The apparent density as a function of the specific surface of copper powder and the shape of the particle size distribution curve

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Abstract: The relation between the specific surface and apparent density of copper powders electrodeposited from acid copper sulphate solutions is established. It is shown that the apparent density is inversly proportional to the specific surface of copper powder. The shape of the particle size distribution curve is also discussed.

Keywords: copper powder, apparent density of copper powder, specific surface of copper powder, particle size distribution of copper powder.

INTRODUCTION

Some properties, called decisive properties, charcterise the behaviour of copper powder. The most important of these are the specific surface and the apparent density.[1,2] These properties had not been related to the conditions of electrodeposition by any quantitative or semiquantitative relationships, until it was shown recently[3,4] that the specific surface, S_{Sp}, of copper powder can be related to the deposition overpotential, η. The aim of this work was to relate the apparent density of copper powder, ρ, to the corresponding value of the specific surface, S_{Sp}, and, hence, to the deposition overpotential, η, and other deposition conditions.

DISCUSSION

Using the data of Calusaru,[1] it is possible to obtain the diagram given in Fig. 1, which indicates

$$\rho = \frac{K}{S_{Sp}} \tag{1}$$

where K is a constant, as the relation between the apparent density and the specific surface of a copper powder. This is confirmed by the plot in Fig. 2, which was obtained by

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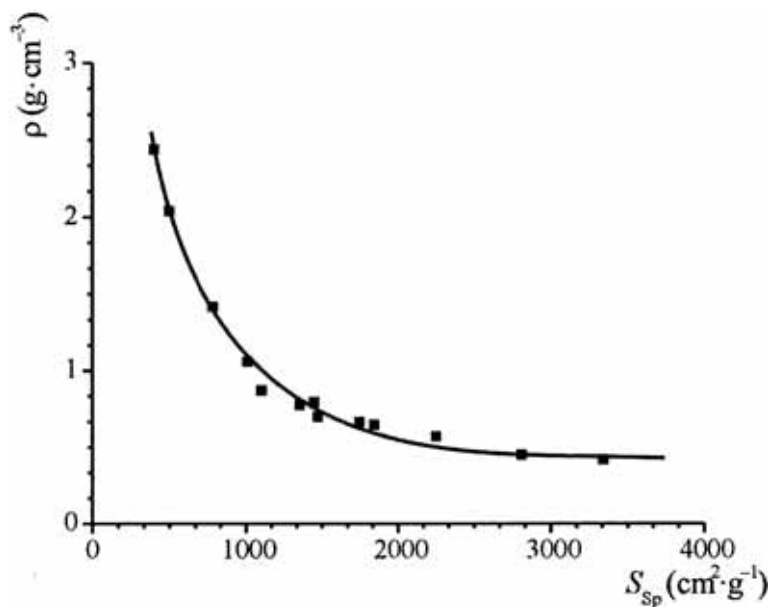[#]   Serbian Chemical Society active member.

Fig. 1. The apparent density, ρ, of copper powder as a function of powder specific surface S_{Sp}.

replotting the data from Fig. 1 in the $\rho - 1 / S_{Sp}$ coordinates. From the slope of the straight line from Fig. 2, $K = 1009$ cm^{-1} is determined. The maximum difference between experimental value of the apparent density and the one calculated using Eq. (2) is 20 % and less then 10 % in other cases. Hence, Eq. (1) correlates the apparent density with the
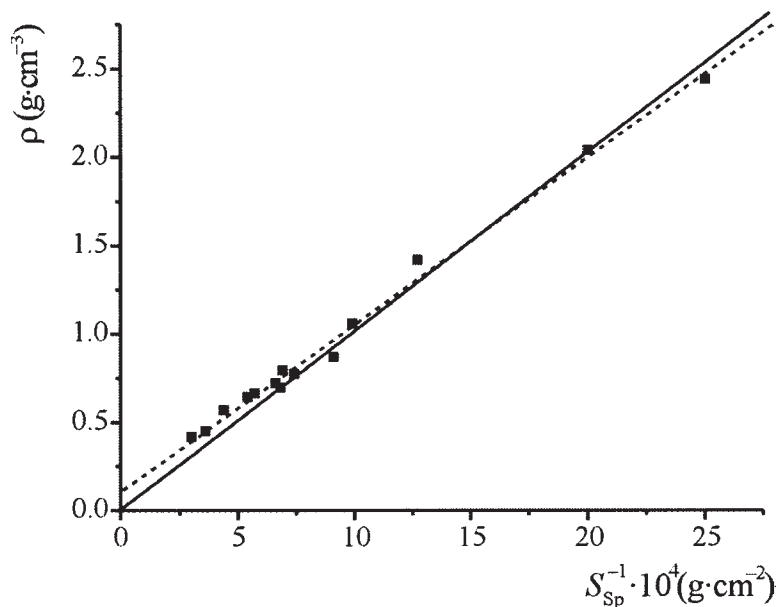

Fig. 2. $2\rho - 1/S_{Sp}$ dependence obtained by replotting the data from Fig. 1.

specific surface of a copper powder well. On the other hand, Eq. (1) can be rewritten in the form:

$$K = \rho \times S_{Sp} \tag{2}$$

which means that the value of K can be estimated using the values of the specific surface and apparent density of each particular powder.

It was shown in a previous paper[5] that copper powder could be treated as a homogeneous material the density of which is equal to the apparent density of the copper powder. The mass, m, of the volume, V, of the powder is given by:

$$m = \rho \times V \tag{3}$$

If S is the corresponding surface of the powder, Eq. (3) can be written as:

$$\frac{S}{V} = \frac{\rho \times S}{m} \tag{4}$$

or

$$\frac{S}{V} = \rho \times S_{Sp} \tag{5}$$

where:

$$S_{Sp} = \frac{S}{m} \tag{6}$$

It follows from Eqs. (2) and (5) that:

$$K' = \frac{S}{V} \tag{7}$$

Hence, the physical meaning of K is the surface per unit volume of copper powder. The values of S_{Sp} and ρ used for plotting Figs. (1) and (2) correspond to powders obtained under very different deposition conditions and $K = 1009$ cm^{-1} can be considered to be valid for any powder obtained by electrodeposition from a pure sulphate bath. It is interesting that this value is not valid for commercial copper powders.[6] It can be seen from Fig. 2 that the equation:

$$\rho = 0.12 + 944 \frac{1}{S_{Sp}} \tag{8}$$

valid for $S_{Sp} \geq 400$ cm^2/g, fits the data of Calusaru better. This plot is presented by the dashed line in Fig. 2. Substitution of ρ from Eq. (8) in Eq. (2) produces:

$$K' = 944 + 0.12\, S_{Sp} \tag{9}$$

meaning that K' increases slightly with increasing S_{Sp}.

It was shown in a previous paper[5] that the size H of the representative particle of a powder is given by:

$$H = \frac{6}{\rho S_{Sp}} \tag{10a}$$

or

$$H = \frac{6}{K} \tag{10b}$$

Hence, because of Eq. (2) and taking into account Eqs. (9) and (10a).

$$H = \frac{6}{944 + 012 S_{Sp}} \tag{11}$$

assuming the particles have a cubic shape. It follows from Eq. (11) that the size of the representative particle decreases slightly with increasing specific surface of the powder and deposition overpotential, which is in accordance with literature data.[1,6]
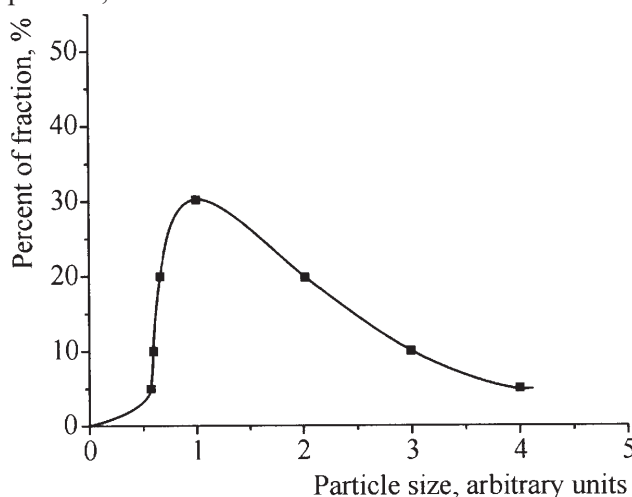

Fig. 3. The shape of the particle size distribution calculated using Eq. (15) and $H = 1$.

The shape of the particle size distribution curves can also be discussed.

The representative particle of a copper powder has the same specific surface as the powder,[5] meaning that the mass m of powder should have the same surface as mass m of the representative powder particles. It follows from the above fact that two equal portions of two fractions of the particles can have the same surface as the same quantity of representative powder particles. Hence,

$$S_1 + S_2 = 2S_r \tag{12}$$

or

$$S_{Sp1} + S_{Sp2} = 2S_{Sp} \tag{13}$$

where S_1, S_2 and S_r are the surfaces of mass m of particles 1, 2 and representative ones, respectively, and S_{Sp1}, S_{Sp2} and S_{Sp} are the corresponding values of specific surface. Taking into account Eq. (10a), Eq. (13) can be rewritten in the form:

$$\frac{1}{H_1} + \frac{1}{H_2} = \frac{2}{H} \qquad (14)$$

assuming that ρ' is approximatly the same for all fractions as shown earlier,[7] where H_1 and H_2 are the sizes of the particles 1 and 2, respectively, and H is the size of the representative particle. It follows from Eq. (14) that:

$$H_1 = \frac{H_2 \times H}{2H_2 - H} \qquad (15)$$

which is valid for $H_2 > H$, if

$$H_1 < H < H_2 \qquad (16)$$

Assuming that the large fraction of particles corresponds to the representative ones, it is now possible to calculate the shape of the particle size distribution curves, which is presented in Fig. 3. It is obvious that its shape is in perfect agreement with literature data.[1,6]

И З В О Д

НАСИПНА МАСА КАО ФУНКЦИЈА СПЕЦИФИЧНЕ ПОВРШИНЕ БАКАРНОГ ПРАХА И ОБЛИК ЗАВИСНОСТИ РАСПОДЕЛЕ ВЕЛИЧИНЕ ЧЕСТИЦА

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Утврђена је зависност између специфичне површине и насипне масе бакарног праха исталоженог електрохемијским поступком из киселог бакарног купатила. Показано је да је насипна маса обрнуто сразмерна специфичној површини бакарног праха. Размотрен је и облик зависности расподеле величина честица.

(Примљено 2. јуна 2003)

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