Part 01

Making History: The Large Format Lithium Ion Battery

Evolving to Prismatic Cases and Vertically Oriented Electrodes

In this series we will explore some of GS Yuasa' s subtle technological contributions to improving the large format lithium ion battery. As we examine our prismatic case and our vertically oriented electrode, in particular, you may discover that these improvements are the foundation for many of our unique developments.
GS Yuasa began developing lithium ion batteries around the 1990s, and started producing lithium ion batteries for mobile phones in 1997. We shifted our focus from small to large batteries, and this shift in focus culminated in the production of our industrial lithium ion batteries ("LIM Series" ; ●Fig. 1) in 2002. The "LIM Series" delivered favorable results in numerous industrial applications including railway, machinery, energy, and power supplies. In 2008, we were the first to develop an automotive lithium ion battery, the "LEV50," which was used in mass-produced electric cars (●Fig. 2).

1. Developing the First Prismatic Case

GS Yuasa was the first to develop the "GP Series," small sealed nickel-cadmium batteries which used rectangular (prismatic) cases in 1985 (●Figs. 3 and 4).

These rectangular nickel-cadmium batteries were used in portable music players which were extremely popular at the time; the batteries were highly valued for not creating wasted space when assembled in a product[3]. We continued on to develop prismatic nickel-hydrogen batteries, the "HP Series" in 1992, and prismatic lithium ion batteries, the "LP Series" in 1995.

2. Developing the World's First Vertically Oriented Electrode

Mainstream small lithium ion batteries for cell phones and other portable electronics use a horizontally oriented electrode. In this kind of electrode, the positive and negative electrode plates are wound into a coil and fitted into a case with the center of the coil oriented top-to-bottom (left, ●Fig. 5). With a horizontally oriented electrode, however, the end of the electrode would get caught on the edge of the rectangular case, resulting in damage to the electrode. Consequently, to solve the problem, the electrode had to be made thinner than the width of the prismatic case by as much as 90%. Challenged by this problem, GS Yuasa came up with the LP Series of small lithium ion batteries. An LP Series battery houses a "vertically oriented electrode" where the positive and negative plates for the electrode are wound into an oblong shape which is then inserted into a prismatic case with the curves of the oblong oriented downward (right, ● Fig. 5).

●Fig. 1 LIM40 battery[1]

●Fig. 2 LEV50 batteries[2]

●Fig. 3 GP Series Batteries

●Fig. 4 Continuous deep drawing process used for prismatic cases

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Since the electrode is inserted into the case, curved part first, the vertically oriented electrode is less likely to be damaged by the edge of the case compared to a horizontally oriented electrode. A thicker electrode can be inserted into the case without problems, compared to the horizontally oriented electrode. The "vertically oriented electrode," allowed us to simultaneously improve energy density and yield.

3. Advantages in Automotive Applications

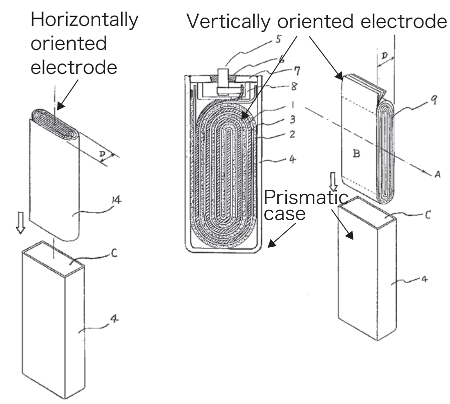
The first large lithium ion battery put into mass production by GS Yuasa was for aerospace, and the battery used a horizontally oriented electrode (●Fig. 6). Since aerospace applications require extremely high energy density, a combination of an elliptical cell case and horizontally oriented electrode was used to best minimize the dead space.

However, automotive applications, especially electric vehicle applications require that multiple large lithium ion batteries are stored efficiently in a limited amount of space. At the same time, each battery has to be shorter while guaranteeing a certain battery capacity. Therefore, our engineers invented a structure that called for multiple vertically oriented electrodes to be inserted into a laterally long case (Fig. 7).

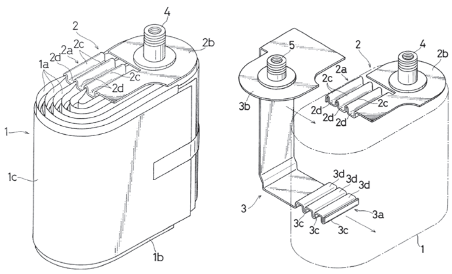
Storing multiple electrodes in the case reduces the amount of dead space; that is, we are able to effectively utilize the space while improving the battery capacity and the energy density. For instance, there is approximately 22% of dead space in a case containing a single cylindrical electrode. The amount of dead space falls to approximately 11% when the case contains two electrodes, and to approximately 5% when the case contains four electrodes. Providing multiple electrodes in a laterally long case effectively took advantage of the problems solved using the vertically oriented electrode – reducing the likelihood of damage from the edge of the prismatic case – while also largely improving the energy density and yield of the batteries.

In this article, we highlighted some of the technological transitions leading to GS Yuasa adopting the prismatic case and the vertically oriented electrode in its large lithium ion batteries. The second part of this series will discuss the development of the collector, which is an important element of large lithium ion batteries.

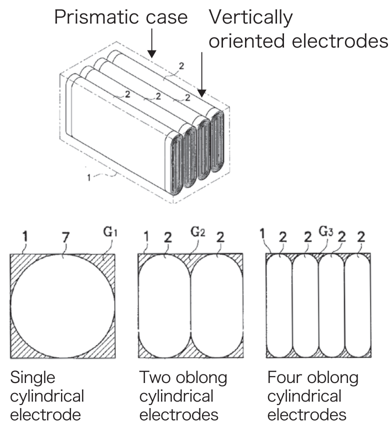
●Fig. 5 Comparison of horizontally oriented (left) and vertically oriented (right) electrodes used in small batteries[4]



●Fig. 6 The first large lithium ion battery developed[5]



●Fig. 7 Multiple vertically oriented electrodes in a prismatic case[6]



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2.GS Yuasa Technical Report Vol. 5, No. 1, 2008
3. "Latest Practical Secondary Batteries – How to Select and Use Them –," Ed. by Japan Storage Battery Co., Ltd., Nikkan Kogyo Shimbun Ltd., 1995
4.Japan Patent No. 2692533 (1993 application)
5.Japan Patent No. 4099609, Japan Patent No. 4099610, U.S. Patent No. 6440604 (1998 application)
6.Japan Patent No. 4552237 (1999 application)

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