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The principles of the Samsonov's electronic theory of sintering *

The sientists engaged in solving problems of sintering have occupied themselves with work on models for a long time. However, recently, in the science of sintering appeared some inclination, which has become stronger and stronger, to consider, the sintering proces, as much as possible, as a uniform complex process in which a series of elementary processes are acting, or at least tc establish the stages where one elementary process is of dominant influence. Thus D.L. Johnson [1] has theoretically studied the problem of roles of particular elementary mechanisms in the initial and intermediate stages of sirtering. The theoretically obtained results showed a very good agreement with the experiment when sintering of spherical particles of the same sizes was concerned.

Statistical models of the intermediate and final stages of sintering of powder compacts are explored [2] . If Zener's relations is accepted as grain growth equation thar several important relations between porosity, average pore radius, average grain size and total pore area per unit volume can be derived.

Quite a number of researchers have tried to apply the theories of G.Kuczinksy and B.Pines to sintering of real systems. However, here everything came to the formal establishment of the time exponent in already classic phenomenology equation of sintering. In spite of everything, this equation has much been used ill literature today, although the purposes of its application are sometimes not even quite clear.

Contemporary sintering theories are often an example of the theory of mathematica formalization which sometimes presses out the physical sense: the theories have begun to be distinguished not by internal contents and ideas, but by the names of authors and their collaborators. However, bearing in mind everything that has been done in this field, it is certain that the most gneral notions of the sintering theory might be developed on the electronic level, as mass transfer, in essense, depends on the solid-body electron-ic structure. Nevertheiess, the insufficient working out of particular problems of sintering at the electronic level in detail is caused, first of all, by the

* Presented atthe International Summer School on subject electronics materials (Herceg-Novi 1975)

lack of unequivocal notions of the electronic structure of materials in the condensed state.

Here it is of special importance to underlint that by the consideration of the pressing process on the electronic level it can be shown that the processes of pressing and sintering are in essence inseparable and that they are stages of one and the same process of object formation from powder.

Formation of defect configurations (on the boundary of crystallites) and the organization of bonds between the contacting atoms on surfaces make possible electronic exchange between such atoms; while the contact area should be considered as an energetic barrier which prevents the tunnel penetration of atoms into the neighboiring crystallite. The transparency of the barrier (D), according to the quantum theory, is defined by equation:

$$D = \exp\left(-\frac{4}{h}\sqrt{2m}\right)\int_a^b (U-E)^{\frac{1}{2}}\,dx$$

where: m - mass of electrons,
h - Planck's constant,
U - height of barrier,
E - energy of a particle,
a and b - coordinates of the beginning and the end of the barrier

From this it follows that the intensification of the electronic exchange may be realized in tree ways:
- by reducing the width of barrier b - a,
- by increasing the energy of tunneling electrons,
- by reducing the height of barrier U.

The first way is adequate for the approach of crystallites by increase in pressure during pressing. The second way is realized by deformations of electronic orbitals (by exciting atom configurations which are located on the surface). The barrier height depends on the degree of stability the configurations which are forming the crystallite and it increases parallel with the configuration stability. It is the high stability of $s^x p^y$ - configurations that accounts for the low pressability of boron and graphite powders. On the contrary, passing to Ae, Bi and Su, when a decrease in the stability of their configurations in concerned, the pressability is increasing intensely.

One can suppose that the statistical weight of the stable configurations in atoms located on particle surfaces is always considerably lower than that in atoms in material volumes, and at that position the weight is lower if the material is more deformed and its surface more defected. While two particles some into contact due to thermal excitement, the process of electronic exchange takes place. This is directed to the recovery of defect configurations as well as to the formation of new stable ones on the border between the particles.

An increase in temperature is needed for the real progress in the sintering process. which helps to derangle stable atom configurations as well as volume mass transfer.

Such an approach certainly contributes to the uniform view of the sintering process, although, due to the reasons given, it still does not offer sufficient posibilities for an absolute quantitative description of the process

Perhaps the transition from the atomic theories to the electronic theory of sintering should be examined for a uniform quantitative description of the fundamental phenomena in diffusion and creep. One of the possibilities in the use of activation volumes, especially because it allows, in a definite way, simultaneous considerations of the problem concenrning both the stress and the transfer.

In any case, the science of sintering, obviously, can expect further development not only in accumulation of experimental data but, above all, in a stronger connection with solid-state physic and chemistry, which at the same time may be an inspirer for these two vranches of science.

References

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