Capture of volatile fission products: present status and future perspectives

Italian national agency for new technologies, energy and sustainable economic development

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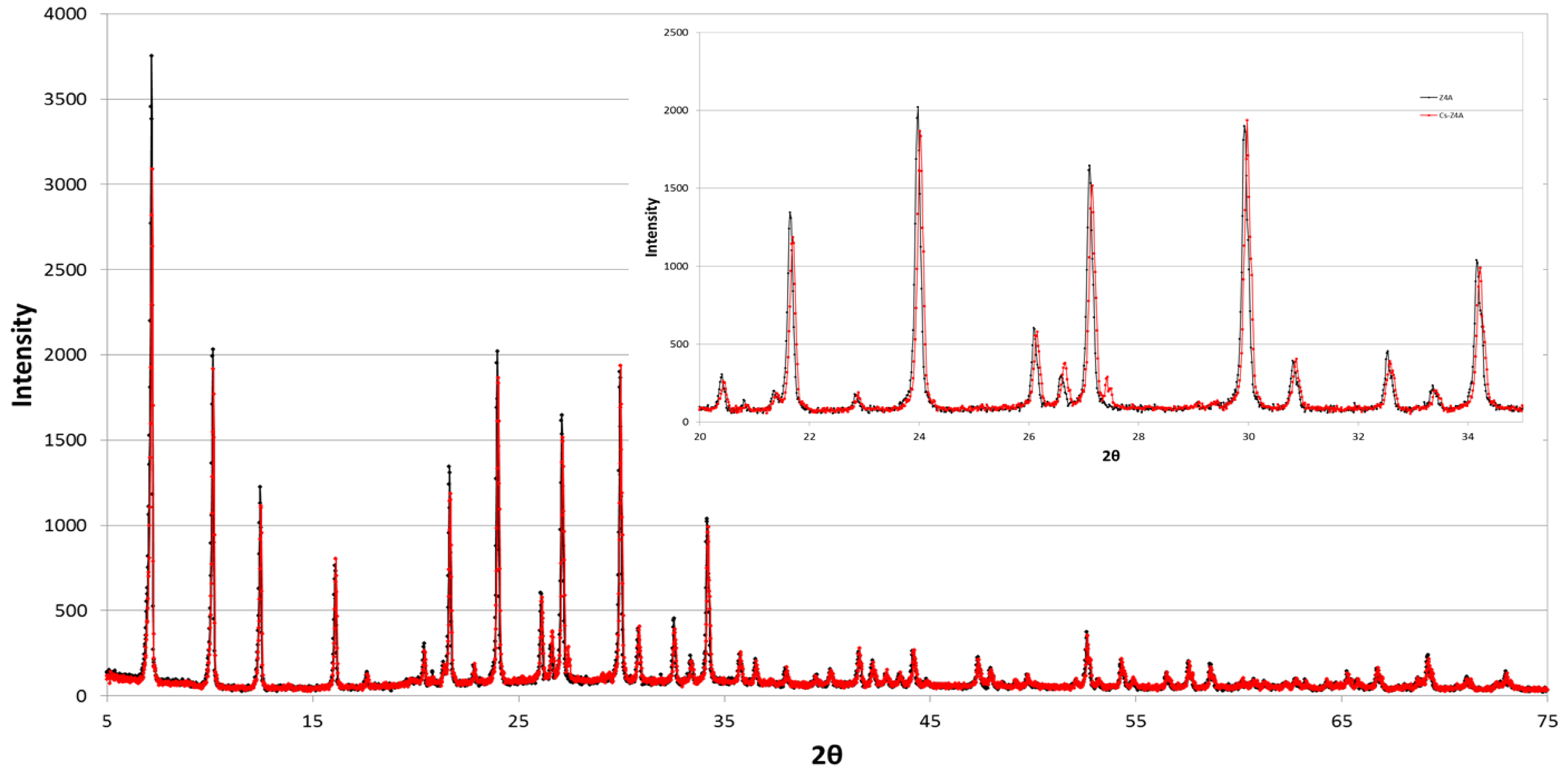
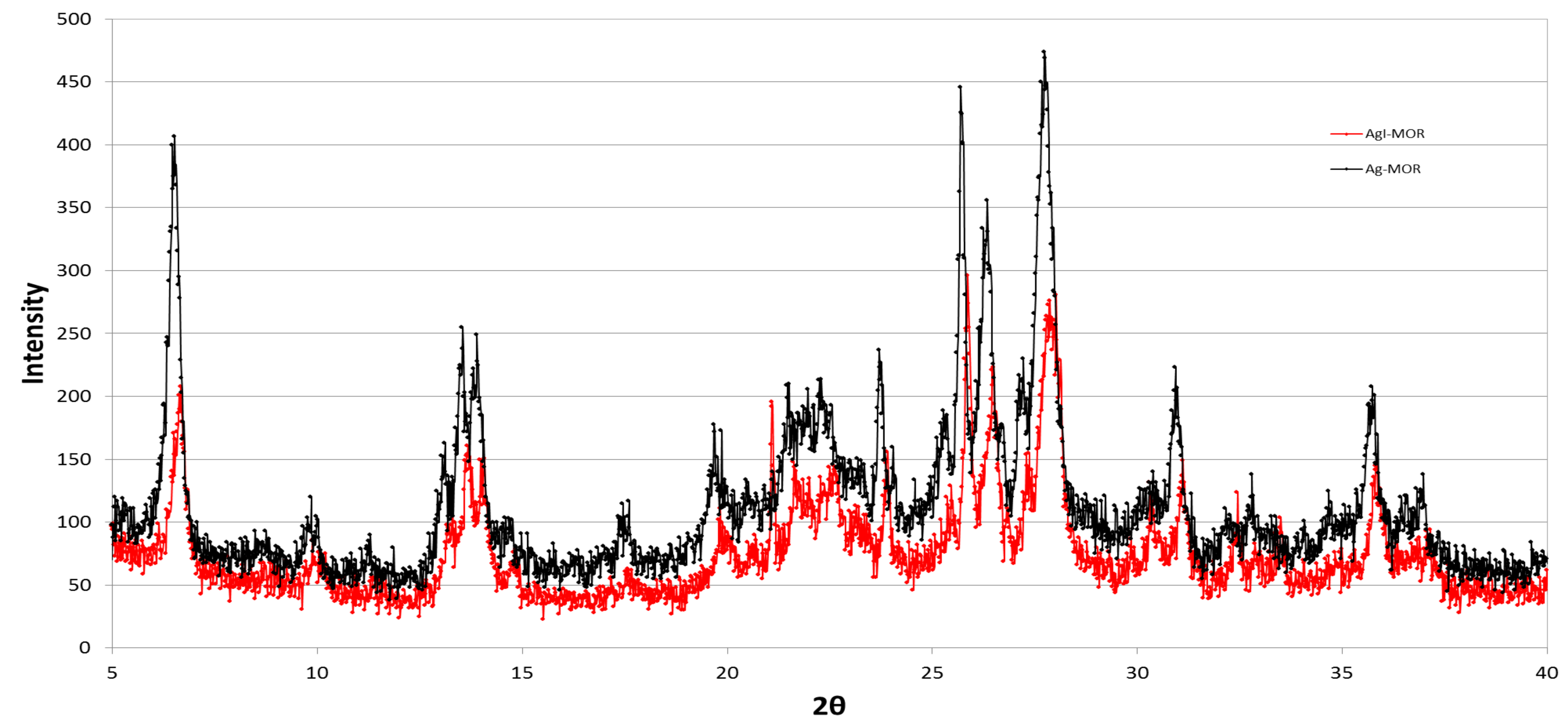
General view of OGATA pilot plant

The performance of some adsorbent materials for retention of volatile fission products has been assessed. Two different zeolites (Zeolite 4A and silver-coated mordenite) have been chosen owing to their known capacity to entrap cesium and iodine, respectively. To this purpose experiments have been made with the pilot plant OGATA (Off-GAs Treatment Apparatus), installed at ENEA laboratories. The tests have been carried out by heating the volatile species at 900°C and passing them through zeolite pellets with the help of argon as carrier gas. The products arising from the interaction with the zeolites have been analyzed mainly by X-rays diffractometry and scanning electron microscopy. The general conclusion from these experiments is that the retention of volatile elements, like cesium and iodine, occurs through a simple adsorption mechanism, which confirms the need to improve the trapping capacity of these materials, especially in view of the final disposal. Moreover, a metal-organic framework (MOF-5), as representative of the new class of materials proposed as adsorbents for volatile radionuclides has been taken into account.

Financial support from Italian Ministry for Economic Development (Accordo di Programma: Piano Annuale di Realizzazione 2013) is gratefully acknowledged.

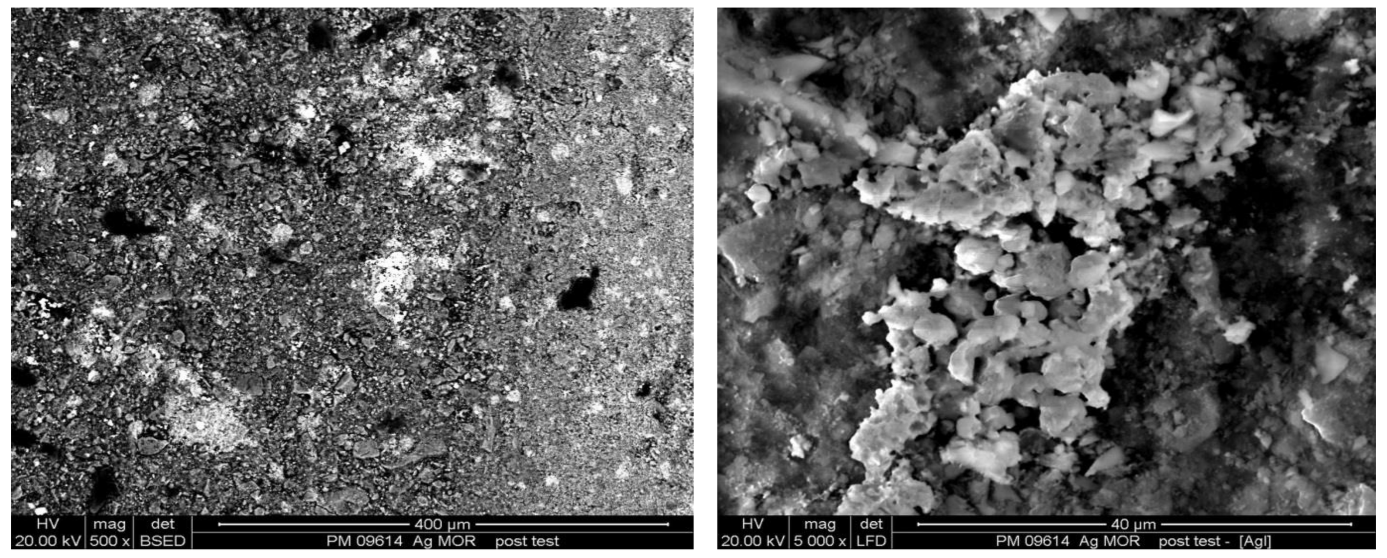


XRD spectra of Zeolite 4A before (*black line*) and after (*red line*) the test with cesium



XRD spectra of Ag-mordenite before (*black line*) and after (*red line*) the test with potassium iodide

Pictures of Ag-mordenite pellets before (*left*) and after (*right*) the test with KI



Micrographs showing the formation of silver iodide onto the surface of silver-mordenite

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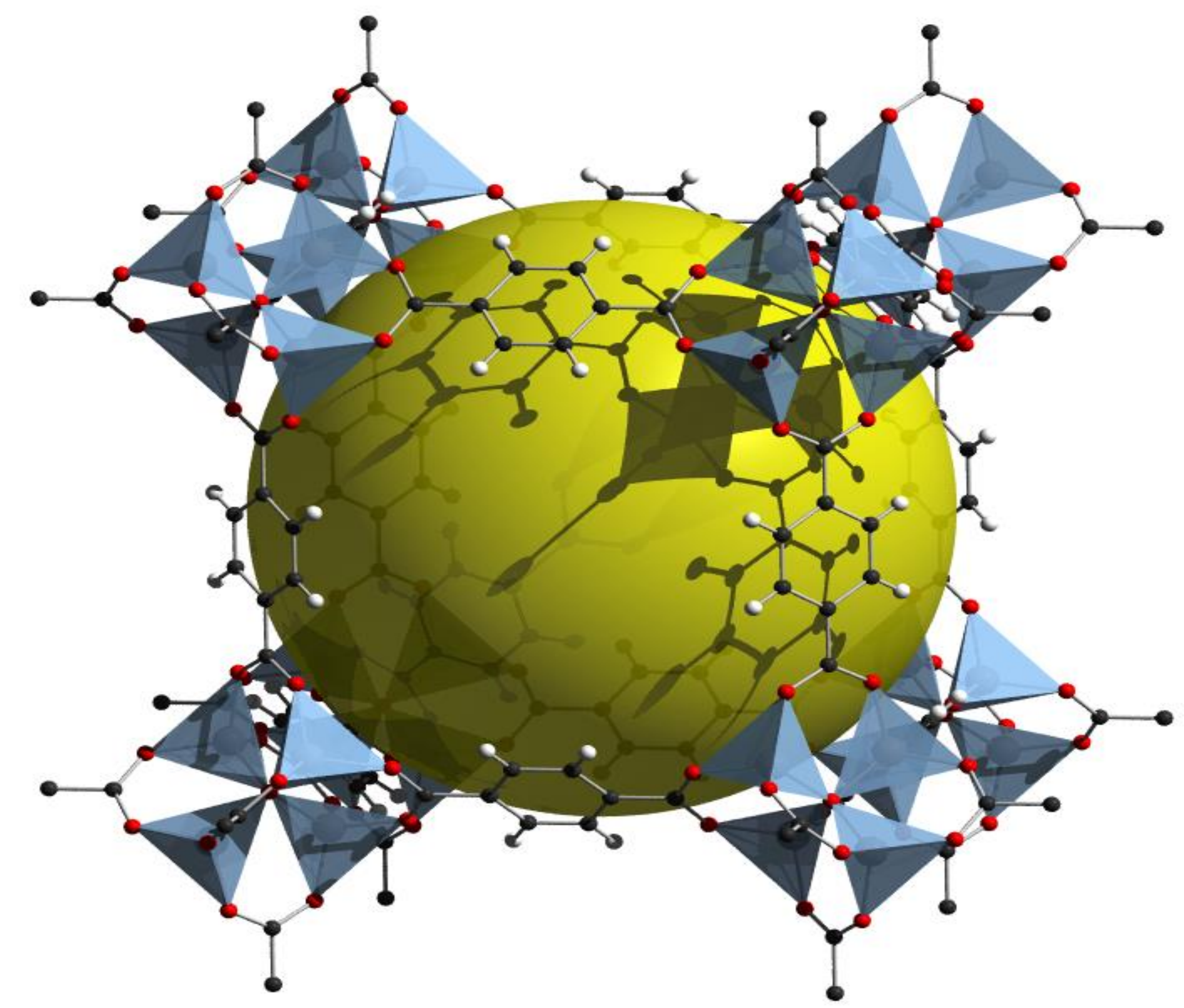
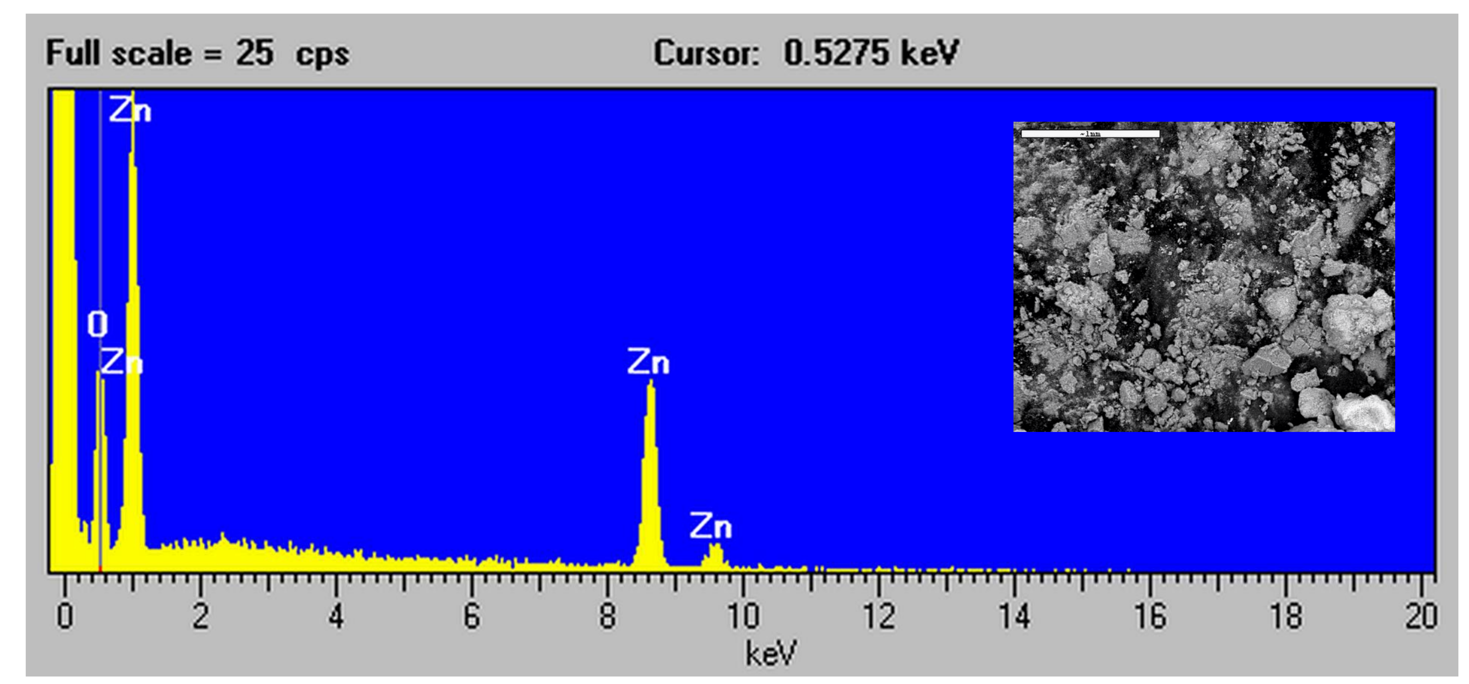
Synthesis of MOF-5

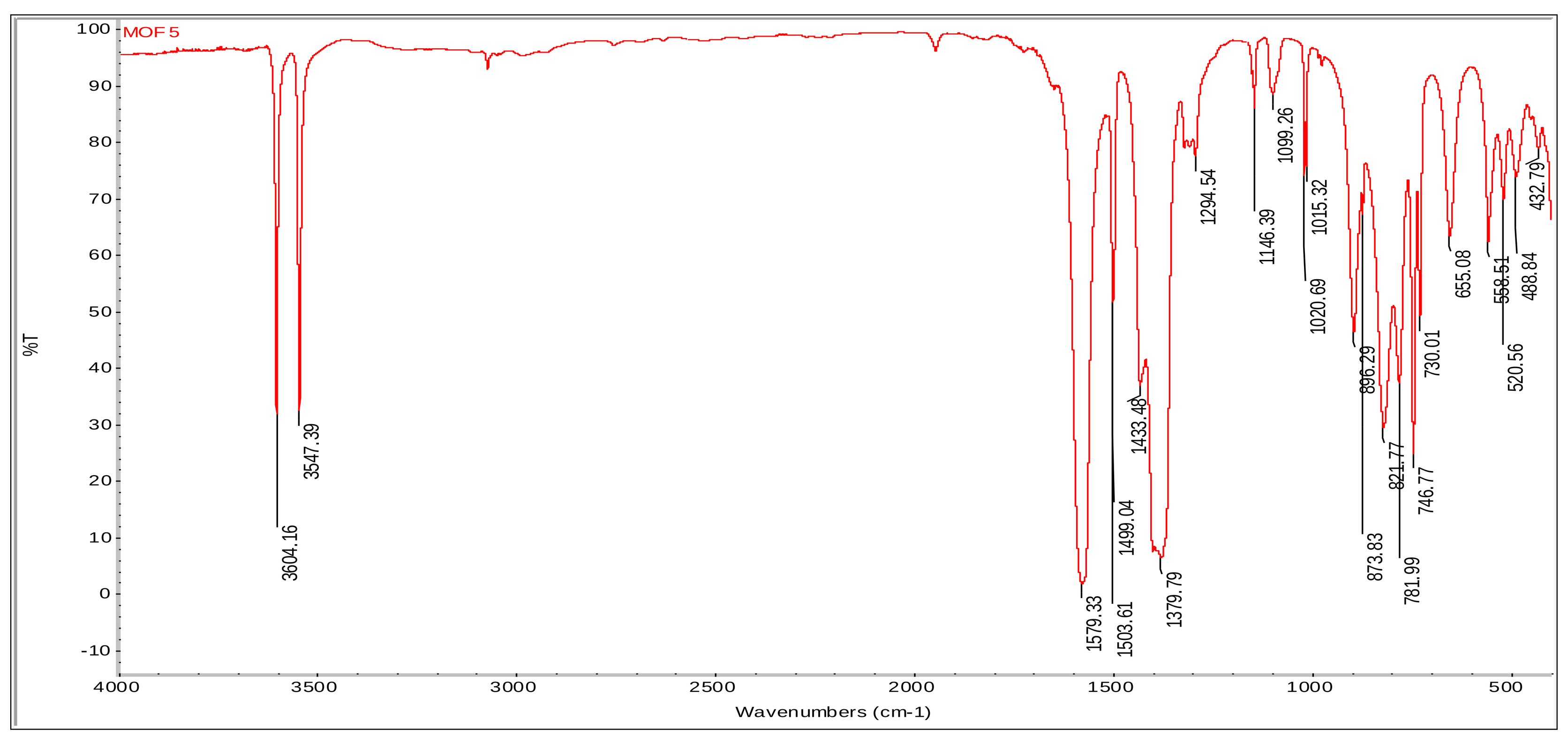
The metal-organic frameworks (MOFs) are a sub-family of the nanoporous crystals, characterized by metal-oxygen cages (vertices) connected by organic bridges. MOFs currently attract intensive interest for their excellent potential for storing and separating gases. Moreover, by changing the organic bridge and/or its functionalization, new MOFs can be designed and synthesized without changing the underlying topology. MOF-5 consists of ZnO_4 inorganic mojety, that acts as secondary building unit, coordinating to benzene 1,4-dicarboxylate, a bidentate ligand that acts as spacers, to form a three dimensional structure. It can be synthesized as follows: about 1.2 g of zinc nitrate hexahydrate and 0.334 g of benzene dicarboxylic acid (BDC) are dissolved in a solution containing 40 mL of dimethyl formamide (DMF) and 5 mL of chlorobenzene under constant stirring. Then 2.2 mL of triethyl amine (TEA) solution and 3–4 drops of Hydrogen Peroxide are added to the mixture. After agitation for 30–45 min a white precipitate is filtered off, washed with DMF and immersed in chloroform for 24 h to exchange DMF solution. Finally, it is dried in vacuum oven at 120 °C for 2 h and stored in vacuum desiccator. All the procedures are performed in a venting hood at ambient temperature (25 °C).



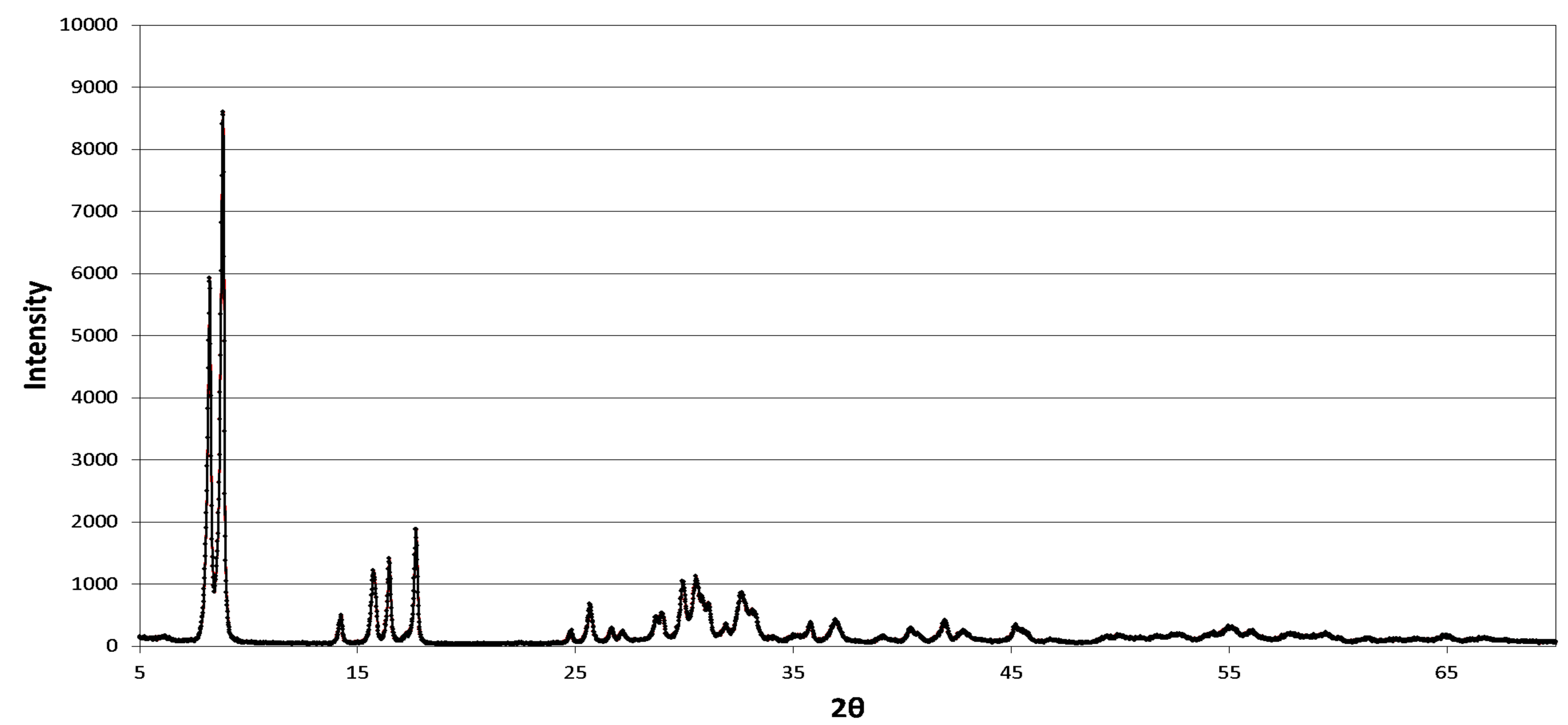
Structure of MOF-5



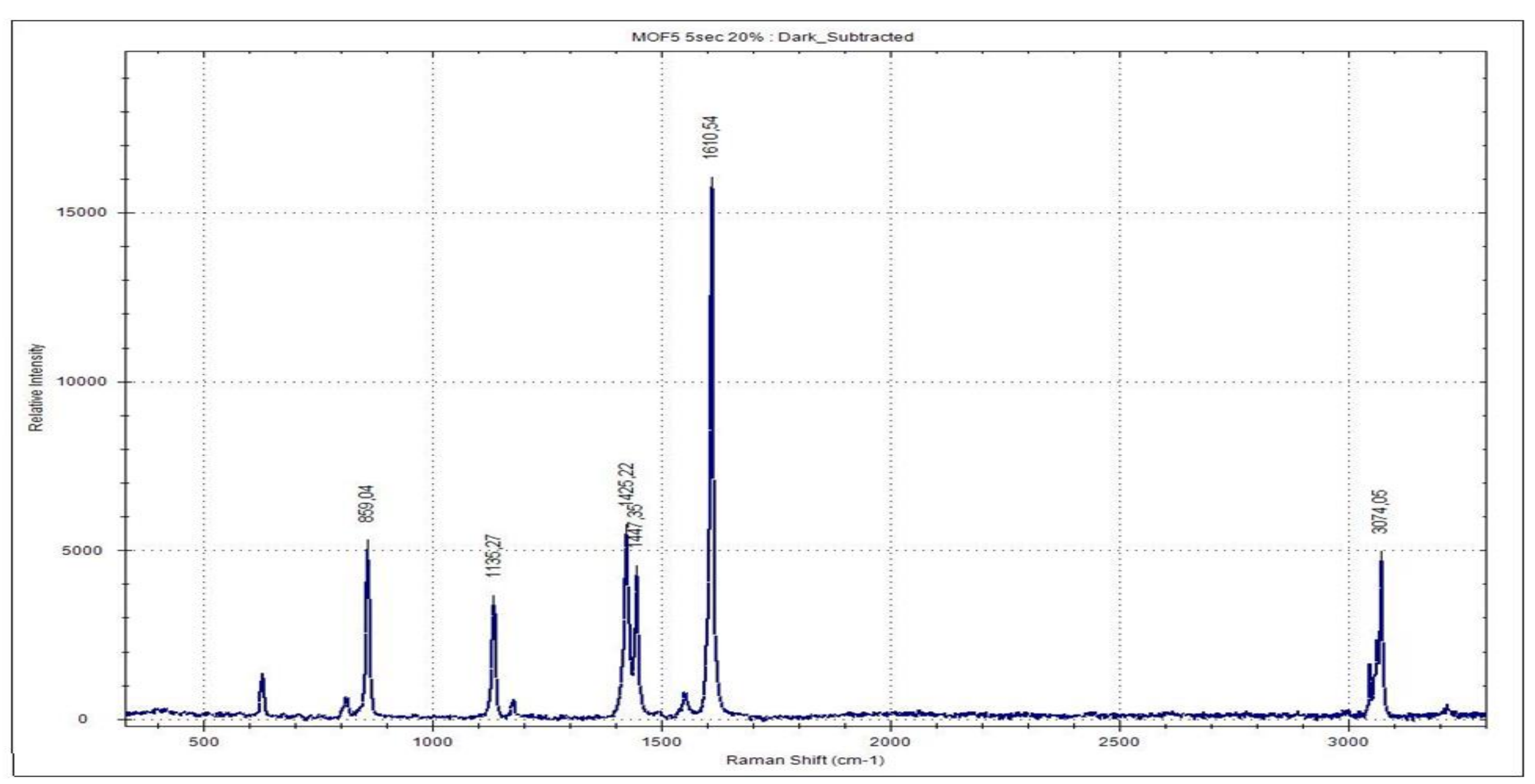
SEM-EDS analysis of MOF-5



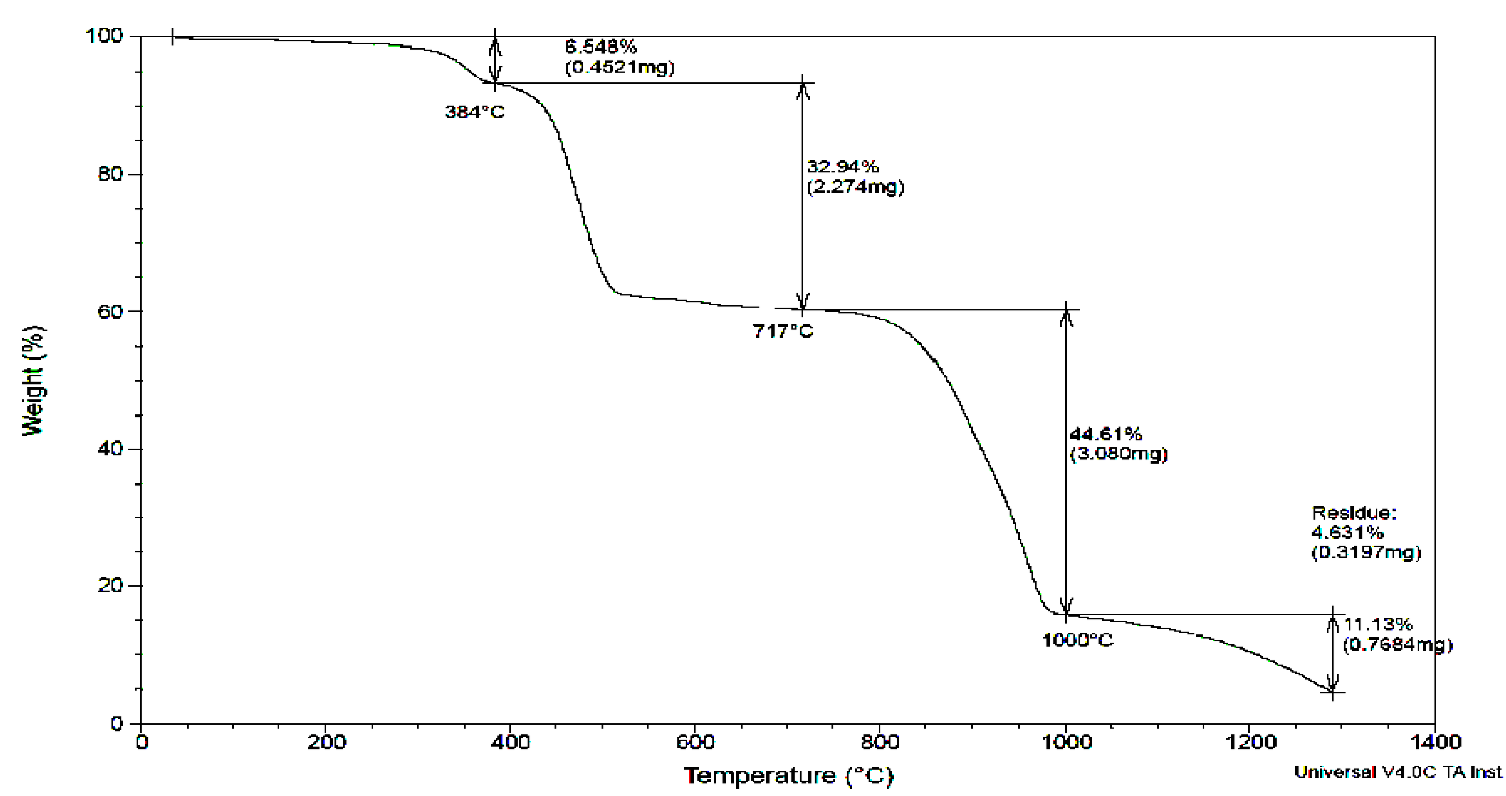
FTIR spectrum of MOF-5



XRD spectrum of MOF-5



Raman spectrum of MOF-5



TGA analysis of MOF-5

Synthesis steps of MOF-5