed together with other companies (per priority year)



Key takeaways

- Since 2016, OEMs have filed almost double the amount of joint patents compared with cell suppliers
- Especially Toyota is filing a lot of cooperative IP in partnership with other Asian companies or institutes
- Seemingly, non-Asian players struggle on joint-innovation ownership on both OEM and cell supplier level

The fast-growing battery innovation landscape presents exciting insights about relevant players along battery cell and system level

Key take-aways

EV battery innovation landscape

EV battery related innovation grows steadily showing the vast potential for future products

A small number of players dominates the patent landscape with current change in leading players as newcomers catch up speed

Battery system patents

Battery system innovations show highest growth underlining the current focus of both OEMs and cell suppliers

Cell suppliers focus stronger on mounting and casing inventions, while **OEMs focus on thermo and testing challenges**

Battery cell patents

Silicon-blended electrodes have emerged as a “hot-topic” over the last 5 years

LFP chemistry cell patents peaked in 2012, while **NMC chemistry cell activities grew further**

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