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SCK•CEN STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

CTBTO PREPARATORY COMMISSION

Study of materials for improved adsorption of xenon at IMS radionuclide stations

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Introduction

A crucial part of the verification system of the Comprehensive nuclear-Test-Ban Treaty (CTBT) are the radioxenon monitoring systems that are monitoring the atmosphere for potential xenon releases from nuclear explosions. The efficient adsorption and desorption of the xenon isotopes in adsorbent materials is essential for the detection capability of these radioxenon monitoring systems.

Recent studies on xenon adsorption in porous materials have shown promising results for the further improvement of the detection capability of the IMS noble gas systems. In the framework of the two previous EU Joint Action programs, SCK•CEN designed a laboratory set-up to perform breakthrough experiments on different adsorbent materials and developed a model for the simulation of the adsorption process. Although this research was in another context, it was obvious that the studies performed and the methods developed were also suitable for xenon monitoring purposes.

The SCK•CEN has been contracted by the CTBTO under the EU JA VII program to perform a fundamental study of xenon adsorption materials for a **more efficient noble gas monitoring** at IMS stations, which could be translated in lower detection limits or shorter collection and processing times.

Project

Phase 1 – Material selection and first comparison

11/2018 – 11/2019

- Literature review of novel Xe adsorption materials
- Xe/N_2 adsorption isotherm of selected material
- Xe selectivity in air through breakthrough measurement

➔ **Sub-selection of most promising materials**

Phase 2 – In-depth studies of selected materials

11/2019 – 11/2020

- Investigate adsorption, desorption and diffusion mechanisms
- Analysis and simulation of the experimental results
- Bridge the in-depth studies to real operational conditions
- Tests for Xe extraction in different conditions

➔ **Optimal operational conditions for each material**

Results

1. Literature review of novel Xe adsorption materials

A literature review was performed to identify new potentially promising materials, with an emphasis on MOFs (Metal-Organic Framework), for xenon adsorption. MOFs have been intensively studied in recent years for the adsorption of xenon due to their chemical tuneability and functionalization. 4 MOFs materials were selected based on their **commercial availability**, their **stability** and their reported **Xe adsorption capacities**. In addition, three reference materials were selected (1 activated carbon and 2 Ag-doped zeolites).

Activated carbon: NUSORB GXK
Silver-doped zeolite: Ag-ETS-10 and Ag-ZSM-5
MOFs: HKUST-1, UiO-66, ZIF-8 and NiDOBDC

2. Xe/N_2 adsorption isotherm

The first comparison for the Xe adsorption properties of the different materials is performed through the measurement of the Xe/N_2 adsorption isotherm of each material at **room temperature** for Xe concentrations ranging from **100 ppb to 10 000 ppm**. The results that were collected for the moment are compared to the pure Xe adsorption isotherms that were reported by different authors in Figure 1.

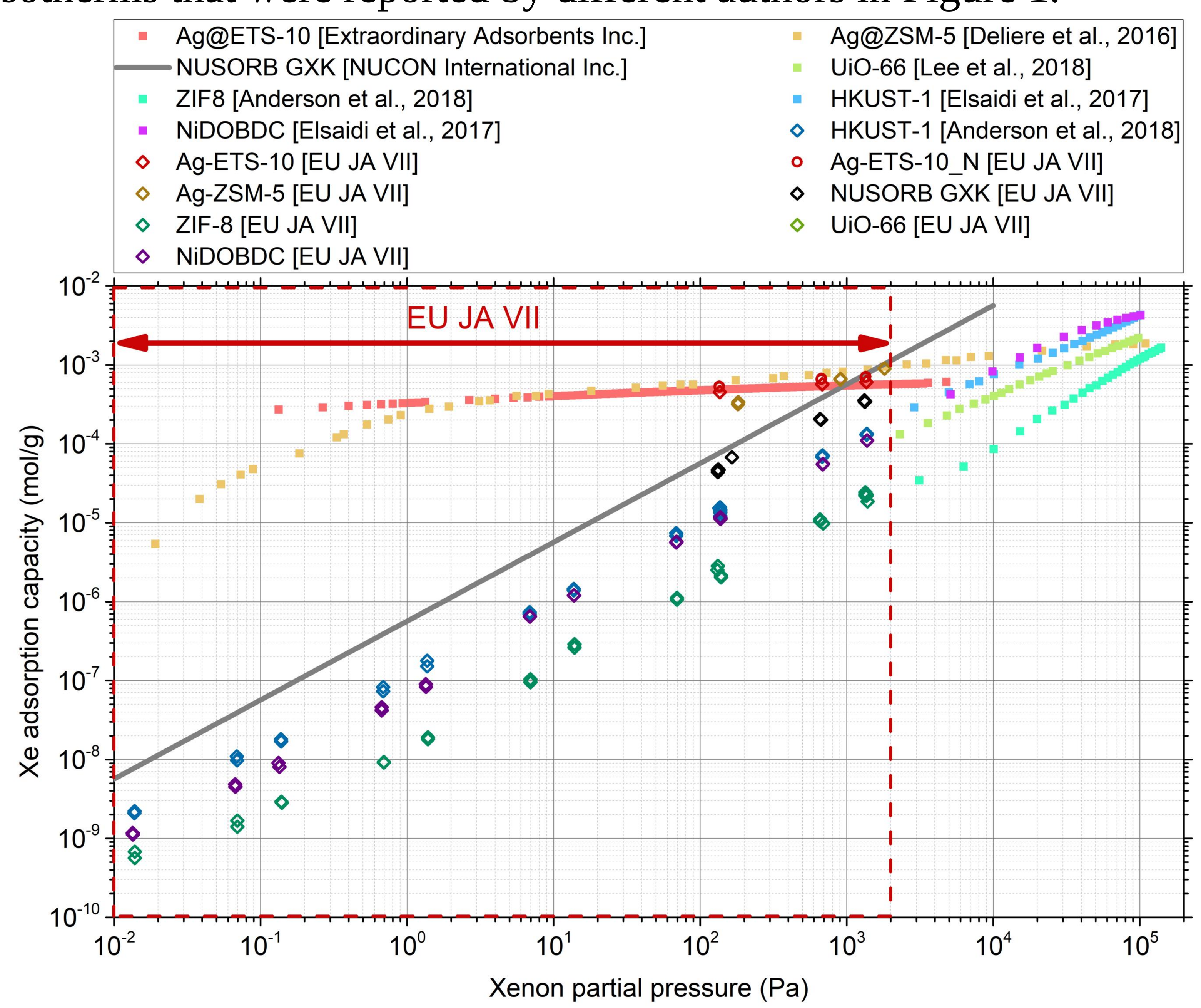

Figure 1 – Xe adsorption isotherm (EU JA VII results are for Xe/N_2).

Results

3. Desorption

A number of desorption runs were performed on each material. The number and conditions of the desorption runs for each material are summarized in Table 1. **No degradation** of any material was observed at present. A typical desorption curve is shown for each material in Figure 2.

Material	Flow N2 (cm³/min)	T (°C)	# Desorption
Ag-ETS-10	400	200	4
Ag-ETS-10_N	400	200	3
Ag-ZSM-5	150	200	6
NUSORB GXK	400	165 - 210	13
HKUST-1	200 - 400	25 - 160	16
ZIF-8	200 - 400	25 - 160	24
NiDOBDC	400	25 - 150	15

Table 1 – Summary of the desorption runs performed on the different materials.

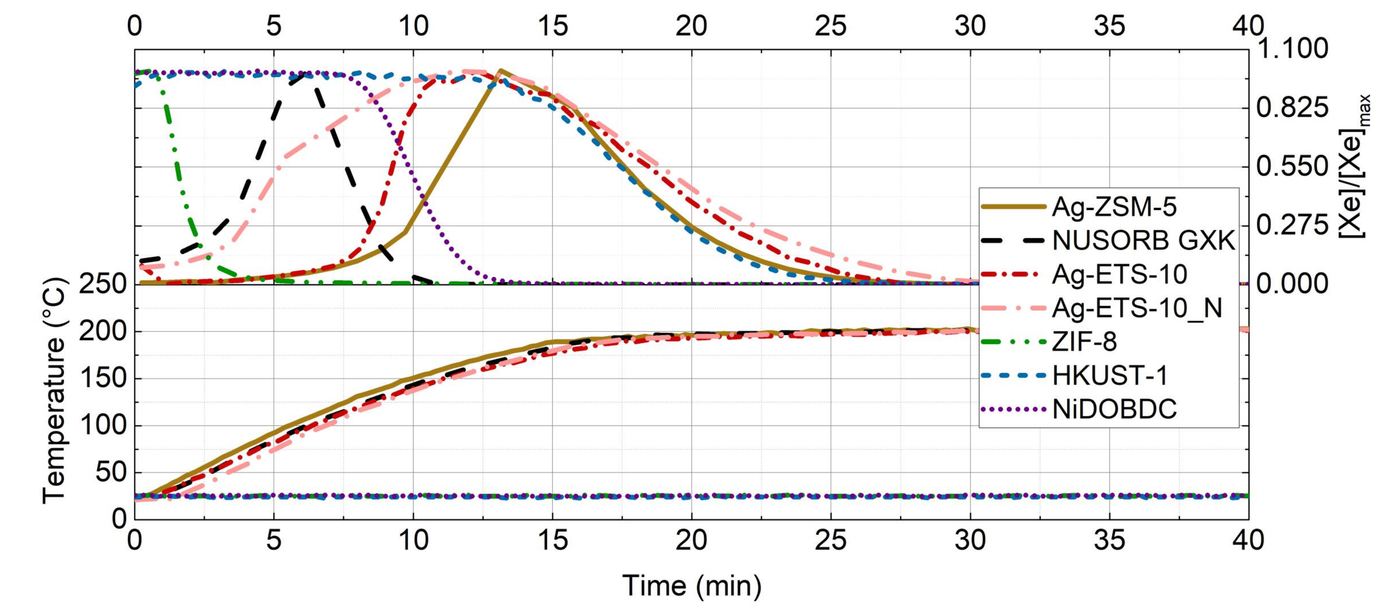

Figure 2 – Typical desorption curve for each material.

Conclusions

1. At low Xe concentration, silver-doped zeolite materials are the most efficient for Xe adsorption (for Xe/N_2). However, these materials are known to be sensitive to other gas components.
2. The Xe selectivity over other gas components in air will be investigated to prove the benefit of using MOFs.
3. The adsorption, desorption and diffusion mechanisms of the selected materials will also be investigated.
4. The adsorption model developed by SCK•CEN will be refined to investigate the scale-up to IMS operational conditions.
5. The results will support a more efficient Xe collection in the IMS in the future.

References

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