A novel methodology for the synthesis of silicon oxide mesoporous materials has been developed using soft reaction conditions, unlike other synthesis conditions present in the literature. The synthesis involves the use of the lyotropic liquid crystals formed by mixing the surfactant hexadecyltrimethylammonium (CTAB), sodium nitrate as catalyst, water and tetraethyl orthosilicate (TEOS) as the inorganic precursor. The silicon oxide samples were characterized by high-resolution transmission electron microscopy (HRTEM) and EDX analysis. The specific surface area, pore size and thickness of the wall. Additionally, other factors have been considered: the surfactant concentration, the inorganic precursor ratio and the acidity of the medium. Xiao et al. studied the effect of the molar TEOS/HNO$_3$ ratio on the synthesis of mesoporous silica hollow spheres with uniform pore diameter of 3.6 nm to 3.8 nm. These hollow spheres allow the encapsulation of different types of metals (Au, Ag), semiconductors (ZnS, TiO$_2$, Fe$_3$O$_4$) and conductive polymers (polyaniline).

In general, the route to obtain mesoporous materials involves the use of supramolecular structures (templates) and a strong acid medium, high temperatures and pressures. These parameters directly influence the properties of the obtained mesoporous materials, such as type of structure, morphology, specific surface area, pore size and thickness of the wall. Additionally, other factors have been considered: the surfactant concentration, the inorganic precursor ratio and the acidity of the medium. Xiao et al. studied the effect of the temperature on the synthesis of mesoporous silica nanofibers obtained at 283 K exhibiting a specific surface area of 952 m$^2$/g. As the temperature increased from 283 K to 293 K and to 308 K, the specific surface areas of the mesostructure containing aggregates of particles, decreased to 656 m$^2$/g and 462 m$^2$/g respectively.

J.H. Zhu et al. studied the effect of the molar ratio of CTAB to Na$_2$SO$_4$ on the ordering degree of the mesoporous structure. These authors have found that when the molar ratio of CTAB to Na$_2$SO$_4$ exceeds 3:5, the mesophase loses its structural order. Another conclusion of this work is related to the absence or presence of phenol in the mixture. It was determined that when the ratio is 1:2, lamellar silica is obtained. Meanwhile, when the ratio is 1:2, lamellar silica is obtained.

In this work, we present a methodology for the synthesis of silicon oxide mesoporous materials under soft reaction conditions, namely one atmosphere, 313 K and pH 7. The synthesis involves the use of a lyotropic liquid crystal as the template, as suggested by Xiao et al.
Currently, we are con-
et, P. Beaunier, F. Audonnet,
ions plays an im-
anion having a high binding selectivity in relation to
can be explained
from negatively charged precursors. Therefore, positively charged surfaces fa-
since most of the oxides used in the manufacture of these devices are formed
is important to expand the scope of the use of silicon oxide as the template,
pzc, at pH 3.1 indicating that their surface is positively charged. This parameter
curves with the pH axis present the same value for the point of zero charge,
possible to obtain the surface area of SiO
sized under conditions previously mentioned
BET measurements are used primarily to determine the pore diameter
with the pH size, since the shape of the adsorption isotherm allows to catalog
Figure 1. HRTEM images series for the sample m-SiO$_2$.

Figure 2. STEM-HAADF and EDX measurements for the sample synthet-
sized under conditions previously mentioned
Figure 3. BET analysis of mesoporous silicon oxide. A) Pore volume vs. pore diameter, B) volume of gas adsorbed vs relative pressure.

Figure 3 shows the pore diameter distribution as a function of pore volume, as can be appreciated the majority pore diameter is in the range of 2 nm to 4 nm. On the other hand, Fig. 3B shows a typical IV adsorption isotherm type characteristic of mesoporous solids, with a hysteresis loop associated with tubular capillaries open at both ends. From this isotherm it was possible to obtain the surface area of SiO$_2$, whose calculated value was 587 m$^2$/g. This relatively high value indicates a high density of pores available for using SiO$_2$ as template. From these results it is possible to confirm the forma-
tion of mesoporous structures.

CONCLUSIONS

Silicon oxide mesoporous materials can be easily prepared using a soft

template route which involves the initial formation of the liquid crystal with
CTAB in water using NaNO$_3$ as the catalyst, followed by the addition of TEOS

Further, the concentration of the NO$_3^-$ ions plays an im-
portant role on the catalytic hydrolysis of TEOS and the formation of the final
nanostructure. In fact, depending on the NaNO$_3$/TEOS molar ratio used, the
particle morphology that is obtained changes from aggregate particles (NaNO$_3$
/TEOS = 0.3) to fiber (NaNO$_3$/TEOS = 1). The role of the NO$_3^-$ can be explained
on the basis of the NO$_3^-$ anion having a high binding selectivity in relation to
the cationic surfactant CTAB and leading to long cylindrical micelles which
would facilitate the formation of the nanostructure. Currently, we are con-
ducting work to clarify this further.

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