

## Effects of Additives on Positive and Negative Electrodes of Lead-Acid Batteries

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Many additives such as chelete compounds, organic Ge compounds, electrolyzed carbon particles, organic polymers, etc. have been proposed to reactivate the deteriorated batteries due to sulfation although the working mechanism is not clear. In this study, the effects of additives on the both electrode of lead-acid batteries have been electrochemically investigated by mainly cyclic voltammetry (CV) and working mechanism will be proposed.

The working electrode was a pure Pb sheet of 20×20 ×1.0 mm. In order to remove the oxide layer of the Pb electrode, CV cycles between -1.80 and -1.40 V vs. Hg-Hg<sub>2</sub>SO<sub>4</sub> (0.5 M H<sub>2</sub>SO<sub>4</sub>) were carried out for several times. It was directly used as the negative electrode. As the positive electrode, additional cycles between +1.20 and +1.85 V were carried out to form the PbO<sub>2</sub> layer. The counter electrode was a piece (ca. 50×50 mm) of the Pb or PbO<sub>2</sub> electrode cut from the practical battery. CV was carried out in 5 M H<sub>2</sub>SO<sub>4</sub> solutions using a conventional potentiostat and a function generator between -0.50 and -1.80 V for negative electrodes and +0.50 and +1.80 V for positive electrodes, respectively. Additives employed are listed in Table 1 and were used mainly at 10 vol%.

Figure 1 shows typical CV curves taken with the addition of Carbon (L) particles.

As the measure of effects of additives, the over-voltages,  $\eta$ , for hydrogen and oxygen evolution reactions were obtained from the CV curves at -0.10 A and +0.50 A, respectively. The additives all increased the hydrogen overvoltages of the Pb negative electrode, consequently they may eliminate the sulfation by depressing the hydrogen evolution during the charge period, while all of them slightly decreased the oxygen overvoltage.

Although many additives did not affect the intensity of the oxidation current peak of PbO<sub>2</sub> electrode, they enhanced the reduction current peak, i.e. discharge capacity, except for PVA. In the case of the Pb negative electrode, almost all additives depressed the cathodic, i.e. charging, current peak area and strongly depressed the anodic, i.e. discharging, current peak area, except for Carbon (L) which enlarged both peaks as shown in Fig. 2. The tendency is large in the organic additives, especially in the case of PVA.

From the CV curves the reactivation functions of deteriorated lead-acid batteries by additives are thought to be divided to instantaneous effect provided by Carbon (L), which promote the electrode reactions, and slow acting one such as PVA [1], of which reason will be discussed elsewhere.

### Reference

[1] M. Sugawara, et.al., *ITE Lett.*, **4** (4), 424 (2003).

Table 1 Contents and characteristics of additives.

|            | Contents                      | Characteristics          |
|------------|-------------------------------|--------------------------|
| Carbon(L)  | Electrolyzed carbon particles | Mean dia. 515 nm (Shion) |
| Carbon(S)  | Electrolyzed carbon particles | Mean dia. 357 nm (AUG)   |
| Organic Ge | Ge compound                   | (Takehara)               |
| PVA        | Polyvinyl alcohol             | Special blend (ITE)      |
| Chelete    | Sulfate                       | (Takehara)               |

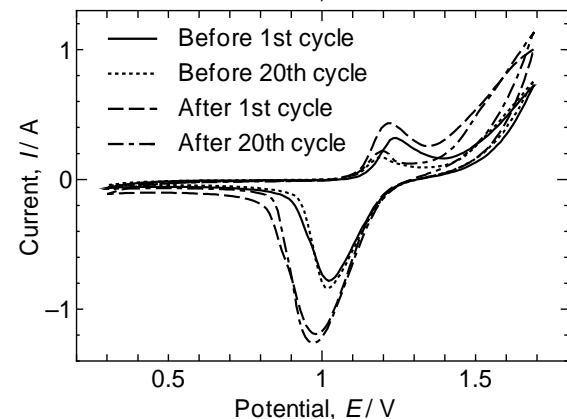
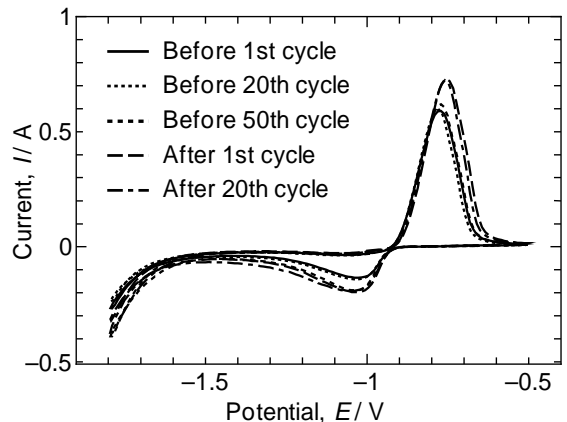


Fig. 1 Cyclic voltammograms of Pb and PbO<sub>2</sub> electrodes in 5 M H<sub>2</sub>SO<sub>4</sub> solution before and after addition of Carbon(L) (10 vol%).

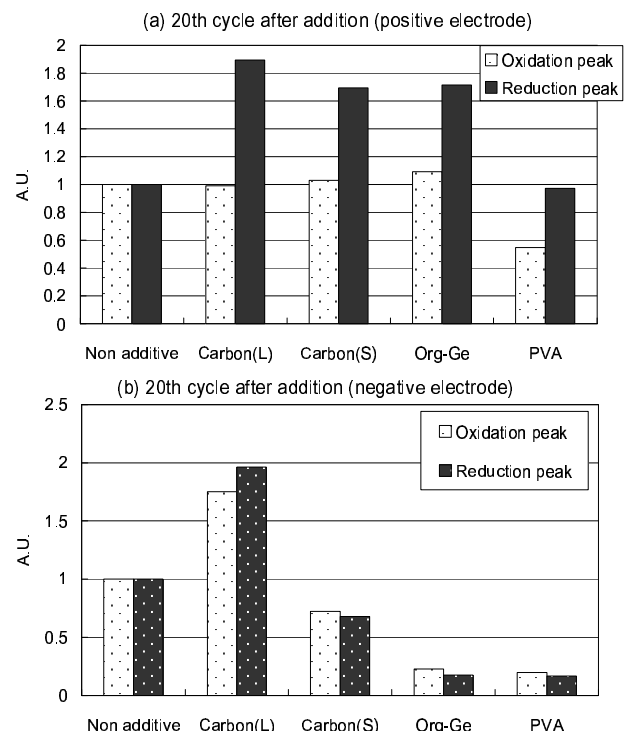


Fig. 2 Comparison of effects of additives on positive (a) and negative (b) electrodes at 20th cycle after addition.