INVESTIGATION OF FERROFLUIDS FOR BIOMEDICAL APPLICATION

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INTRODUCTION: The recent development of a large variety of ferrofluids has led to a range of new biomedical and diagnostic applications. A major drawback for many applications remains the lack of well-defined and well-characterized particles.

Growing attention is paid to iron oxide nanoparticles embedded in a polymer matrix. The matrix fulfills several demands: on the one hand it acts as a stabilizer, or even controls the particle formation, on the other hand it determines the physicochemical properties of the material, or allows surface functionalization.

In this study magnetic nanoparticles were prepared either in the presence of polyvinylic alcohol or were redispersed after precipitation and isolation of iron oxide powder. Aqueous suspensions of magnetic particles were obtained under identical reaction conditions by coprecipitation of Iron(III)- and Iron(II)-salts using aqueous ammonia. The suspensions were finally dialyzed against distilled water to approximately pH 6.5.

METHODS: For a better understanding of the colloidal and magnetic properties, an extensive characterization of the ferrofluids must be carried out. Three major points are discussed in this work: composition, size distribution, and first tests with human endothelial and synovial cells.

Composition: The iron oxide particles, with and without coating, were analyzed using XRD as well as FTIR. High resolution TEM measurements were also carried out to obtain qualitative information about the presence of an amorphous phase.

Size distribution: Different techniques were applied in order to obtain information about the iron oxide particle size distribution. Among these are X-ray diffraction peak broadening, TEM picture analysis, magnetic characterization techniques, photon correlation spectroscopy, or analytical ultracentrifugation. Although the obtained results are not always comparable, valuable information is provided by their interconnection.

Cell survival tests: In collaboration with the Tierspital Zuerich (Musculoskeletal Research Unit), first tests with human endothelial cells and synovial cells have been carried out. The cell survival after different time periods has been

compared for different concentrations as well as different methods of synthesis.

RESULTS: The main characterization results are summarized in the following.

Composition: XRD patterns show a large amorphous zone as well as typical peaks, which can be attributed to nanocrystalline magnetite (Fe_3O_4) or maghemite (γ-Fe_2O_3). After close examination the presence of two distinct phases is excluded, and the composition is thought to consist of a defective magnetite structure with a lattice parameter in between the one of bulk magnetite and bulk maghemite. FTIR investigations yield the same results.

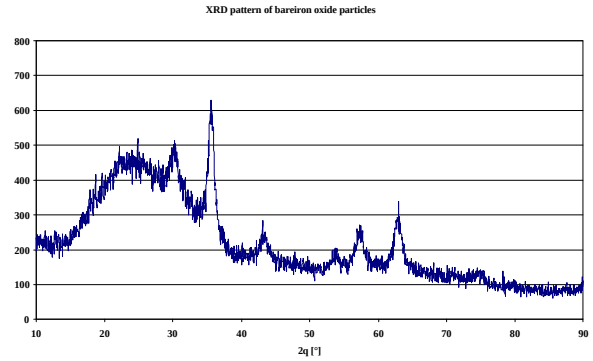

Fig. 1: XRD pattern of uncoated iron oxide nanoparicles showing a wide amorphous zone and typical inverse spinel peaks.

Size distribution: Typical monomodal distributions were found with an average size slightly smaller than 10nm.

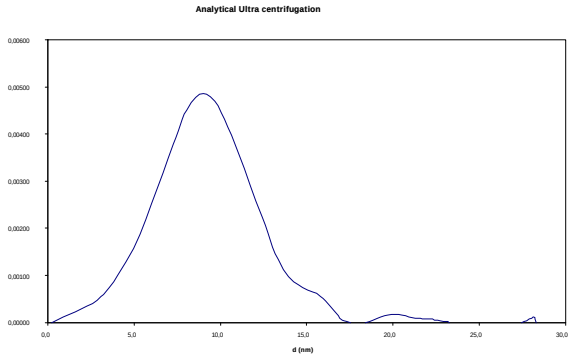

Fig. 2: AUC size distribution of bare iron oxide

The differences in size distribution determined by various methods show the necessity of combined size characterization for particles of that size. The comparison of the results also gives qualitative information about other properties such as the density or the refractive index. In particular, the spherical assumption for the particle shape proved to be satisfactory.

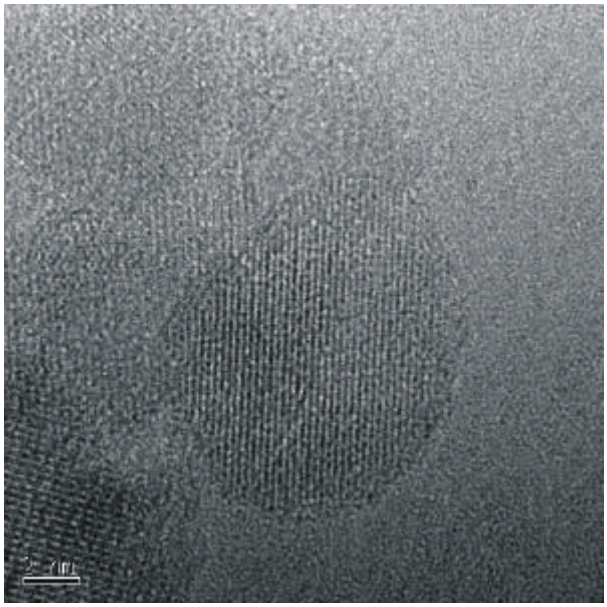

Fig. 3: High resolution TEM picture of crystalline iron oxide particles.

Cell survival tests: It could be shown that the concentration of the polymer as well as the ammonia concentration plays a very important role in the cell survival tests. As a first result it can be concluded that a minimum concentration of ammonia during the preparation of the polymer is essential for cell survival.

CONCLUSION: Ferrofluids were synthesized using PVA to ensure the colloidal stability at neutral pH. The composition, structure, and size distribution of these iron oxide particles were characterized, and the influence of the synthesis parameters was studied. After the first tests, the obtained ferrofluids seem to be non-toxic to human endothelial as well as synovial cells.

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