THEORY, MANUFACTURING TECHNOLOGY,
AND PROPERTIES OF POWDERS AND FIBERS

EFFECT OF BIOLOGICAL MEDIA ON THE PHYSICAL,
CHEMICAL, AND MAGNETIC PROPERTIES OF CARBONYL
IRON AND NICKEL POWDERS

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The paper examines changes in carbonyl iron and nickel powders subjected to model biological media: water media and media containing human blood plasma. It is established that carbonyl iron powder interacts with biomedia containing blood plasma six times as fast as with water media. No oxidation or corrosion is observed in the process. The magnetic properties of the powder after the interaction with plasma-containing media do not practically deteriorate. Iron powder is intensively absorbed by blood plasma, Fe$^{3+}$ ions forming complex compounds with proteins. On the contrary, carbonyl nickel is not absorbed by blood plasma for five days, and the powder specific surface area and particle morphology remain practically unchanged after the interaction. Blood plasma seems to dissolve and transform metals according to the human body’s demands. In the case of carbonyl iron, this process proceeds faster than corrosion does. In the case of carbonyl nickel, the opposite is observed.

Keywords: carbonyl iron, carbonyl nickel, biological media, human blood plasma, powder specific surface area, magnetic properties.

Superfine metal powders are widely used in many areas including medicine; therefore, unwanted side effects may occur in their production and application. A clear idea of how superfine metal powders affect the human body is crucial for their implementation and use. To grasp this idea, the transformation of powders in the body’s biological media should be studied.

The objective of this paper is to study how model biological media affect the physical, chemical, and magnetic properties of iron and nickel powders. The results may further be used as reference for other superfine iron- or nickel-based powders.
The study focuses on metal powders produced with the carbonyl method: high-purity carbonyl iron and carbonyl nickel (Table 1). The carbonyl process is known to be advantageous in that it produces pure metals containing minor admixtures of carbon, nitrogen, and oxygen.

We used standard chelatometry [1] to determine the content of total iron Fe_{(total)} of powders and a chemical analysis developed for tungsten–copper alloys at the Institute for Problems of Materials Science (National Academy of Sciences of Ukraine) to determine the content of total nickel Ni_{(total)}. The content of C_{(total)} was determined using an AN-7529 rapid-response analyzer and a coulometric analysis, the content of O_{2(total)} and N_{2(total)} was determined using redox melting and an LKhM-72 gas chromatograph, and the content of H_{2(total)} using redox melting and an AV-1 analyzer. A spectral analysis of the powders for the presence of admixtures was carried out using an ISP-28 spectrograph; the admixtures being burnt in arc discharge (Table 2).

The chemical and spectral analyses showed (Tables 1 and 2) that the powders were actually pure: the amount of the base element was more than 99 wt.%. Carbonyl iron is oxidized to a greater extent than carbonyl nickel is: the amount of oxygen was 0.34 and 0.07 wt.%, respectively. The content of copper is 0.0001 wt.% for both powders.

X-ray diffraction (DRON-3 diffractometer, Fe-Kα radiation) and a computer program for diffraction data analysis and processing were used to examine the phase composition of carbonyl iron and nickel powders. The size of the coherent scattering regions (CSRs) was calculated based on the broadening of x-ray lines and using the Selyakov–Scherrer formula. The magnetic properties were measured with a ballistic magnetometer at room temperature and a magnetic force from −800 to 800 kA/m.

For biological media, we used distilled water, physiological solution (0.9% NaCl), a 1 : 1 mixture of physiological solution and human blood plasma, and human blood plasma. A mixture of 0.9% NaCl with blood plasma is a model solution of human tissue fluid [2] and blood plasma represents human blood. The analysis took five days using a TVZ-25 constant-temperature cabinet at 37–38°C.

The total iron content of the filtrate was determined with a standard method [3], which involves forming a complex compound of iron with sulfosalicilic acid. A FEK-56PM photoelectric calorimeter was used to measure the optical density. The nickel content of model biological media was determined with a standard method [4] using a FEK-56PM photoelectric calorimeter. The results are summarized in Table 3.

An insignificant amount of brown sediment showed up only after the five-day interaction of carbonyl iron and distilled water. Brown sediment was observed even in a day in 0.9% NaCl, and its amount substantially increased in five days. No sediment was observed in blood plasma mixed with 0.9% NaCl (1 : 1), the medium changed its color from yellowish to red-brown. No changes occurred in the interaction of carbonyl nickel with any biological media.

### Table 1. Chemical Composition of Starting Powders, wt.%

<table>
<thead>
<tr>
<th>Sample</th>
<th>Me_{(total)}</th>
<th>C_{(total)}</th>
<th>O_{2(total)}</th>
<th>N_{2(total)}</th>
<th>H_{2(total)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonyl iron</td>
<td>99.35</td>
<td>0.002</td>
<td>0.34</td>
<td>0.004</td>
<td>0.18</td>
</tr>
<tr>
<td>Carbonyl nickel</td>
<td>99.95</td>
<td>0.002</td>
<td>0.07</td>
<td>0.004</td>
<td>–</td>
</tr>
</tbody>
</table>

### Table 2. Admixtures in Starting Powders, wt.%

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fe</th>
<th>Ni</th>
<th>Cu</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonyl iron</td>
<td>Base</td>
<td>10^{-3}</td>
<td>10^{-4}</td>
<td>–</td>
</tr>
<tr>
<td>Carbonyl nickel</td>
<td>10^{-3}</td>
<td>Base</td>
<td>10^{-4}</td>
<td>&lt;10^{-3}</td>
</tr>
</tbody>
</table>