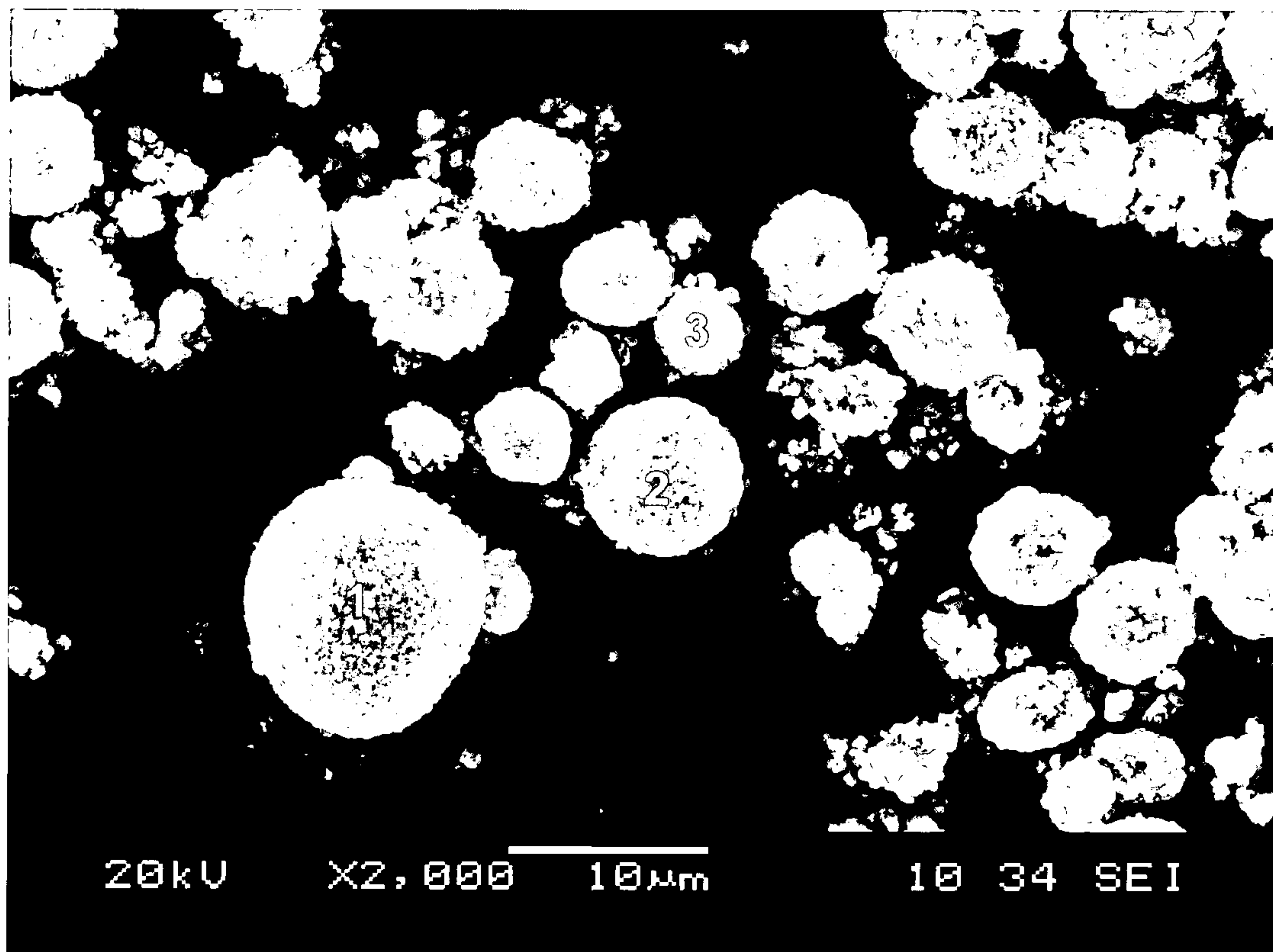




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(54) Titre : MATERIAUX D'ELECTRODE POSITIVE NON HOMOGENES COMBINANT UNE HAUTE SECURITE ET UNE FORTE PUISSANCE DANS UNE BATTERIE RECHARGEABLE AU LITHIUM
 (54) Title: NON-HOMOGENEOUS POSITIVE ELECTRODE MATERIALS COMBINING HIGH SAFETY AND HIGH POWER IN A LI RECHARGEABLE BATTERY



(57) Abrégé/Abstract:

The invention relates to a $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2\pm e}\text{A}_f$ composite oxide for use as a cathode material in a rechargeable battery, with a non-homogenous Ni/Al ratio in the particles, allowing excellent power and safety properties when used as positive electrode material in



(57) **Abrégé(suite)/Abstract(continued):**

Li battery. More particularly, in the formula $0.9 < a < 1.1$, $0.3 \leq x \leq 0.9$, $0 \leq y \leq 0.4$, $0 < z \leq 0.35$, $e = 0$, $0 \leq f \leq 0.05$ and $0.9 < (x + y + z + f) < 1.1$; M consists of either one or more elements from the group Al, Mg and Ti; A consists of either one or more elements from the group S and C. The powder has a particle size distribution defining a D10, D50 and D90; and said x and z parameters varying with the particles size of said powder, and is characterized in that either one or both of: $x_1 - x_2 \geq 0.010$ and $z_2 - z_1 \geq 0.010$; x_1 and z_1 being the parameters corresponding to particles having a particle size D90; and x_2 and z_2 being the parameters corresponding to particles having a particle size D10.

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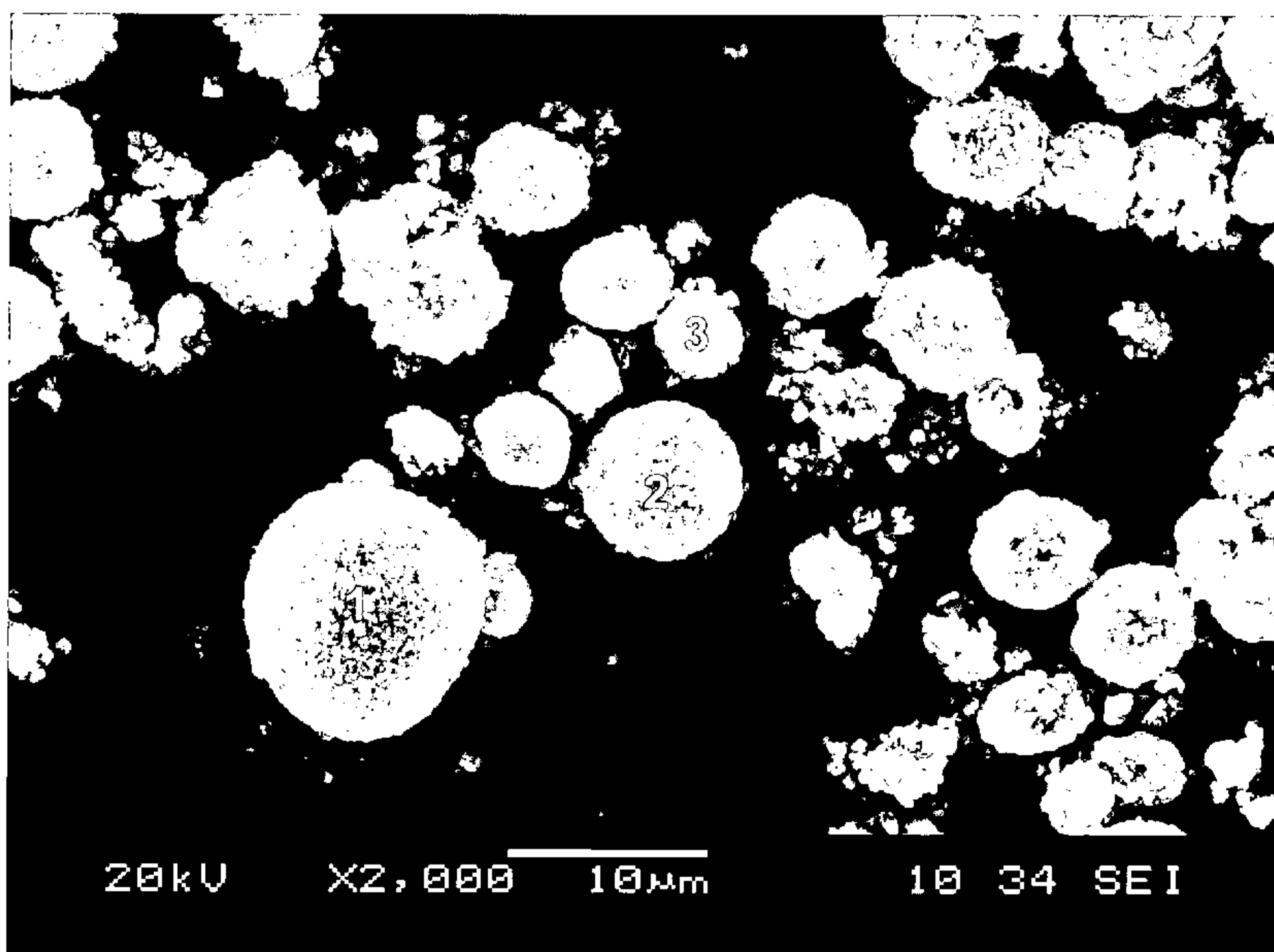
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(54) Title: NON-HOMOGENEOUS POSITIVE ELECTRODE MATERIALS COMBINING HIGH SAFETY AND HIGH POWER IN A LI RECHARGEABLE BATTERY

Fig.1

(57) Abstract: The invention relates to a $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2+e}\text{A}_f$ composite oxide for use as a cathode material in a rechargeable battery, with a non-homogenous Ni/Al ratio in the particles, allowing excellent power and safety properties when used as positive electrode material in Li battery. More particularly, in the formula $0.9 < a < 1.1$, $0.3 \leq x \leq 0.9$, $0 < y \leq 0.4$, $0 < z \leq 0.35$, $e = 0$, $0 \leq f \leq 0.05$ and $0.9 < (x+y+z+f) < 1.1$; M consists of either one or more elements from the group Al, Mg and Ti; A consists of either one or more elements from the group S and C. The powder has a particle size distribution defining a D10, D50 and D90; and said x and z parameters varying with the particles size of said powder, and is characterized in that either one or both of: $x_1 - x_2 \geq 0.010$ and $z_2 - z_1 \geq 0.010$; x_1 and z_1 being the parameters corresponding to particles having a particle size D90; and x_2 and z_2 being the parameters corresponding to particles having a particle size D10.

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Non-homogeneous positive electrode materials combining high safety and high power in a Li rechargeable battery.

Technical Field

The invention relates to a $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2$ composite oxide with a non-homogenous Ni/Al ratio in the particles, allowing excellent power and safety properties when used as positive electrode material in Li battery.

Background of the Invention

Due to their high energy density, rechargeable lithium and lithium-ion batteries can be used in a variety of portable electronics applications, such as cellular phones, laptop computers, digital cameras and video cameras. Commercially available lithium-ion batteries typically consist of graphite-based anode and LiCoO_2 -based cathode materials. However, LiCoO_2 -based cathode materials are expensive and typically have a relatively low capacity of approximately 150 mAh/g.

Alternatives to LiCoO_2 -based cathode materials include LiNiO_2 -based cathode materials, which are less expensive. Typical LiNiO_2 -based cathode materials include compositions having a formula $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$. These materials are relatively more expensive than cobalt-free LiNiO_2 -based cathode material due to the higher cost of cobalt relative to nickel, but are far easier to manufacture. Nevertheless, LiNiCoO_2 -based cathode materials usually have a lower safety in the charged state compared to LiCoO_2 -based cathode materials, because of the lower structural stability of LiNiO_2 type cathode materials.

A way to improve the safety has been to dope LiNiCoO_2 materials with inert elements such as Al, Mg, Ti, in order to stabilise the structure when heated in the charged state. A drawback to that major improvement regarding safety is the fact that inert element doping is detrimental for power and reversible capacity within the LiNiCoO_2 material. In order for this material to be industrially usable, manufacturers had to find a compromise between safety and performance, thus using the lowest amounts of Al, Ti and Mg required for obtaining a satisfying safety, while keeping decent power and capacity performances. Such products, like the $\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Al}_{0.05}\text{O}_2$ (also referred to as "NCA" product) or $\text{LiNi}_{0.7}\text{Co}_{0.2}\text{Ti}_{0.05}\text{Mg}_{0.05}\text{O}_2$ compositions for example, are nowadays commercialized by companies like TODA, Honjo-FMC and Nichia. However, as explained above, these products typically suffer from a difficult compromise between safety and electrochemical performances, thus resulting in medium level of overall performances.

With the appearance of new applications for large batteries on the market (e.g. for hybrid vehicles or stationary power devices) and a need for meeting high safety

requirements, without compromising on power performances, it appears that a breakthrough is needed in the synthesis of these NiCo-based materials.

As there has always been a concern to manufacture materials that are as homogeneous as possible, the state of the art manufacturing process of $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_2$ (M=Al, Mn, Ti, Mg...) products uses doped precursors such as hydroxides (see for example in US6958139), carbonates, nitrates or oxides, that are sintered at temperatures above 600°C. Thus, the material is perfectly homogeneous in composition, and the resulting positive electrode material shows medium level of global performances.

Considering fundamentals from solid state chemistry applied to battery materials, it is known that for LiCoO_2 material, smaller particle size gives better power performances (as discussed in Choi et al., J. Power Sources, 158 (2006) 1419). It is however also known that a smaller particle size gives lower safety, as safety characteristics are somewhat linked to surface area (see for example Jiang et al., Electroch. Acta, 49 (2004) 2661). It follows that for the $\text{LiNi}_x\text{Co}_y\text{M}_z\text{O}_2$ system, where the presence of given amounts of Ni and M (M being e.g. Al) are focussed both on improving power behaviour and safety, a homogenous composition both for small and large particles leads to a compromise between power and safety performance, due to the unavoidable spread of particle size. Indeed, for the small particles in which safety behaviour is directly related to M content, a higher M concentration would be needed to achieve the same safety behaviour as for larger particles. On the other hand, the increase of the nickel content in the large particles could enhance the performances of the $\text{LiNi}_x\text{Co}_y\text{M}_z\text{O}_2$ system.

Summary of the Invention

The present invention provides for a solution to this problem. It covers a lithium metal oxide powder for use as a cathode material in a rechargeable battery, having a general formula $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2+e}\text{A}_f$, with

$0.9 < a < 1.1$, $0.3 \leq x \leq 0.9$, $0 < y \leq 0.4$, $0 < z \leq 0.35$, $e < 0.02$ (mostly $e=0$ or e being close to 0), $0 \leq f \leq 0.05$ and $0.9 < (x+y+z+f) < 1.1$;

M consisting of either one or more elements from the group Al, Mg and Ti; A consisting of either one or both of S and C; said powder having a particle size distribution defining a D10, D50 and D90; and said x and z parameters varying with the particles size of said powder, and characterized in that either one or both of:

$x_1 - x_2 \geq 0.010$ and $z_2 - z_1 \geq 0.010$;

x_1 and z_1 being the parameters corresponding to particles having a particle size D90; and x_2 and z_2 being the parameters corresponding to particles having a particle size

D10. For the corresponding Co contents preferably the absolute value of $(y_1 - y_2)$ is less than 0.010, or even $y_1 = y_2 = y$.

Preferably both $x_1 - x_2 \geq 0.030$ and $z_2 - z_1 \geq 0.030$; and more preferably both $x_1 - x_2 \geq 0.050$ and $z_2 - z_1 \geq 0.050$.

- 5 In another preferred embodiment, the Ni content of said powder increases with increasing particle size, and the M content of said powder decreases with increasing particle size.

In preferred oxide powders M consists of Al. In another embodiment A consists of either one or both of S and C with $f \leq 0.02$. Also preferred is an embodiment where A
10 consists of C, with $f \leq 0.01$. One embodiment consists of an oxide powder having a general formula $\text{Li}_a\text{Ni}_{0.80}\text{Co}_{0.15}\text{Al}_{0.05}\text{C}_{0.01}\text{O}_2$.

It should be mentioned here that WO2005/064715 describes a cathode active material comprising a lithium transition metal oxide $\text{Li}_a\text{M}_b\text{O}_2$, with $M = \text{A}_z\text{A}'_{z'}\text{M}'_{1-z-z'}$, M' being $\text{Mn}_x\text{Ni}_y\text{Co}_{1-x-y}$, A=Al, Mg or Ti and A' being a further dopant, where $0 \leq x \leq 1$, $0 \leq y \leq 1$,
15 $0 \leq z + z' < 1$, $z' < 0.02$. The composition M of this product varies with the size of the particles. In particular, smaller particles contain less cobalt and more manganese than larger particles. The Ni, Al, Mg and Ti contents however do not vary as described above.

The invention also covers the use of the oxide powder described before in a Li
20 secondary battery.

The invention is directed also at a process for the manufacture of the powder oxide according to the invention, and comprising the steps of:

- providing at least two $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2\pm e}\text{A}_f$ precursor powders having a different particle size distribution characterized by different D10 and D90 values, and wherein a
25 powder having a lower D10 and D90 value has a lower Ni content and a higher M content than a powder having a higher D10 and D90 value,
- mixing said at least two precursor powders together with a lithium precursor, preferably lithium hydroxide,
- heating said mixture at a temperature of at least 600°C

30 Preferably, said precursor powders are hydroxide or oxyhydroxide compositions obtained by precipitating metal sulphates, nitrates, chlorides or carbonates in the presence of an alkali hydroxide and a chelating agent, preferably ammonia. It is well known that the precipitation of such hydroxides or oxyhydroxides lead to the formation

of Layered Double Hydroxides or LDH. Those LDH are made of layers of metal hydroxides into which water and anions are intercalated. Therefore, the materials contain anions such as sulphate, nitrates, chlorides or carbonates. Hence, the anion content in the material can amount up to 5 wt%.

5 Also, preferably the Co content of said precursor powders are identical.

The invention covers a material having a formula $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_2\text{A}_f$ for use as positive electrode in Li batteries, and having a non-homogeneous Nickel-M ratio in the particles for a constant cobalt content. This comes to meet the need for a $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_2\text{A}_f$ material to be tailored to achieve at the same time a high nickel content for high power in the larger particles and a high stabilizing metal content, such as aluminum, for high safety in the smaller ones. Hence, as a result, the relative content of each species is strongly correlated to the size of the particle. The Co content can be kept constant whatever the particle size, as this contributes to make the synthesis easier by maintaining the layered character of the LiNiO_2 -type material.

Compared to prior art and current $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_2\text{A}_f$ materials, the advantages of the invention are:

- improved power performances as the Ni and M content is optimised (resp. increased and decreased) in the large particles while these large particles are known to be limiting the power performances,
- improved safety performances as the Ni and M content is optimised (resp. decreased and increased) in the fine particles while these small size particles are known to be detrimental for safety.

In addition, the presence of a controlled amount of C in the battery increases also its safety.

Preferably, the Ni and M (preferably Al) concentration should follow a continuous increase and decrease respectively with increasing particle size.

Preferably also, the dependency (in %mol) of Ni and M (preferably Al) with particle size should follow a linear trend $\% \text{mol Ni} = s \cdot D + t_1$, and $\% \text{mol M} = u \cdot D + t_2$, D being the particle size as measured from SEM pictures, with $s > 0$ or $\text{Abs}(s) > 0.1$, preferably > 0.4 , and more preferably > 0.6 ; and/or $\text{Abs}(u) > 0.05$, preferably > 0.4 , and more preferably > 0.6 .

In a preferred embodiment, Ni and Al should be homogeneously dispersed within each single particle in order to avoid mechanical stresses while intercalating/deintercalating Li when using the powder in a rechargeable battery.

In another embodiment, the use of a $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_2\text{A}_f$ material with a non-homogenous Ni/Al ratio in its particles in the manufacture of a lithium insertion-type electrode, is disclosed, by mixing said powder with a conductive carbon-bearing additive. The corresponding electrode mixture is also claimed.

Brief Description of the Drawings

The invention is illustrated by the following figures:

10 Fig. 1: SEM picture of the material according to the invention showing spherical particles of different sizes.

Fig. 2: variation of the Ni and Al content (in mol%) as a function of particle size measured by EDS in the material according to the invention. This measurement clearly shows that the Ni/Al ratio varies continuously with particle size.

15 Fig. 3: Ni, Co and Al mapping by EDS on cross-sections of particles of the material according to the invention. This measure clearly shows homogeneous repartition of the species within a single particle.

20 Fig. 4: Galvanostatic discharge curve of the material of the invention at different rates (C/10 (right), C (middle) and 2C (left)). This shows the excellent capacity and power properties of this material.

Fig. 5: SEM picture of the state of the art material showing spherical particles of different sizes.

25 Fig. 6: variation of the Ni and Al content (in mol%) as a function of particle size measured by EDS in the state of the art material. This measurement clearly shows that the Ni/Al ratio is constant whatever the particle size.

Fig. 7: Galvanostatic discharge curve of the state of the art material at different rates (C/10 (right), C (middle) and 2C (left)). This shows the low capacity and power properties of the state of the art material.

Detailed Description

30 The invention is further illustrated in the following examples:

Example 1:

In a first step, a NCA hydroxide precursor with molar composition 77.5:15:7.5 (Ni+Al=85) is precipitated from Ni, Co and Al sulphates in the presence of NaOH and Ammonia. The obtained NCA hydroxide has a spherical shape and the average particle size as measured from laser granulometry is centered around D50=3.9 μ m (D10=0.6 μ m, D90=6.5 μ m). The NCA hydroxide also contains 2.31%wt of sulphate.

In a second step, a NCA hydroxide precursor with molar composition 80:15:5 (Ni+Al=85) is precipitated from Ni, Co and Al sulphates in the presence of NaOH and Ammonia. The obtained NCA hydroxide shows spherical shape and the average particle size as measured from laser granulometry is centered around D50=6.3 μ m (D10=3.9 μ m, D90=8.9 μ m). The NCA hydroxide also contains 1.95%wt of sulphate.

In a third step, a NCA hydroxide precursor with molar composition 82:15:3 (Ni+Al=85) is precipitated from Ni, Co and Al sulphates in the presence of NaOH and Ammonia. The obtained NCA hydroxide shows spherical shape and the average particle size as measured from laser granulometry is centered around D50=9.4 μ m. (D10=6.8 μ m, D90=12.8 μ m). The NCA hydroxide also contains 1.77%wt of sulphate.

In a last step, the three hydroxide precursor powders as synthesised above are mixed in the ratio 0.3:0.3:0.4 and mixed with LiOH such that $\text{Li}/(\text{Ni}+\text{Co}+\text{Al})=1.02$. The mixture is then heated in a tubular furnace under an oxygen flow at 750°C for 20h. The global composition of the obtained $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2\text{A}_f$ powder as deduced from ICP AES is Ni:Co:Al 80:15:5. Due to the presence of sulphate in the three precursors, the powder obtained contains sulphur of about 0.7%wt. In addition to the hydroxide precursors, the LiOH also contains some Li_2CO_3 which leads to a powder containing about 0.15%wt of carbon. The global composition of the powder can thus be written as $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2\text{A}_f$ with for this example A representing the mixture $\text{S}_{1.0}\text{C}_{0.5}$ and f being equal to about 0.02.

The particle size distribution of the product after firing is measured by laser diffraction granulometry and shows a psd with D10=1.5 μ m, D50=7.6 μ m, D90=20.2 μ m.

A FEG-SEM and EDS analysis is performed on the $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2\text{A}_f$ material made according to Example 1 (see Fig. 1). The EDS analysis performed on various particles clearly shows that the chemical composition (Ni/Co/Al) of the final product is varying as a function of its particle size (see Table 1a & Fig. 2).

5

Table 1a: Composition according to particle size

N° particle	Size from SEM (μm)	EDS %Ni (mol)	EDS %Co (mol)	EDS % Al (mol)
1	12.5	82.2	15.1	2.7
2	7.9	79.7	15.1	5.2
3	4.2	76.3	15.0	8.7

It can be concluded that the values for D10 and D90 should be as in Table 1b:

Table 1b:

particle size	Size (μm)	%Ni (mol)	%Al (mol)
D90	20.2	>82.2	<2.7
D10	1.5	<76.3	>8.7

10

As can be deduced from Fig. 2, there is a very good correlation between Ni (and Al) content (%mol) with particle size as measured from SEM picture (D), the linear trend (%mol Ni = $s \cdot D + t1$ and %mol Al = $u \cdot D + t2$) being:

- for Ni: $\text{Ni (\%mol)} = 0.71 \cdot D + 73.5$

15

- for Al: $\text{Al (\%mol)} = -0.71 \cdot D + 11.4.$

Moreover, EDS analysis on cross section of a single particle (see Fig. 3) clearly shows that the Ni/Co/Al distribution within a particle is fully homogeneous, with no composition gradient. This allows for optimized electrochemical performances by minimizing the stresses that could occur upon cycling during Li deintercalation/intercalation.

20

The XRD pattern shows a single phase material corresponding to NCA with FWHM (Full Width at Half Maximum) deduced from XRD profile refinement by Fullprof program for (003) and (110) lines equal to 0.1003 and 0.1314 resp. (in $^\circ 2\theta$). As expected, despite

the high synthesis temperature, the broad XRD lines suggest the coexistence of several slight deviations from the global composition due to the fact that particles with slightly different composition coexist within the powder. The hexagonal cell parameters as calculated from XRD (full pattern matching refinement) are $a=2.846(2)\text{\AA}$ and $c=14.174(8)\text{\AA}$.

A slurry is prepared by mixing the NCA powder of Example 1 with 5%wt carbon black and 5% PVDF into N-Methyl Pyrrolidone (NMP), and is deposited on an Al foil as current collector. The obtained electrode containing 90%wt active material is used to manufacture coin cells with 14mg/cm^2 active material. The negative electrodes are made of metallic Li. The coin cells are cycled in LiPF₆ based electrolyte between 3.0 and 4.3V vs Li⁺/Li. Fig. 4 shows that a high reversible capacity is obtained upon cycling with a reversible capacity of 186mAh/g at a discharge rate of C/10 (full discharge in 10h). 90% of the capacity is retained at a discharge rate of C (full discharge in 1h) with 167mAh/g, and 86% is obtained at a discharge rate of 2C (full discharge in 1/2h) with 160mAh/g.

To measure the safety of the material, DSC (differential Scanning Calorimetry) measurements are performed on unwashed charged positive electrodes (4.1V/Li⁺ after charging at C/2 in galvanostatic mode + Constant Current for 1h) using a NETZSCH calorimeter with a heating ramp of 5°C/min from Room Temperature to 350°C. The total energy released by the exothermic decomposition of the electrode material upon heating is 1000J/g.

Example 2 (Counter Example):

In first step, a NCA hydroxide material with molar composition 80:15:5 is precipitated from Ni, Co and Al sulphates in the presence of NaOH and Ammonia. The average particle size as measured from laser granulometry is centered around $D_{50}=6.1\mu\text{m}$ ($D_{10}=3.1\mu\text{m}$, $D_{90}=10.0\mu\text{m}$). The NCA hydroxide also contains 1.80wt% of sulphate.

In a second step, the hydroxide is mixed with LiOH such that $\text{Li}/(\text{Ni}+\text{Co}+\text{Al})=1.02$. The mixture is then heated in a tubular furnace under oxygen flow at 750°C for 20h. The composition of the obtained $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2\text{A}_r$ powder as deduced from ICP AES is Ni:Co:Al 80:15:5. Due to the presence of sulphate in the precursor, the powder obtained contains sulphur of about 0.6%wt. In addition to the hydroxide precursors, the LiOH also contains some Li₂CO₃ which leads to a powder containing about 0.38%wt

of carbon. The global composition of the powder can thus be written as $\text{Li}_a\text{Ni}_x\text{Co}_y\text{Al}_z\text{O}_2\text{A}_f$ with for this example A representing the mixture $\text{S}_{0.8}\text{C}_{1.2}$ and f being equal to about 0.027.

The particle size distribution from the product after firing is measured by laser diffraction granulometry and gives a psd with $D_{10}=1.4\mu\text{m}$, $D_{50}=7.4\mu\text{m}$, $D_{90}=18.1\mu\text{m}$ which is considered to be equivalent to that of the product of Example 1. The EDS analysis performed on the product of the counterexample shows that the composition does not vary substantially with the particle size (see Fig.5 & Table 2).

10 Table 2: Composition according to particle size

N° particle	Size from SEM (μm)	EDS %Ni (mol)	EDS %Co (mol)	EDS % Al (mol)
1	14.6	79.7	15.1	5.2
2	11.5	79.4	15.0	5.6
3	5.0	80.3	14.7	5.0

The figures for particles corresponding to the D_{10} and D_{90} values correspond to the ones in Table 2.

15 As can be deduced from Fig. 6, there is a no correlation between Ni and Al content (%mol) and particle size as measured from the SEM picture (D). Indeed the calculated trends are:

- for Ni: $\text{Ni}(\% \text{mol}) = -0.07 \cdot D + 80.5$
- for Al: $\text{Al}(\% \text{mol}) = 0.03 \cdot D + 4.9$

20 The a and b factor in the equations ($\% \text{mol} = s \text{ (or u)} \cdot D + t1 \text{ (or t2)}$) being close to 0 confirms that the Ni and Al contents are constant in the powder.

The XRD pattern show a single phase material corresponding to NCA with FWHM deduced from XRD profile refinement by Fullprof program for (003) and (110) lines equal to 0.082 and 0.1081 resp. (in $^\circ 2\theta$). As expected, and in contrast with Example 1, the narrow XRD lines are typical for a product synthetised at high temperature, and suggest that the Ni, Co and Al elements are homogeneously distributed within the powder. The hexagonal cell parameters as calculated from the XRD are $a=2.844(1)\text{\AA}$

and $c=14.172(4)\text{\AA}$. These are considered to be equivalent to those from the product obtained in Example 1 - the difference being within the error margin of the cell parameter refinement.

A slurry is prepared by mixing the NCA powder obtained according to Example 2 with
5 5%wt carbon black and 5% PVDF into N-Methyl Pyrrolidone (NMP), and is deposited on an Al foil as current collector. The obtained electrode containing 90%wt active material is used to manufacture coin cells, with 14mg/cm^2 active material. The negative electrodes are made of metallic Li. The coin cells are cycled in LiPF₆ based electrolyte between 3.0 and 4.3V vs Li⁺/Li. Fig. 7 shows that the reversible capacity
10 obtained upon cycling has a reversible capacity of only 176mAh/g at a discharge rate of C/10. Only 87% of the capacity is retained at a discharge rate of C with 154mAh/g, and 83% is obtained at a discharge rate of 2C with 146mAh/g, i.e. 10% less capacity at high rate than the product according to the invention. This clearly emphasizes the benefit of the invention compared to state of the art materials regarding power
15 properties of NCA materials.

DSC measurements were performed on unwashed charged positive electrodes (4.1V/Li⁺ after charging at C/2 in galvanostatic mode + Constant Current for 1h) using a NETZSCH calorimeter with a heating ramp of 5°C/min from RT to 350°C. The total
20 energy released by the exothermic decomposition of the electrode material upon heating is 1200J/g, which is 20% higher than that of the material according to the invention. This clearly emphasizes the benefit of the invention compared to state of the art materials regarding safety properties of NCA materials.

Claims

1. A lithium metal oxide powder for use as a cathode material in a rechargeable battery, having a general formula $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2+e}\text{A}_f$, with $0.9 < a < 1.1$, $0.3 \leq x \leq 0.9$, $0 < y \leq 0.4$, $0 < z \leq 0.35$, $e < 0.02$, $0 \leq f \leq 0.05$ and $0.9 < (x+y+z+f) < 1.1$; M consisting of either one or more elements from the group Al, Mg, and Ti; A consisting of either one or both of S and C; said powder having a particle size distribution defining a D10, D50 and D90; and said x and z parameters varying with the particles size of said powder, characterized in that either one or both of:
 - $x_1 - x_2 \geq 0.010$ and
 - $z_2 - z_1 \geq 0.010$;
 - x_1 and z_1 being the parameters corresponding to particles having a particle size D90; and x_2 and z_2 being the parameters corresponding to particles having a particle size D10.
2. The oxide powder of claim 1, characterized in that both $x_1 - x_2 \geq 0.030$ and $z_2 - z_1 \geq 0.030$.
3. The oxide powder of claim 1 or 2, characterized in that the Ni content of said powder increases with increasing particle size, and the M content of said powder decreases with increasing particle size.
4. The oxide powder of any one of claims 1 to 3, characterized in that A consists of S and C, with $f \leq 0.02$, and M consists of Al.
5. The oxide powder of any one of claims 1 to 3, characterized in that A consists of C, with $f \leq 0.01$, and M consists of Al.
6. The oxide powder of claim 5 having a general formula $\text{Li}_a\text{Ni}_{0.80}\text{Co}_{0.15}\text{Al}_{0.05}\text{C}_{0.01}\text{O}_2$.
7. Use of the oxide powder according to any one of claims 1 to 6 in a Li secondary battery.
8. A process for the manufacture of the oxide powder according to any one of claims 1 to 6, comprising the steps of:
 - providing at least two $\text{Li}_a\text{Ni}_x\text{Co}_y\text{M}_z\text{O}_{2+e}\text{A}_f$ precursor powders having a different particle size distribution characterized by different D10 and D90 values, and wherein at least one of the at

least two precursor powders having a lower D10 and D90 value has a lower Ni content and a higher M content than another of the at least two precursor powders having a higher D10 and D90 value,

- mixing said at least two precursor powders together with a lithium precursor,
- heating said mixture at a temperature of at least 600°C.

9. Process according to claim 8, wherein said at least two precursor powders are hydroxide or oxyhydroxide compositions obtained by precipitating metal sulphates, nitrates, chlorides or carbonates in the presence of an alkali hydroxide and a chelating agent.

10. Process according to claim 8 or 9, wherein the Co content of said at least two precursor powders is identical.

11. The oxide powder of claim 1, characterized in that both $x1 - x2 \geq 0.050$ and $z2 - z1 \geq 0.050$.

12. The process according to claim 8, wherein said lithium precursor is lithium hydroxide.

13. The process according to claim 9, wherein said chelating agent is ammonia.

Fig.1

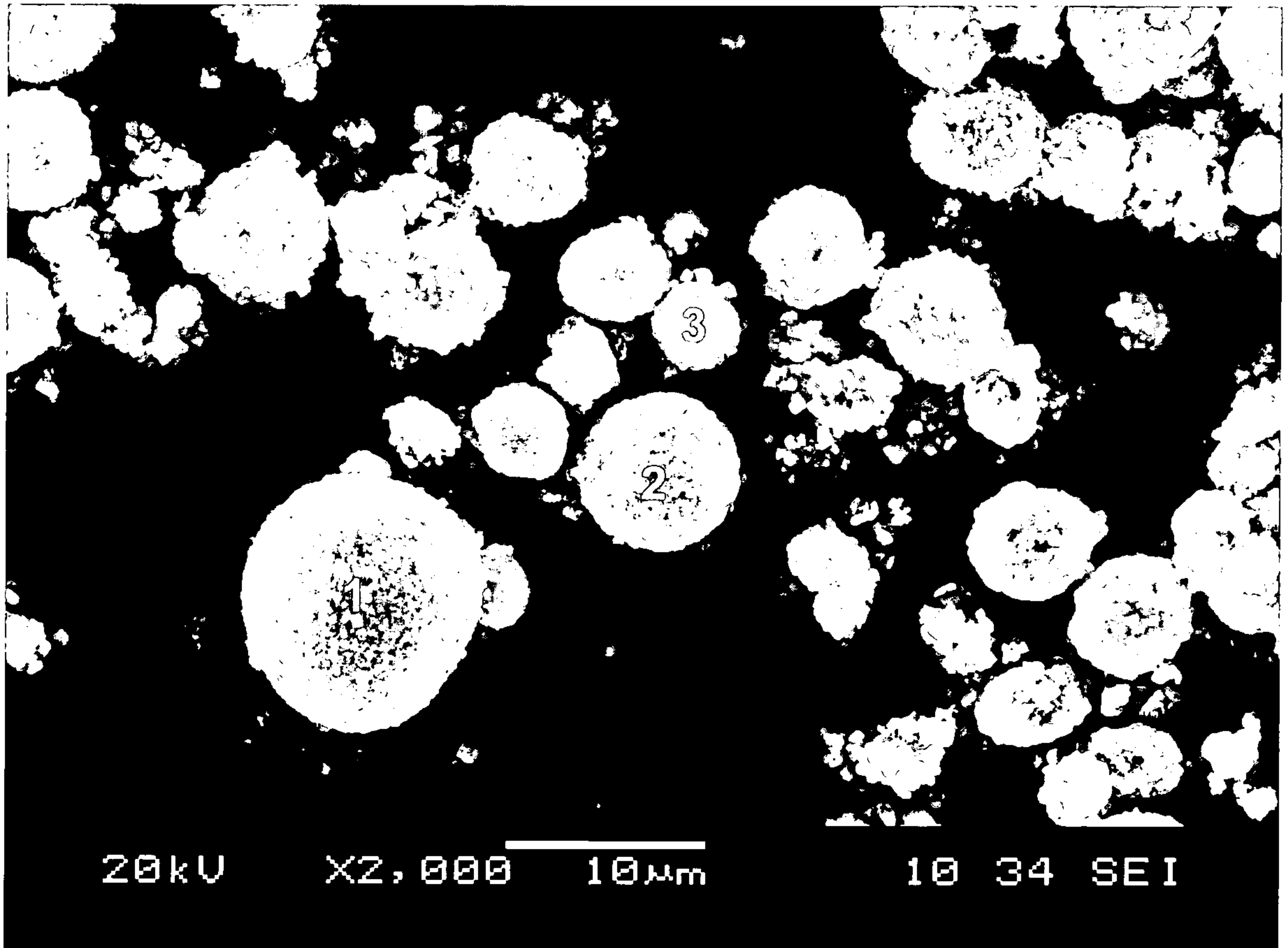


Fig. 2

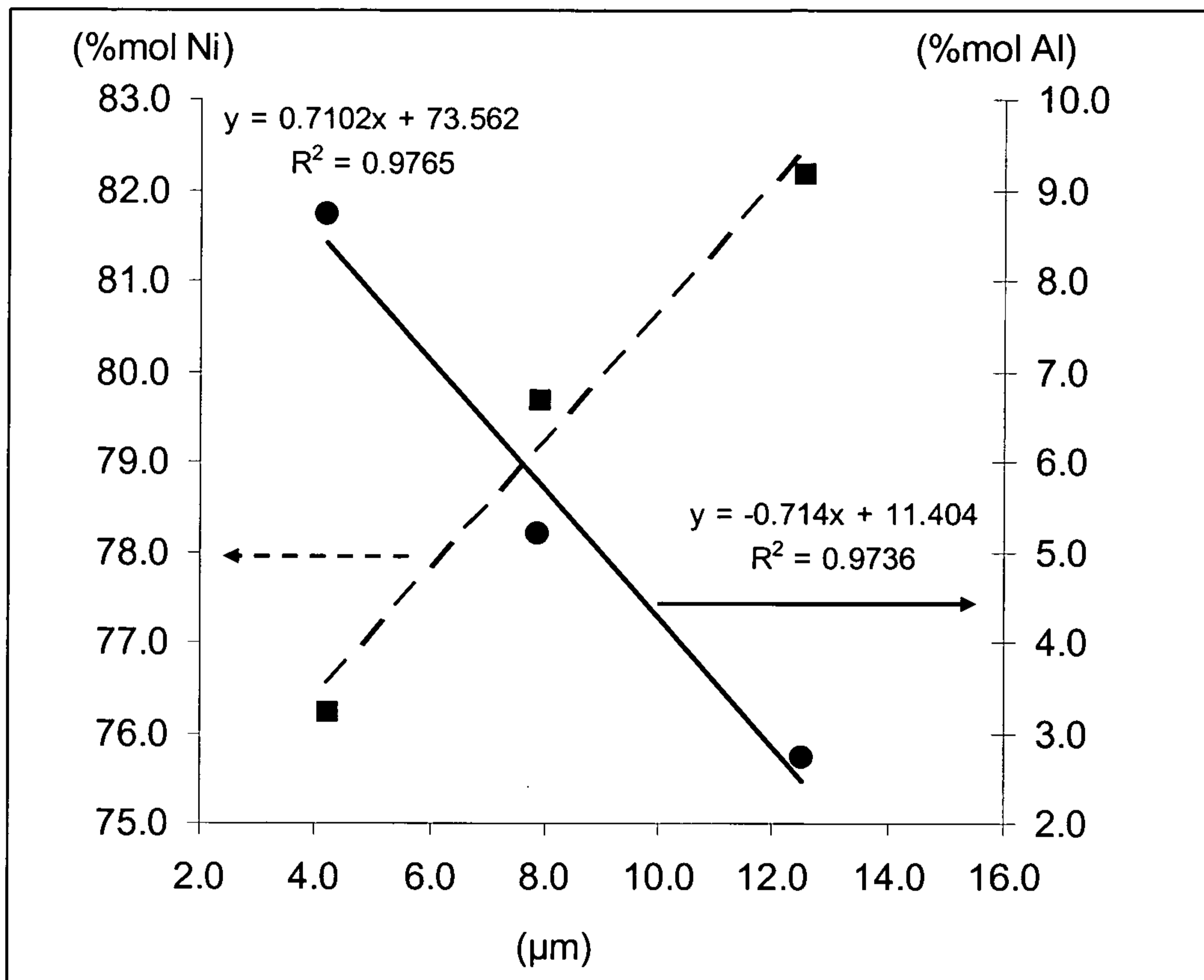
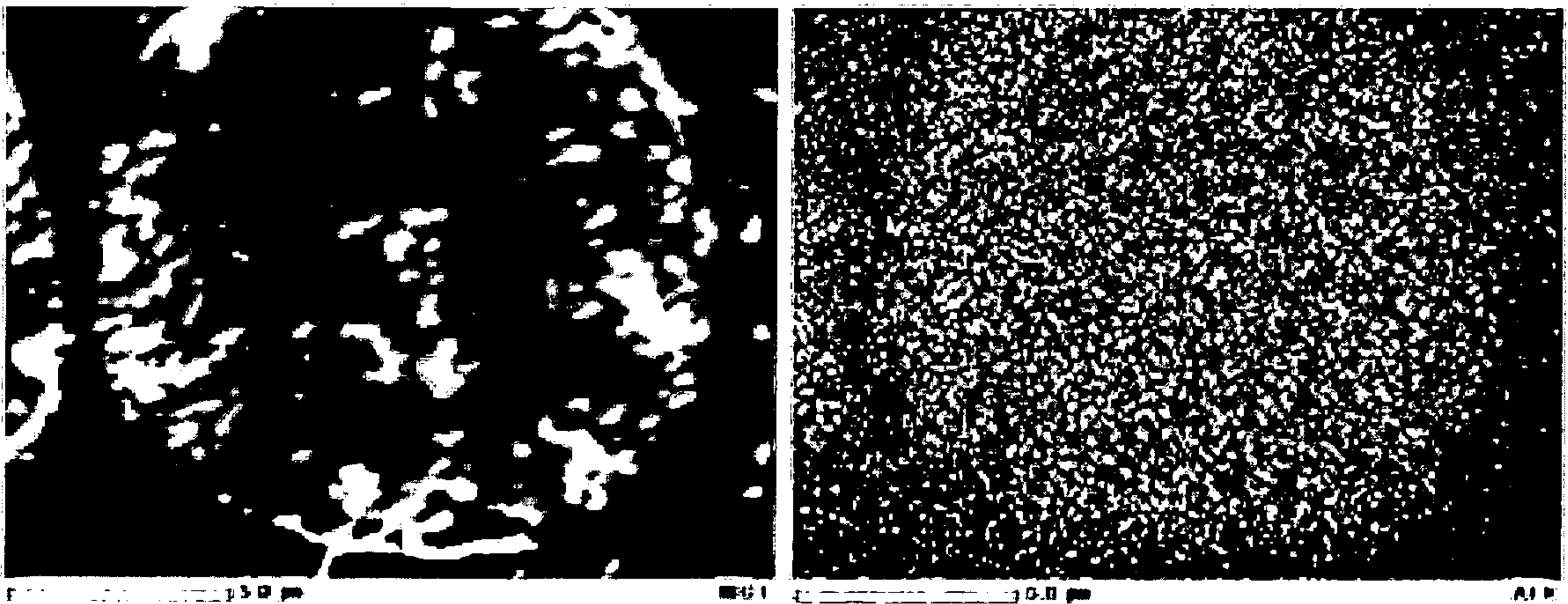
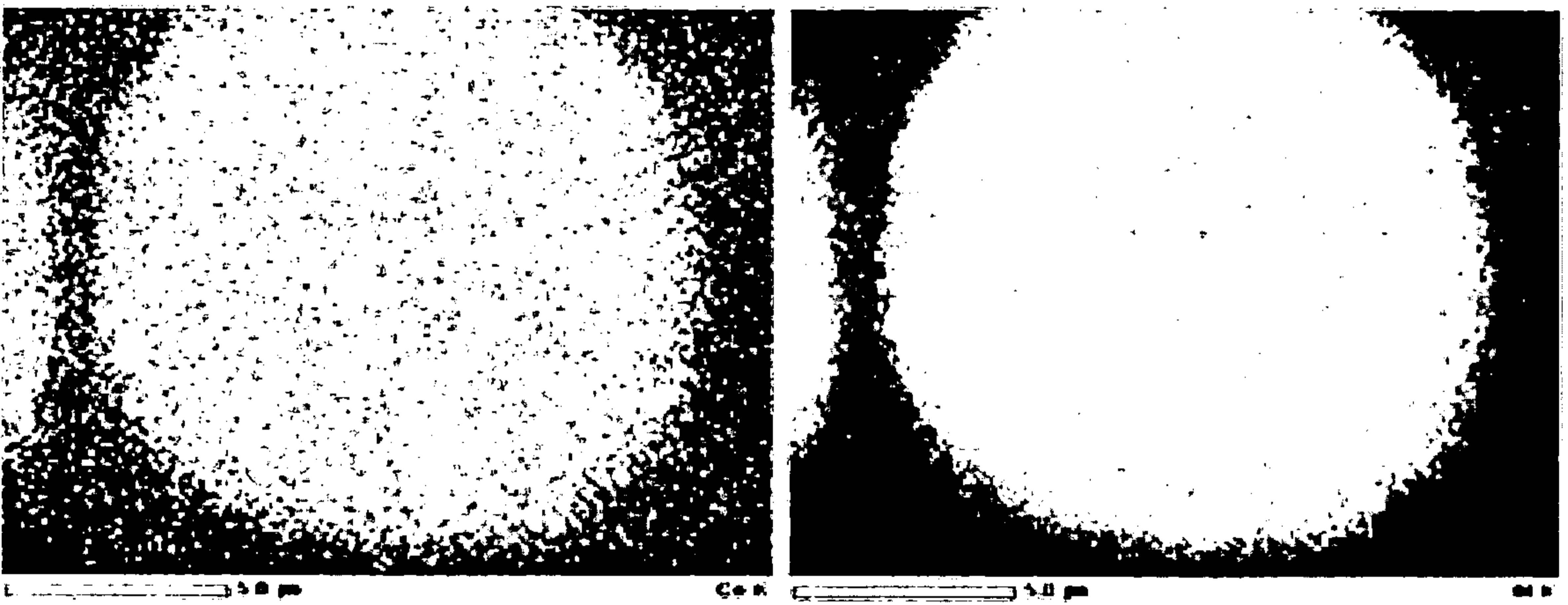


Fig.3



Al

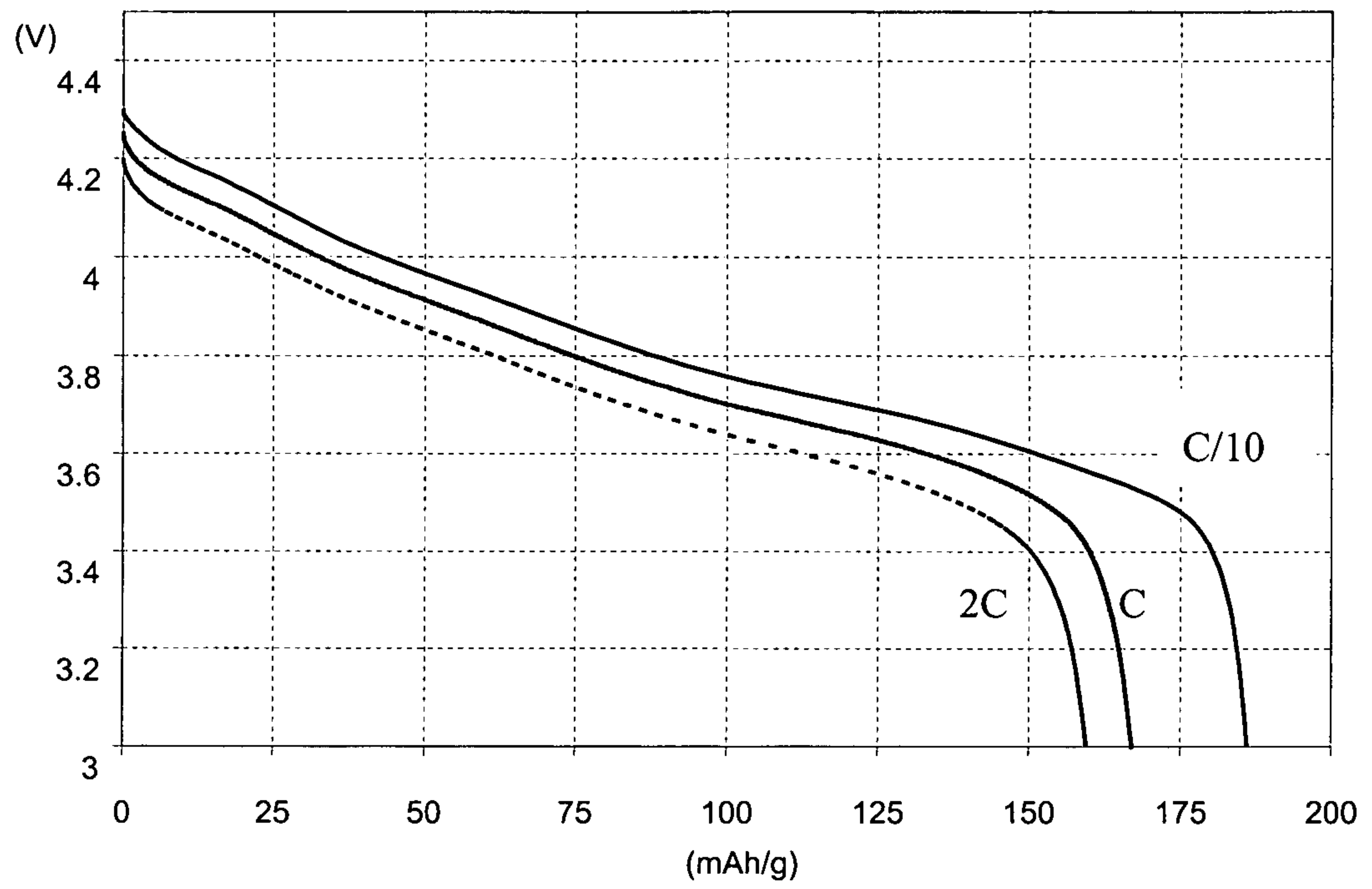


Co

Ni

4/7

Fig.4



5/7

Fig.5

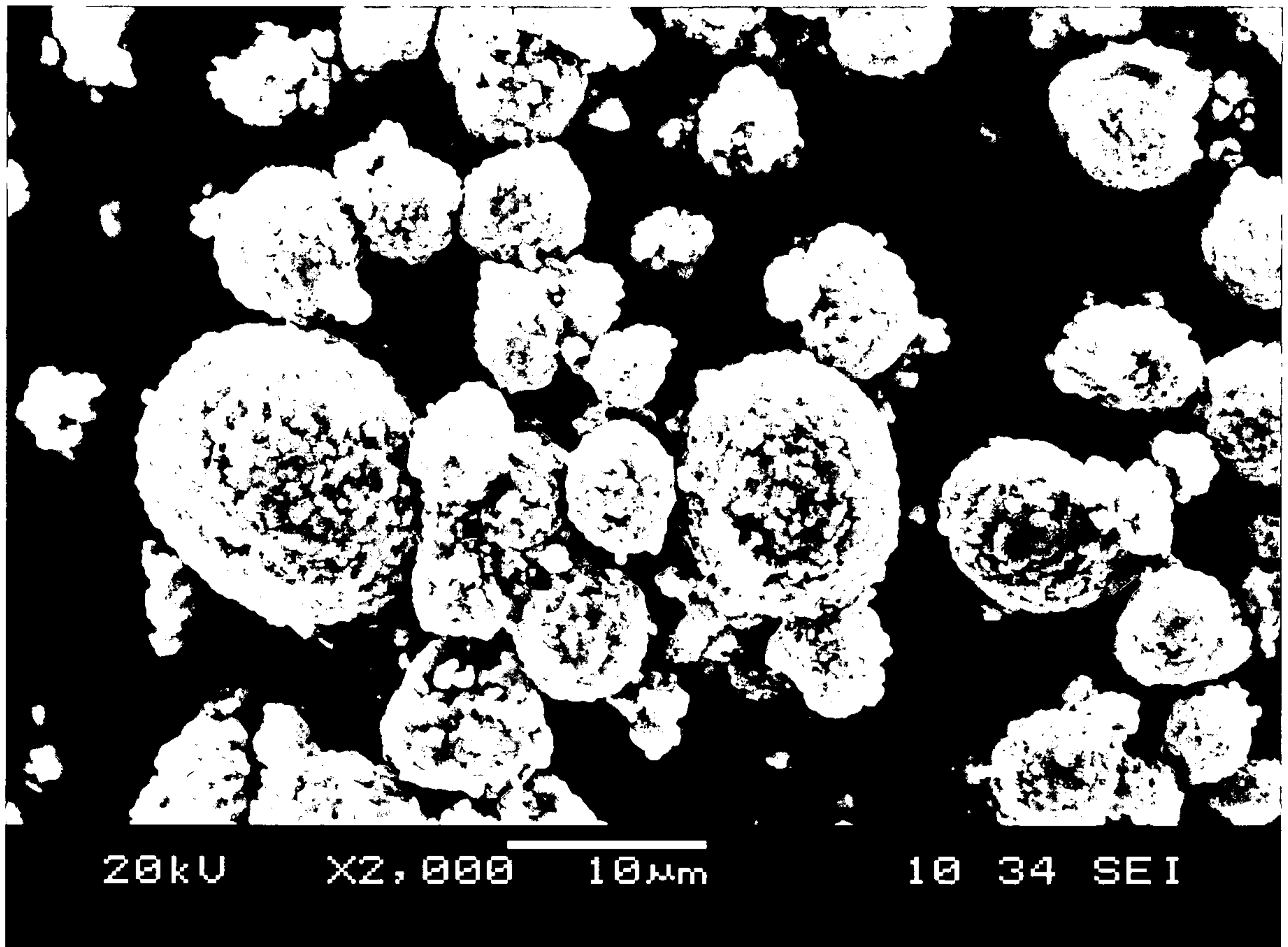


Fig.6

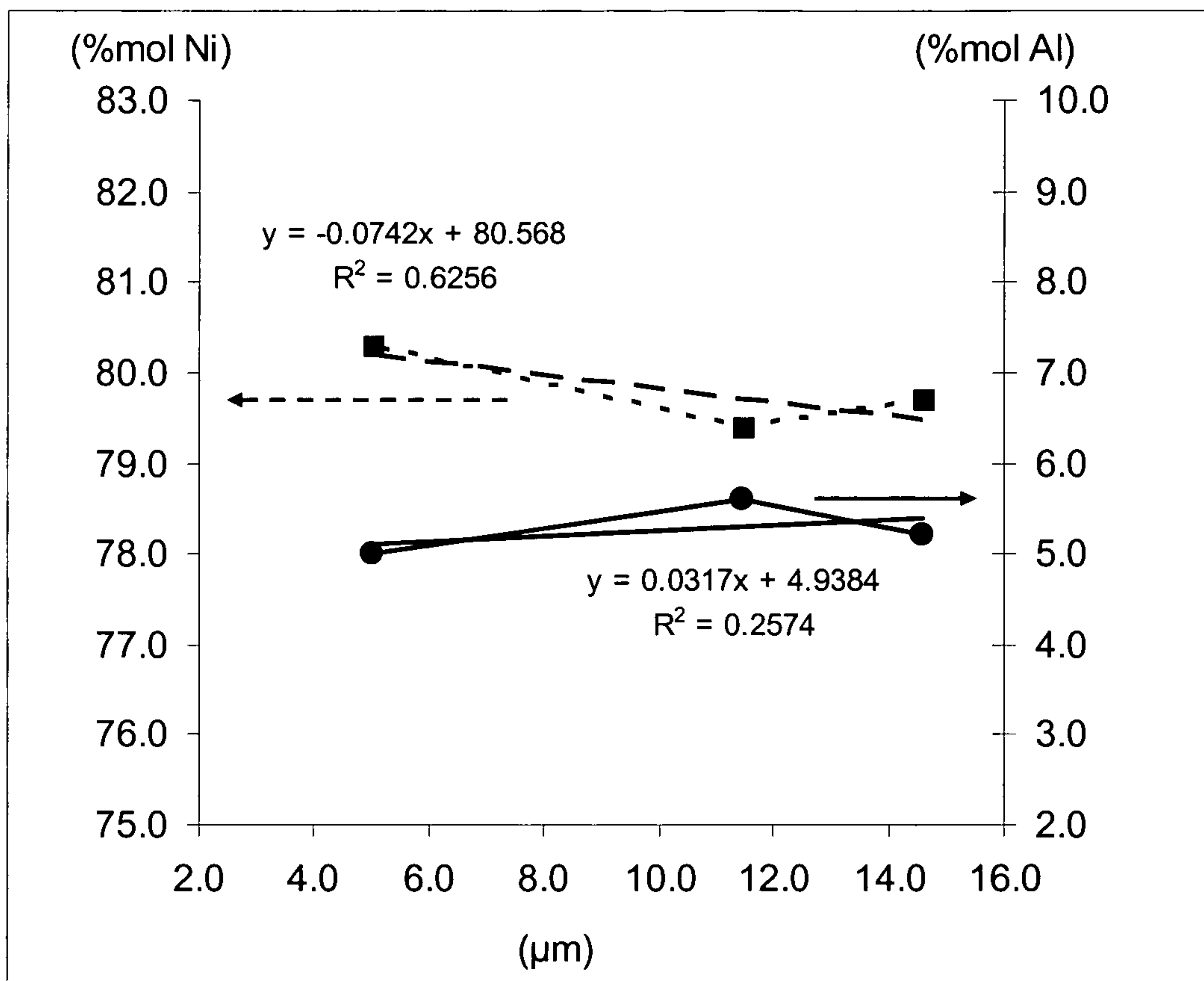
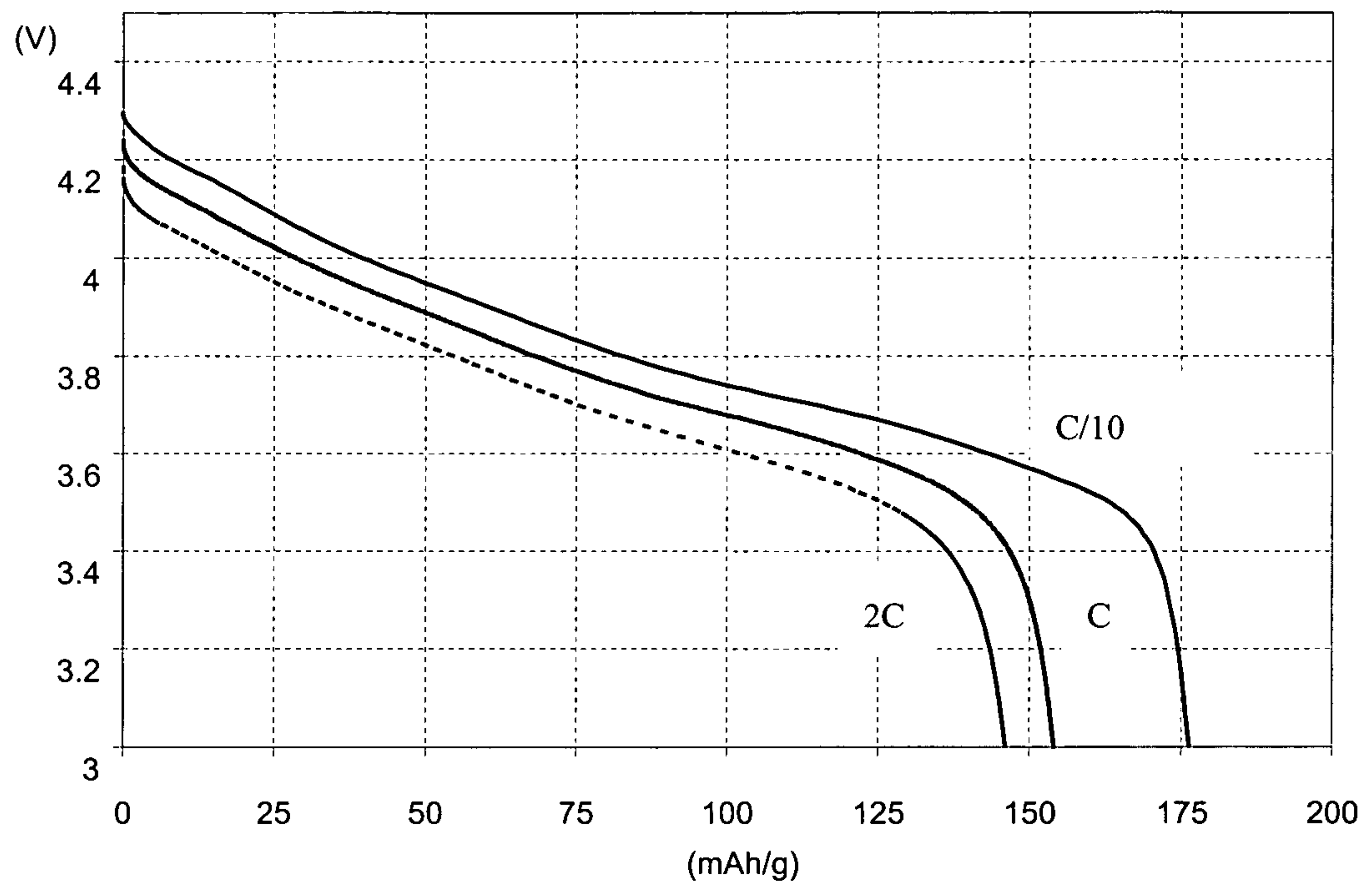
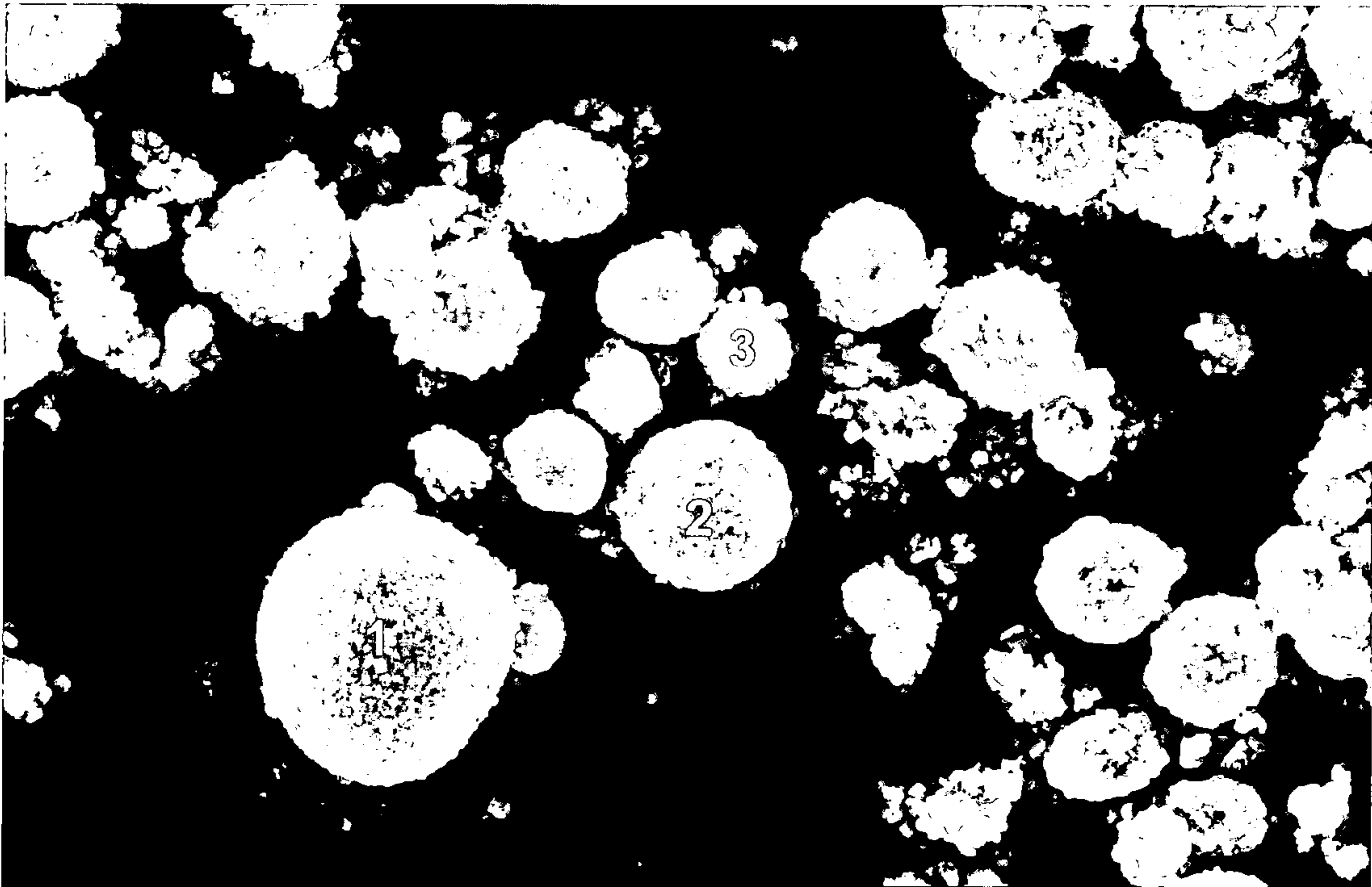


Fig.7 (Counter Ex)





20kV

X2,000

10µm

10

34

SEI