

Apple Inc.
v.
RJ Technology, LLC

Patent Owner Demonstratives
IPR2023-01350
U.S. Patent No. 7,749,641
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Minghui Yang
James Carmichael
Carmichael IP, PLLC

Michael Ng
Daniel Zaheer
George Stamatopoulos
Robert Zhou
Kobre & Kim LLP

Outline

- 1. The '641 Patent**
- 2. Claim Construction: “charge cut-off voltage”**
- 3. Claim 5 is not obvious over Yamaki and Sakamoto (Ground 1A - Claims 5-8 and 11-14; Ground 1B - Claims 9-10)**
- 4. Claim 5 is not obvious over Yasunami and Koyama (Ground 2A – Claims 5-14; Ground 2B – Claims 9-10)**
- 5. Neither of Petitioner’s combinations renders obvious claims 11-14 (Ground 1A; Ground 2A)**

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4. Claim 5 is not obvious over Yasunami and Koyama (Ground 2A – Claims 5-14; Ground 2B – Claims 9-10)
5. Neither of Petitioner’s combinations renders obvious claims 11-14 (Ground 1A; Ground 2A)

The '641 Patent

 US007749641B2	
(12) United States Patent Ren et al.	(10) Patent No.: US 7,749,641 B2 (45) Date of Patent: Jul. 6, 2010
(54) SECONDARY LITHIUM ION CELL OR BATTERY, AND PROTECTING CIRCUIT, ELECTRONIC DEVICE, AND CHARGING DEVICE OF THE SAME	
(76) Inventors: Xiaoping Ren , 17A No. 4 Building, Shijijayuan, 45 Xiaoguanbeili, Anwai, Beijing, 100029 (CN); Jie Sun , 17A, No. 4 Building, Shijijayuan, 45 Xiaoguanbeili, Anwai, Beijing, 100029 (CN)	
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(51) Int. Cl. H01M 10/44 (2006.01) H01M 10/42 (2006.01) H01M 4/58 (2010.01) H02J 7/00 (2006.01)	
(52) U.S. CL. 429/50; 429/49; 429/231.6; 320/137	
(58) Field of Classification Search 429/60, 429/231.95, 49, 50; 320/137 See application file for complete search history.	
(56) References Cited U.S. PATENT DOCUMENTS 5,260,148 A * 11/1993 Idota 429/307	
FOREIGN PATENT DOCUMENTS CN 1135103 A 11/1996 CN 1185860 A 6/1998 JP 2000-270491 A 9/2000	
OTHER PUBLICATIONS K. Mizushima et al., "Li ₂ Co ₂ (0<x<1): A New Cathode Material for Batteries of High Energy Density", Mat. Res. Bull., vol. 15, pp. 783-789 1980. G. Pistoia et al., Synthesis of Mn spinels from different polymorphs of MnO ₂ , Journal of Power Sources, 56 (1995) 37-43. Lei Yongquan, "Materials for New Energy", 2000, p. 136. Office Action dated Jun. 9, 2009, in corresponding Japanese Application No. 2003-533374, English Translation 3 pages. Patent Abstracts of Japan Publication No. 2001-176559 dated Jun. 29, 2001, *Abstract*. Patent Abstracts of Japan Publication No. 09-259928 dated Oct. 3, 1977, *Abstract*. International Search Report, Dated: May 6, 2003. * cited by examiner Primary Examiner—Patrick Ryan Assistant Examiner—Muhammad Siddiquee (74) Attorney, Agent, or Firm—Stephen A. Bent; Foley & Lardner LLP	
(57) ABSTRACT The present invention provides a new method for improving capacity, average operating voltage and specific energy of a secondary lithium ion cell or battery. This method is achieved by means of properly adjusting the ratio between a positive material and negative material, which is calculated by theoretical specific energy, and properly increasing charge cut-off voltage. The present method can greatly increasing specific energy and average operating voltage of a secondary lithium ion cell without influence on recycle property of the cell. The present invention also provides a secondary lithium ion cell or battery practicing the method, a protecting circuit adapted for the secondary lithium ion cell or battery, a electronic device using said protecting circuit and said secondary lithium ion cell or battery, and a charging device for the secondary lithium ion cell or battery.	
18 Claims, No Drawings	

(10) **Patent No.:** **US 7,749,641 B2**
 (45) **Date of Patent:** **Jul. 6, 2010**

(57) **ABSTRACT**

The present invention provides a new method for improving capacity, average operating voltage and specific energy of a secondary lithium ion cell or battery. This method is achieved by means of properly adjusting the ratio between a positive material and negative material, which is calculated by theoretical specific energy, and properly increasing charge cut-off voltage. The present method can greatly increasing specific energy and average operating voltage of a secondary lithium ion cell without influence on recycle property of the cell. The present invention also provides a secondary lithium ion cell or battery practicing the method, a protecting circuit adapted for the secondary lithium ion cell or battery, a electronic device using said protecting circuit and said secondary lithium ion cell or battery, and a charging device for the secondary lithium ion cell or battery.

18 Claims, No Drawings

The '641 Patent

5. A secondary lithium ion cell or battery, characterized in that the secondary lithium ion cell or battery has a charge cut-off voltage of greater than 4.2 V but less than 5.8 V, and a ratio of positive electrode material to negative electrode material of the secondary lithium ion cell or battery is from 1:1.0 to 1:2.5, as calculated by a theoretic capacity with a charge cut-off voltage set at 4.2 V.

APPLE-1001 [the '641 Patent], Cl. 5

The '641 Patent

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SUMMARY OF INVENTION

As to the common opinion in the art that increasing the charge cut-off voltage above 4.2 V may greatly shorten the recycle life, the inventor of the present invention conducted a large number of experiments and studies to elevate the charge cut-off voltage and the capacity of cell. Contrary to this opinion, the inventor unexpectedly found that the efficacy of electrode active materials is greatly increased by increasing the charge cut-off voltage and properly adjusting the ratio of positive electrode material to negative electrode material of single lithium ion cell. Consequently, the specific energy, capacity and average operating voltage of secondary lithium ion cell or battery are improved, while the performance of cell is substantially not changed. The present invention is fulfilled based on the aforesaid discovery.

APPLE-1001 [the '641 Patent], 3:1-16; POR at 11-12

The '641 Patent

11. A secondary lithium ion cell or battery according to claim 5, wherein the secondary lithium ion cell or battery maintains at least 7500 of capacity after 400 cycles.

12. A secondary lithium ion cell or battery according to claim 5, wherein the secondary lithium ion cell or battery maintains at least 75.83% of capacity after 400 cycles.

13. A secondary lithium ion cell or battery according to claim 5, wherein the secondary lithium ion cell or battery maintains at least 80% of capacity after 400 cycles.

14. A secondary lithium ion cell or battery according to claim 5, wherein the secondary lithium ion cell or battery maintains at least 80.72% of capacity after 400 cycles.

APPLE-1001 [the '641 Patent], Cl. 11-14

The '641 Patent

Example 1

Several lithium ion cells of quadrate type 653466 are prepared according to the above method, and they each have a ratio of positive electrode material to negative electrode material of 1:1.0, 1:1.05, 1:1.1, 1:1.15, 1:1.2, 1:1.25 and 1:1.3. After formation and test using an charge cut-off voltage of 4.20 V, these cells have an arithmetic mean capacity of 1113 mAh, a weight specific energy of 102 Wh/kg, an average operating voltage of 3.70 V, and maintain 85.72% of capacity after 400 recycles.

Example 2

Several lithium ion cells of quadrate type 653466 are prepared according to the above method, and they each have a ratio of positive electrode material to negative electrode material of 1:1.0, 1:1.05, 1:1.1, 1:1.15, 1:1.2, 1:1.25 and 1:1.3. After formation and test using an charge cut-off voltage of 4.30 V, these cells have an arithmetic mean capacity of 1206 mAh, a weight specific energy of 113 Wh/kg, an average operating voltage of 3.75 V, and maintain 86.31% of capacity after 400 recycles.

Example 3

Several lithium ion cells of quadrate type 653466 are prepared according to the above method, and they each have a ratio of positive electrode material to negative electrode material of 1:1.0, 1:1.05, 1:1.1, 1:1.15, 1:1.2, 1:1.25 and 1:1.3. After formation and test using an charge cut-off voltage of 4.35 V, these cells have an arithmetic mean capacity of 1253 mAh, a weight specific energy of 119 Wh/kg, an average operating voltage of 3.8 V, and maintain 84.79% of capacity after 400 recycles.

Example 5

Lithium ion cells of quadrate type 653466 are prepared according to the above method, and it has a ratio of positive electrode material to negative electrode material of 1:1.45. After formation and test using an charge cut-off voltage of 4.45 V, said cell has a capacity of 1365 mAh, a weight specific energy of 129 Wh/kg, an average operating voltage of 3.85 V, and maintain 84.56% of capacity after 400 recycles.

APPLE-1001 [the '641 Patent], 10:26-11:16

The Charge Cutoff Voltage Was Limited to 4.2V

In fact, the positive electrode materials and negative electrode materials used in the current secondary lithium ion battery have relatively higher theoretical capacity, and the problem merely lies in the lower actual utilization rate of said capacity. For example, lithium cobalt oxides as a positive electrode material of secondary lithium ion cell has a theoretical capacity of 248 mAh/g, while the actually used capacity of it is merely about 140 mAh/g, i.e., about half of said theoretic capacity is not utilized. This is mainly caused by the limitation of charge cut-off voltage commonly used in the art.

At present, the charge cut-off voltage of single secondary lithium ion cell is limited to no more than 4.2 V, and this is well accepted as a technical requirement in the industry of manufacture of secondary lithium ion battery. Further, all lithium ion batteries in the markets around the world are manufactured under this technical requirement For example,

APPLE-1001 [the '641 Patent], 1:36-51; POR at 7

The Charge Cutoff Voltage Was Limited to 4.2V

Common name	Nickel-metal hydride	Rechargeable “primary” types, Zn/MnO ₂	Lithium systems (lithium-ion) ^a
Chemistry:			
Anode	MH	Zn	C
Cathode	NiOOH	MnO ₂	LiCoO ₂
Electrolyte	KOH (aqueous solution)	KOH (aqueous solution)	Organic solvent
Cell voltage (typical), V:			
Nominal	1.2	1.5	4.0
Open circuit	1.4	1.5	4.2
Operating	1.25–1.10	1.3–1.0	4.0–2.5
End	1.0	1.0	2.5

APPLE-1015 [Linden Handbook] at 5-6; POR at 8; Ex. 2007 [Yao Decl.], ¶47

The Charge Cutoff Voltage Was Limited to 4.2V

Table 4

Charging protocol as specified by manufacturer's product literature

Manufacturer	Current (A)	Potential limit (V)	Time (h)
Sony	1.0	4.2	2.5
A&T	1.0	4.2	2.5
Sanyo	1.3	4.1	2.5
Moli	1.2	4.1	2.5
Matsushita	0.5	4.2	2.0 u

Ex. 2009 [Johnson 1998] at 4; POR at 7; Ex. 2007 [Yao Decl.], ¶45

The Charge Cutoff Voltage Was Limited to 4.2V



Dr. Yan Yao

44. For example, lithium cobalt oxide (LiCoO_2) has been a well-studied cathode material in lithium-ion batteries, primarily due to its high energy density and stable electrochemical performance. Traditionally, the charge cutoff voltage for LiCoO_2 has been limited to 4.2V. It was understood that at voltages higher than 4.2V, LiCoO_2 begin to undergo irreversible structural changes and oxygen loss, which not only degrades the material's capacity and cycling stability, but also poses risks of thermal runaway and battery failure.

POR at 7; Ex. 2007 [Yao Decl.], ¶44

The Charge Cutoff Voltage Was Limited to 4.2V

3 What was it about 4.2 volts that was
4 significant enough that that value had become common?

5 A. It was the point where the cell manufacturers
6 clearly found the combination of characteristics that
7 they felt were the best for their system.

8 It wasn't a single point of failure, success,
9 or like -- there are many, many things that are used to
10 evaluate a cell. If a computer manufacturer, for
11 example, was going to choose a cell supplier, he would
12 consider dozens of performance characteristics at many
13 different conditions. And the cell supplier would
14 typically recommend charge -- both charge cutoff voltage
15 and charge technique, for example, constant current up
16 to a voltage and then switch to constant voltage. That
17 was common. There were other systems too.

18 So it's -- while I described it as common, it
19 certainly wasn't the only one. And even then, it was
20 complicated by the actual operating systems.

The Charge Cutoff Voltage Was Limited to 4.2V



Mark Juzkow*

8 Q. And was 4.2 volts the threshold at which a
9 person of ordinary skill in the art would understand a
10 charge might lead to extracting excess lithium from a
11 cathode?

12 ATTORNEY SOMMER: Object to form.

13 A. We started with 4.1 volts and then we moved to
14 4.2 volts. But we did not go beyond 4.2 volts, as we
15 would lessen the cycle life of the cell.

9 Q. So did I understand correctly that one of the
10 reasons you didn't go beyond 4.2 volts was out of
11 concern that doing so would extract an excess amount of
12 lithium that might lead to thermal runaway phenomena?

13 A. That was one of the reasons, yes.

14 Q. And that was considered dangerous?

15 A. Yes.

POR at 9; Ex. 2022 [Juzkow Dep.] at 76:8-15; 77:9-15

How Capacity Ratio Affects Battery Performance Was Not Well-Understood



49. The capacity ratio in lithium-ion batteries generally refers to the ratio of the capacities between the cathode (positive electrode) and the anode (negative electrode). As of the priority date of the '641 Patent, the capacity ratio was not the focus of battery designers and developers. Indeed, more than 10 years after the priority date of the '641 Patent, commentators still suggest that while “many researchers of electrode-design parameters have focused on individual electrodes such as cathode or anode, only limited works have been done for the parameter such as the capacity ratio of negative to positive electrode (N/P ratio).”¹⁰

Ex. 2028 [Kim 2015] at 1; POR at 11; Ex. 2007 [Yao Decl.], ¶49

How Capacity Ratio Affects Battery Performance Was Not Well-Understood

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The current lithium ion batteries (LIBs) have high energy density, flexible and lightweight design, and long cycle life property [1] in comparison with other secondary batteries. However, there have been a lot of efforts to find novel materials [2,3] with higher energy and power density to satisfy the new requirements for future LIBs for personal electronic devices, electric vehicles (EVs), energy storage systems (ESSs), and so on. In addition, there are many systematic researches on the properties of electrode itself (cathode [4,5] and anode [6,7]) to design a high performance full cell. The density and thickness of electrode is considered as an important factor in commercial batteries to get higher energy density [8]. Even though many researches of electrode-design parameters have focused on individual electrodes such as cathode or anode, only limited works have been done for the parameter such as the capacity ratio of negative to positive electrode (N/P ratio). The capacity ratio is practically important to achieve the targeted performance and the reduction of cost since it

Ex. 2028 [Kim 2015] at 1; POR at 11; Ex. 2007 [Yao Decl.], ¶49

Lithium-Ion Batteries Were Designed with Excess Cathode Capacity



51. For example, many in the industry adopted an approach of designing batteries where the cathode capacity exceeded that of the anode.¹¹ This was based on the understanding that some lithium ions are lost due to side reactions. Those side reactions include the formation of the solid electrolyte interface (SEI) on the anode during the initial charge cycles, the formation of cathode electrolyte interface (CEI) films, and reactions with the electrolyte.¹² By providing the cathode with excess capacity, manufacturers aimed to compensate for these losses and maintain battery balance (i.e., ensure that there was sufficient cathode given the amount of anode in the battery, such that the anode was not in excess, which would have been wasteful) over time.¹³

POR at 10; Ex. 2007 [Yao Decl.], ¶51

Lithium-Ion Batteries Were Designed with Excess Cathode Capacity

of the cell. For an ideal cell, the initial lithium capacity available for cycling is constant over the life of the battery. Unfortunately, the true case in actual lithium-ion batteries is more complicated than this, and side reactions and secondary processes are able to perturb the capacity balance from its ideal state. The actual optimized active mass ratio is ca. 2.05-2.15 for the coke/LiMn₂O₄ system, which corresponds to 14% excess capacity in the positive electrode.⁴¹

Ex. 2016 [Arora 1998] at 4; POR at 10; Ex. 2007 [Yao Decl.], ¶51

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- 2. Claim Construction: “charge cut-off voltage”**
3. Claim 5 is not obvious over Yamaki and Sakamoto (Ground 1A - Claims 5-8 and 11-14; Ground 1B - Claims 9-10)
4. Claim 5 is not obvious over Yasunami and Koyama (Ground 2A – Claims 5-14; Ground 2B – Claims 9-10)
5. Neither of Petitioner’s combinations renders obvious claims 11-14 (Ground 1A; Ground 2A)

Claim Construction – “charge cut-off voltage”

Term	Construction
“charge cut-off voltage”	The maximum voltage to which the battery is configured to be charged

POR at 21

Claim Construction – “charge cut-off voltage”

IV. CONCLUSION

For the foregoing reasons, the Court construes the disputed claim terms as follows:

No.	Term	Court’s Construction
1.	“charge cut-off voltage”	“the maximum voltage to which the battery is configured to be charged.”

POR at 21; APPLE-1031 [District Court *Markman* Order] at 31

The “charge cut-off voltage” Is a Battery Property

5. A secondary lithium ion cell or battery, characterized in that the secondary lithium ion cell or battery has a charge cut-off voltage of greater than 4.2 V but less than 5.8 V, and a ratio of positive electrode material to negative electrode material of the secondary lithium ion cell or battery is from 1:1.0 to 1:2.5, as calculated by a theoretic capacity with a charge cut-off voltage set at 4.2 V.

6. A secondary lithium ion cell or battery according to claim 5, characterized in that the secondary lithium ion cell or battery has a charge cut-off voltage within a range from 4.3 V to 5.2 V.

7. A secondary lithium ion cell or battery according to claim 5, characterized in that the secondary lithium ion cell or battery has a charge cut-off voltage within a range from 4.3 V to 4.8 V.

APPLE-1001 [the '641 Patent], Cl. 5-7; Sur-Reply at 9

The “charge cut-off voltage” is a Battery Property

It is one object of the present invention to provide a new method for improving capacity, average operating voltage and energy density of a secondary lithium ion cell or battery, wherein the charge cut-off voltage of the single cell is greater than 4.2 V, and less than 5.8 V, and the ratio of positive electrode material to negative electrode material of the single cell is from 1:1.0 to 1:2.5, preferably from 1:1.16 to 1:2.5, as calculated by the specific capacity with the charge voltage limited to 4.2 V.

Another object of the present invention is to provide a secondary lithium ion cell or battery, wherein the single secondary lithium ion cell has an charge cut-off voltage of greater than 4.2 V but less than 5.8 V, and the ratio of positive electrode material to negative electrode material of the single cell is from 1:1.0 to 1:2.5, preferably from 1:1.15 to 1:2.5, as calculated by the specific capacity with the charge voltage limited to 4.2 V.

APPLE-1001 [the '641 Patent], 3:20-21; 3:26-29; Sur-Reply at 9

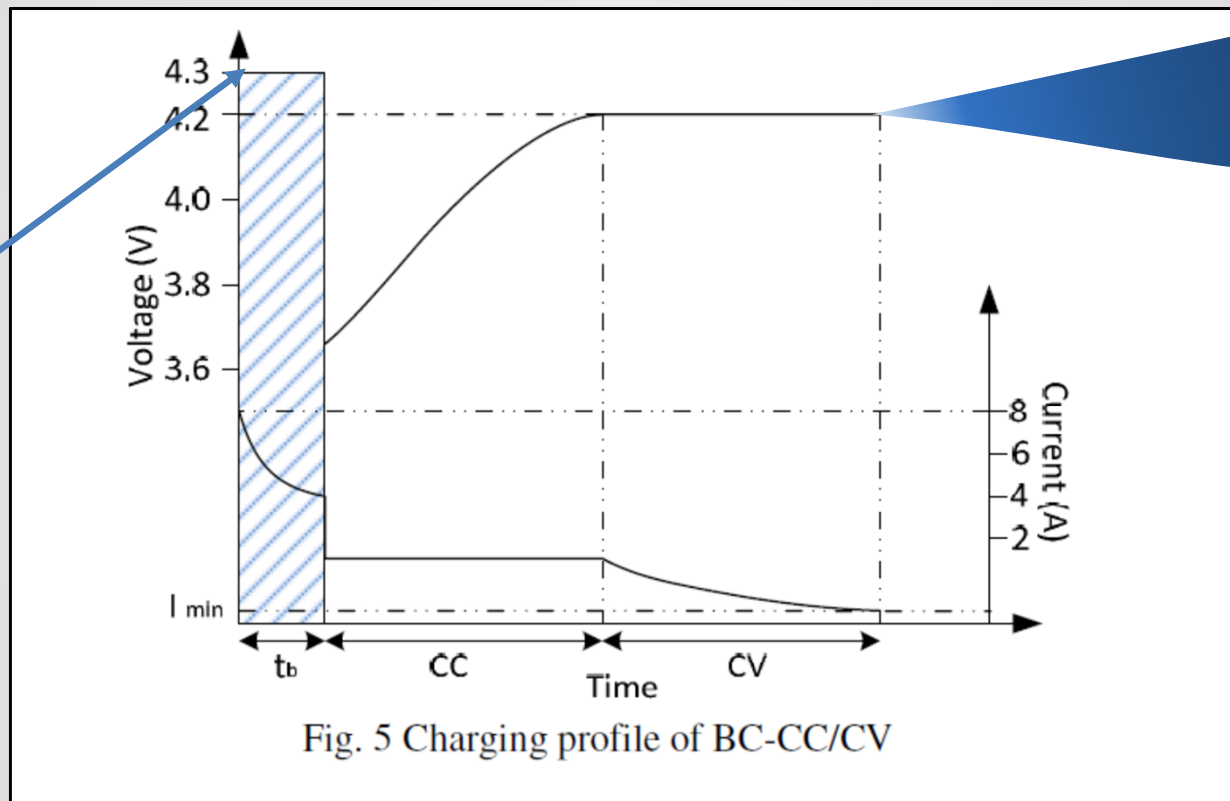
The “charge cut-off voltage” is a Battery Property

Common name	Nickel-metal hydride	Rechargeable “primary” types, Zn/MnO ₂	Lithium systems (lithium-ion) ^a
Chemistry:			
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Cathode	NiOOH	MnO ₂	LiCoO ₂
Electrolyte	KOH (aqueous solution)	KOH (aqueous solution)	Organic solvent
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Nominal	1.2	1.5	4.0
Open circuit	1.4	1.5	4.2
Operating	1.25–1.10	1.3–1.0	4.0–2.5
End	1.0	1.0	2.5

APPLE-1015 [Linden Handbook] at 5-6; POR at 25; Ex. 2007 [Yao Decl.], ¶47; Sur-Reply at 10

The “charge cut-off voltage” is a Battery Property

The applied voltage is 4.3V



The CCV is 4.2V.

APPLE-1038 [Shen] at 4; Sur-Reply at 11

Examples 14 and 15

In the present method, the elevating of the charge cut-off voltage is advantageously carried out during the formation and examination of the cell. The use of charge cut-off voltage of 4.20 V or high could increase the specific energy of cell, the capacity of positive electrode active material and the average operating voltage, and activate the cell so that the cell reaches its optimal working state with simultaneously achieving the effect of the formation, substantial improvement of the specific energy of commercial lithium ion cells, and imparting the competitiveness of lithium ion cells without altering the original process.

Lithium ion cells of quadrate type 653466 are prepared according to the above method, wherein 15% of another
40 lithium-containing compound C is added into the positive electrode slurry, and the ratio of positive electrode material to negative electrode material is 1:2.6. After formation and test using an charge cut-off voltage of 5.90 V, said cell has a
45 capacity of 1565 mAh, and maintain 12.31% of capacity after 15 cycles.

APPL-1001 [the '641 Patent], 4:43-53, 12:38-46, 12:61-62; Sur-Reply at 12

Apple Litigation

The batteries at issue, as well as lithium ion batteries generally, have physical characteristics, some of which are determined by the design and manufacture of the battery, some of which are set by, for example, the first charge to which the battery is charged. And then, obviously, in the process of charging, the charging circuitry actually does charge the battery up to a maximum, which is the limit that we have addressed in our proposed construction.

I think it actually -- again, taking this somewhat on the fly because this is a new argument, introduces new types of uncertainty, to adopt a claim construction that says how it is charged. The physical characteristics of the battery are what counts here. There are physical properties of the battery that set the maximum to which it is charged.

And then obviously in the devices themselves, they are charged up to a particular level. That is not the subjective intent of the designer. It is not the subjective intent of the user. It is the physical characteristic of the battery.

“The physical characteristics of the battery are what counts here.”

Sur-Reply at 12;
APPLE-1033 (PO Sur-Reply in the
Samsung IPR) at 11 (quoting Apple
District Court Litigation *Markman*
Hearing Transcript at 7:24-8:18)

Apple Argued that the CCV is a Physical Property of a Battery

7	Moreover, Plaintiff's added limitation that the maximum voltage must be	
8	"designed and manufactured" (Pl.'s Br. 9) improperly introduces a requirement as to	
9	the <i>subjective intent</i> of a designer or manufacturer regarding the cut-off voltage. In	
10	other words, Plaintiff's proposed construction introduces the new requirement that a	
11	battery be " <i>configured</i> " (" <i>i.e., designed and manufactured</i> ") (<i>id.</i>) to be charged at a	
12	charge cut-off voltage of 4.2 V, not just that it have the physical property of a charge	
13	cut-off voltage set at 4.2 V, as claim 5 requires. See Horn Decl., ¶12. Plaintiff's	

Sur-Reply at 13; APPLE-1040 [District Court Apple Responsive Br.] at 11

Apple Argued that the CCV is a Physical Property of a Battery

21 We think that that portion of the plaintiff's
22 construction based on plaintiff's own argument given just
23 now should be removed. It's the physical characteristics
24 are what counts, not the design somewhere upstream but
25 actually what the battery is in operation, the actual

1 physical battery.

2 The "configured to be" adds exactly what counsel,
3 my friend, just argued should not be mixed in, which is what
4 someone does, some person does. It's what the battery is
5 that matters. If you take out the words "configured to be,"
6 then we'll be clearly doing exactly what the claim language
7 says, which is the battery has a charge cut-off voltage.
8 That's the language in Claim 5. In Claim 6, the battery has
9 a charge cut-off voltage. Again, in Claim 7, the same.

10 So we should be referring to what the battery has,
11 not what someone configured it to have during design but it
12 may not have in actual construction. That's the issue, Your

Sur-Reply at 13 [quoting Apple District Court Litigation *Markman* Hearing Tr. at 9:21-10:12]

The Battery Voltage May Converge to the Maximum Applied Voltage with Slow Charging

16 strike a balance between fast charging and safe charging. But CC/CV charging is
17 not the only way to charge a battery. A charge cutoff voltage can be implemented
18 by other charging algorithms. For example, in many laboratory settings, batteries
19 are charged at a constant current without a constant voltage stage. Once the battery
20 reaches a predetermined voltage (*i.e.*, the charge cut-off voltage), the charging
21 stops. Sometimes the battery is charged at a constant voltage, without first being



1 understand that. In your opinion you're telling
2 the board that constant current charging sometimes
3 will reach the charge cut-off voltage and
4 sometimes will not reach the charge cut-off
5 voltage, depending on conditions?

6 MR. STAMATOPOULOS: Object to
7 form.

8 A. I'm telling the board under current
9 condition sometimes it reach equilibrium if you
10 charge at pretty slow rate. Some -- you know, if
11 you charge at the higher rate or medium rate, it
12 will not reach the equilibrium at the end of the
13 charge.

APPLE-1042 [PO District Court Opening Br.] at 42; APPLE-1041 [Yao Samsung Dep.], 25:1-13; Sur-Reply at 14.

The Battery Voltage May Converge to the Maximum Applied Voltage with Slow Charging

18 Q. And when you analyzed that term, did you take
19 it to mean the externally applied voltage during
20 charging?

21 A. Yes.

22 Q. And that's different than the open circuit
23 voltage. Correct?

24 A. Well, it asymptotically approaches the open
25 circuit voltage as the charge current goes to zero.

1 Q. Essentially, these are two different things, Page 161
2 right?

3 A. No.

4 Q. The open circuit voltage is not different than
5 the externally applied voltage?

6 A. Not when the charge current goes to zero, no.

Sur-Reply at 14-15; Ex. 2008 [Hruska Dep.] at 160:18-161:6

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Yamaki's Preliminary Data Do Not Teach a Battery Configured to a CCV above 4.2V



62. Yamaki prepared different cathode active materials and charged batteries using those cathode active materials to different voltages as part of testing the new cathode.²⁵ A POSITA reviewing Yamaki's testing data would understand that these data were highly preliminary, and that the inventors of Yamaki were conducting a preliminary assessment of the proposed cathode material. Much more experimentation would be needed to confirm whether a secondary lithium-ion battery could be built using Yamaki's proposed cathode.

POR at 13-15; Ex. 2007 [Yao Decl.], ¶¶62; Sur-Reply at 1-2

Yamaki's Preliminary Data Do Not Teach a Battery Configured to a CCV above 4.2V

[0028]

A characteristic of the lithium secondary battery in the present invention is using a Co-based oxide containing at least one element selected from Mg, Al, Mn, Ti and Sr as a positive electrode active material and a carbon conductive material having amorphous carbon in at least the surface layer, and setting the highest potential of the positive electrode during charging to 4.4 V to 4.8 V, preferably 4.4 V to 4.6 V, in terms of metallic Li to obtain a battery with an initial discharge capacity for the positive electrode active material of 160 mAh/g or more, and a capacity retention rate of 80% or more when charging and discharging have been repeated 10 times.

APPLE-1004 [Yamaki], ¶28; POR at 13-15; Ex. 2007 [Yao Decl.], ¶64

Yamaki's Preliminary Data Do Not Teach a Battery Configured to a CCV above 4.2V



63. Each of the example batteries was charged and discharged with a current of 0.5 mA.²⁶ Each of the example batteries in Table 1 of Yamaki had an initial capacity around 4 mAh.²⁷ This means that it is going to take at least 8 hours for the battery to be fully charged. A POSITA would understand that this is a very slow charging rate only used in controlled experimental settings to obtain a preliminary assessment of the cathode active material. Typically, much higher current would be used to assess the normal cycle life of a battery, such as 0.5C or 1C.²⁸ In short, Yamaki's testing was not performed in normal operating conditions.

APPLE-1004 [Yamaki], ¶¶52; POR at 13-15; Ex. 2007 [Yao Decl.], ¶¶63

Yamaki's Preliminary Data Do Not Teach a Battery Configured to a CCV above 4.2V



126. I understand that Petitioner argues that Yamaki already achieves an operable secondary lithium-ion battery with a charge cutoff voltage greater than 4.2V. I disagree. As I have discussed above, Yamaki only presents preliminary experimental data of a secondary lithium-ion battery that was charged and discharged for only 10 cycles under a very low current. Such data could only represent a very limited aspect of the performance of Yamaki's batteries. A POSITA would not be able to reasonably ascertain whether the battery in Yamaki could be safe in normal operating conditions over its life cycle.

POR at 13-15; Ex. 2007 [Yao Decl.], ¶126

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127. In contrast, the industry expended significant resources and conducted extensive testing to arrive at the conclusion that the charge cutoff voltage of a secondary lithium-ion battery could not exceed 4.2V.⁹⁸ Such a conclusion was backed by years of research and rigorous testing for multiple factors (such as safety, capacity retention, tolerance to extreme scenarios). In particular, one would at least test the battery over hundreds of cycles to gauge its performance over an extended period of time. A POSITA would not reasonably expect that it would be possible to successfully exceed the well-known 4.2V charge cutoff voltage limit based on Yamaki's preliminary experimental data.

POR at 27-28; Ex. 2007 [Yao Decl.], ¶127

Yamaki's Preliminary Data Do Not Teach a Battery Configured to a CCV above 4.2V

3 What was it about 4.2 volts that was
4 significant enough that that value had become common?

5 A. It was the point where the cell manufacturers
6 clearly found the combination of characteristics that
7 they felt were the best for their system.

8 It wasn't a single point of failure, success,
9 or like -- there are many, many things that are used to
10 evaluate a cell. If a computer manufacturer, for
11 example, was going to choose a cell supplier, he would
12 consider dozens of performance characteristics at many
13 different conditions. And the cell supplier would
14 typically recommend charge -- both charge cutoff voltage
15 and charge technique, for example, constant current up
16 to a voltage and then switch to constant voltage. That
17 was common. There were other systems too.

18 So it's -- while I described it as common, it
19 certainly wasn't the only one. And even then, it was
20 complicated by the actual operating systems.

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2 Q. For example, identifying the maximum cell
3 voltage limit on charging. Is that important?
4 A. Yes.
5 Q. Why?
6 A. Because you typically rely on the cell
7 manufacturer's experience in developing that cell, and
8 he or they have determined that this maximum limit
9 produces the best results. And it's usually a
10 combination of many, many things.
11 Q. What are those things?
12 A. Well, safety is one of them. Cycle life is
13 one. Performance at a wide range of conditions is
14 another. Calendar life is another. You know, there's a
15 difference between cycle life and calendar life.
16 Holding a cell at a high voltage, even if it's never
17 charged and discharged, can impact its life. You can
18 destroy a cell in a couple of cycles if it's incorrectly
19 held at the wrong voltage. So it's important to adopt
20 the recommendation of the manufacturing organization
21 that has conducted all those tests.
22 Q. So you mentioned safety, cycle life, holding
23 life or calendar life, right?
24 A. I did.
25 Q. And you also mentioned performance at a wide
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1 range of conditions.
2 A. That's correct.

24 Q. I believe before we were disconnected we were
25 talking about why 4.2 volts was a common charge cutoff
Page 84
1 voltage.
2 Do you recall that?
3 A. I do.
4 Q. And I'd asked you about why it had become a
5 common charge cutoff voltage value.
6 Do you recall that?
7 A. I do.
8 Q. And you had listed a number of different
9 performance characteristics that contributed to 4.2
10 volts becoming a common value for charge cutoff voltage.
11 Do you recall that?
12 A. I think I described it as there were a wide
13 variety of conditions that would be tested to make the
14 decision for a charge cutoff voltage recommendation by
15 the manufacturer.
16 Q. And cycle life was one of those, right?
17 A. Yes.
18 Q. And the operating voltage was another one.
19 Correct?
20 A. That's correct.
21 Q. And what are the other performance
22 characteristics that are affected by the charge cutoff
23 voltage?
24 A. The cycle life again is a characterization
25 that would have many, many different values. The

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1 capacity, you know, on the first cycle, the capacity
2 after 10 cycles, after 100, all different values all
3 might be affected in different ways by the charge cutoff
4 voltage.

5 The capacity as measured by amp hours
6 initially is a key variable, and that is clearly
7 affected by the charge cutoff voltage. Safety is
8 another -- it's not as easily quantifiable, but safety
9 is a key question when considering charge cutoff
10 voltages. How close are you to a voltage that might
11 cause some sort of issue, not just lifetime, as in the
12 cell doesn't perform, but actually venting or even fires
13 at very high voltages. So there are many. Those are
14 some of them.

15 Q. Any other ones you can think of?

16 A. I don't think anything else would be as
17 important as those.

18 Q. Would you say safety is a principal driver in
19 connection with determining an appropriate charge cutoff
20 voltage for a battery?

21 A. No. A principal driver is an odd way to
22 describe it, I would think. It's a -- it's an important
23 consideration. Typically, it doesn't come into play
24 because one develops cells that are known to be safe and
25 a long way from conditions that would cause safety

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1 problems.

2 So it's a consideration, but it's not
3 something one would measure very frequently because
4 typically, we design cells that are in a very safe
5 region.

6 Q. Could it be potentially unsafe to charge a
7 battery to a very low charge cutoff voltage?

8 A. If you mean a voltage that's -- so a charge
9 cutoff voltage implies that it's higher than the open
10 circuit voltage of the cell, so very low still has to be
11 above the open circuit voltage of the cell. So no,
12 there's no safety aspect of very low charge rates or low
13 cutoff voltages, no.

14 Q. When does safety come into play as a factor or
15 an element to be considered in connection with a
16 battery's charge cutoff?

17 A. Typically at very high cutoff voltages, one
18 would raise issues of safety.

19 Q. And battery designers want to make sure that
20 they adopt charge cutoff voltages that are safe.

21 Correct?

22 A. Yes. They want their systems to be safe, yes.