FACILITY FOR MODIFICATION AND ANALYSIS OF MATERIALS WITH ION BEAMS (FAMA)*

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Abstract

The facility for modification and analysis of materials with ion beams (FAMA) is the low energy part of the TESLA Accelerator Installation, in the Vinča Institute of Nuclear Sciences, Belgrade, Serbia. It presently comprises two machines: a heavy ion source (M1) and a light ion source (M2), and two experimental channels: a channel for analysis of ion beams (C1) and a channel for surface modification of materials (C2).

In April 2009 the Vinča Institute signed a contract with the Joint Institute for Nuclear Research, Dubna, Russia, on the upgrading of FAMA. The contract comprises: (i) the refurbishment of the M1 and M2 machines and the C1 and C2 channels, (ii) the construction of a channel for surface physics (C3) and a channel for deeper modification of materials (C4), (iii) the construction of a small isochronous cyclotron (M3), and (iv) the construction of a channel for analysis of materials in vacuum (C5) and a channel for analysis of materials in air (C6). This presentation is devoted to the upgraded FAMA and its research program.

PRESENT STATUS OF FAMA

The facility for modification and analysis of materials with ion beams (FAMA) is the low energy part of the TESLA Accelerator Installation (TAI), in the Vinča Institute of Nuclear Sciences, Belgrade, Serbia. It has been used by several user groups performing experiments in different basic and applied research projects. FAMA presently comprises two machines and two experimental channels: a heavy ion source (M1), a light ion source (M2), a channel for analysis of ion beams (C1) and a channel for surface modification of materials (C2). Fig. 1 gives a scheme of present FAMA without M2 machine.

The M1 machine is an ECR ion source providing different kinds of multiply charged ions from gaseous and solid substances [1]. It operates at 14.5 GHz, while the maximal extraction voltage is 25 kV. This machine was designed and constructed jointly by the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research (JINR), Dubna, Russia, and the Laboratory of Physics of the Vinča Institute. It is in operation since 1998.

The C1 channel is used for analysis of heavy ion beams produced with the M1 machine. It comprises a beam emittance meter of the pepper-pot type. This channel was put in operation in 2003 [2].

The C2 channel is used for surface modification of materials with heavy ion beams produced with the M1 machine [3]. It includes a beam scanning system, enabling uniform irradiation of the samples inside the interaction chamber. The main components of the vast (1 m^3) interaction chamber are the following: (a) the target holder enabling positioning and rotation of the samples, (b) a low energy (2 keV) argon gun enabling one to employ the technique of ion beam assisted deposition (IBAD), (c) an electron-beam evaporation source for thin film deposition, (d) a sample heater (T_{max} = 800 ºC) and separate cooling unit with liquid nitrogen, (e) a quadrupole mass spectrometer (1-100 amu). The channel was constructed by Danfysik, Jyllinge, Denmark and commissioned in May 1998.

In addition, there is a separate multicusp ion source (M2 machine) that produces positive or negative light ions (H^-, H_2^+, H_3^+, D^-, D_2^+, D_3^+, He^+). The maximal extraction voltage is 30 kV. It was constructed by AEA Technology, Abingdon, UK and commissioned in July 1997. Initially, this machine was planned to be an injector to the main cyclotron of TAI, but after the TESLA Project has been stopped, it has been occasionally used for surface modification of materials with light ion beams.

UPGRADING THE FAMA FACILITY

The experience of the user groups of FAMA has shown that the facility needs several improvements. These improvements should be (i) to integrate the M2 machine in FAMA and provide irradiation of targets with light ion beams in parallel with heavy beams, (ii) to enable irradiation of targets to high fluences (above 10^{17} cm^{-2}) in relatively short period of time, (iii) to enable one to bombard single crystals, (iv) to increase the beam energy, and (v) to introduce some techniques for analyzing the modified targets.

In April 2009 the Vinča Institute signed a three-year contract with the Joint Institute on the upgrading of FAMA. The contract comprises: (i) refurbishment and upgrading of the M1 and M2 machines and C1 and C2 channels, (ii) construction of a channel for surface physics (C3) and a channel for deeper modification of materials with post-accelerated ion beams (C4), (iii) construction of a set-up for analysis of materials comprising a small isochronous cyclotron (M3) providing proton beams for analysis of materials in vacuum (channel C5) and for analysis of materials in air (channel C6), and (iv) purchasing of a scanning probe microscope. These jobs are performed on the basis of the concepts made by the Laboratory of Physics of the Vinča Institute, in accordance with the previously mentioned necessary improvements of FAMA. Figure 2 gives a scheme of the upgraded FAMA without the M3 machine and the C5 and C6 channels.

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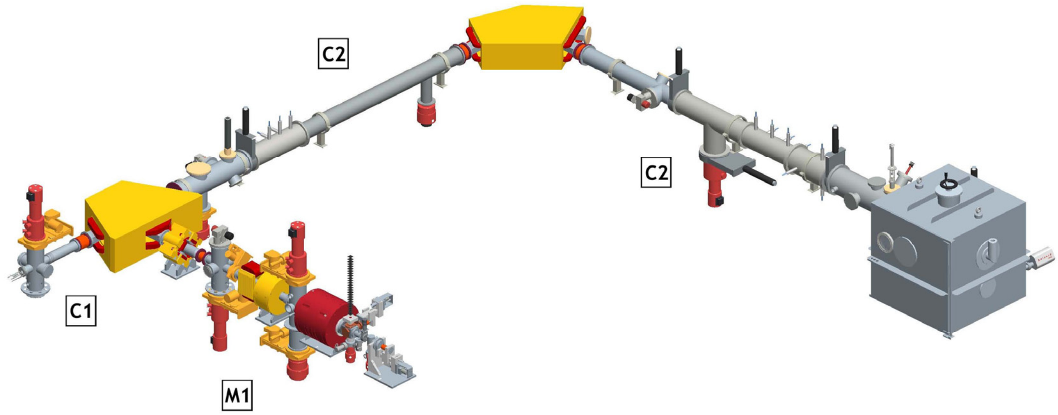

Figure 1: Present experimental facility for surface modification of materials.

The main highlights of the upgraded FAMA are the following:

- Reconstructed ECR ion source (M1) with new hexapole, larger plasma chamber and improved injection chamber should have better performances (higher charge states and higher beam intensities).
- Channel C1 will be used for the ion beam analysis using new emittance meter and for irradiation of samples to high fluences, above $10^{17}cm^{-2}$, usually obtained within one day. Homogenious irradiation will be obtained by mechanical x-y movement of the samples in front of the fixed ion beam [4]. In addition, the interaction chamber will have 6-axes target goniometer enabling one to perform implantation into single crystals.
- Channel C2 will be reconstructed in order to improve its ion beam transmission coefficient and to enable integration of light ion source (M2) into FAMA.
- Channel C3 will comprise an ultrahigh vacuum chamber for experiments in the field of surface physics.
- Channel C4 will provide additional acceleration of ions by biasing the target to the negative potentials of down to -100 kV, thus overriding the limitation in beam energy given by maximal extraction voltage of the ECR ion source (+25 kV). For example, we shall be able to bombard the target with the Xe^{24+} ion beam of the energy up to 3 MeV, instead of 600 keV without the biasing system [5].

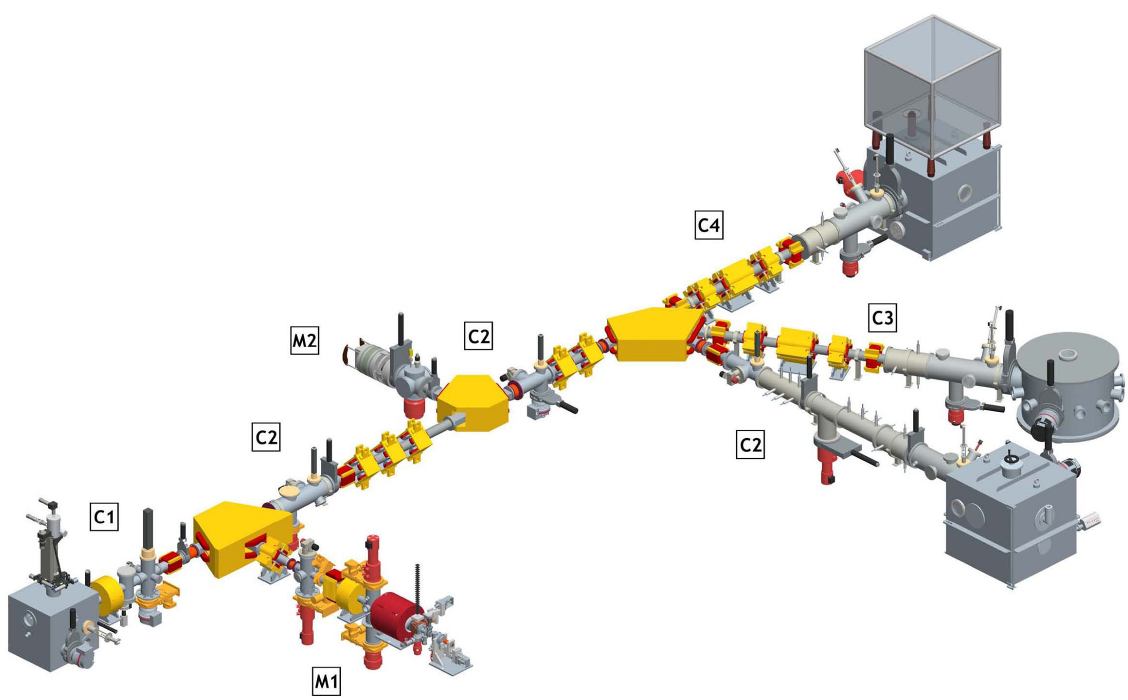

Figure 2: The scheme of upgraded FAMA.

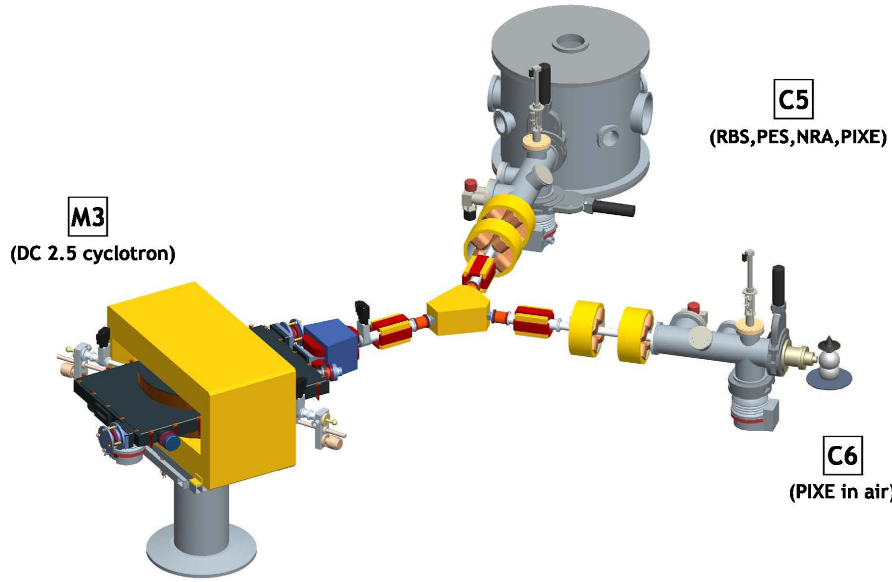

Figure 3: Set-up for analysis of materials using different techniques (RBS, PES, NRA, PIXE).

The scheme of the set-up for analysis of materials (e.g. irradiated samples) is shown in Fig. 3. It comprises a small isochronous cyclotron (machine M3) based on the DC 2.5 cyclotron prototype whose concept was made in JINR few years ago. It has 52 cm diameter of poles, four pairs of straight sectors, internal PIG ion source and extraction by stripping foil system, delivering proton beams of energies between 1 and 2.7 MeV. These beams will be used for different techniques of material analysis, realized in channels C5 and C6. In the C5 channel one will be able to perform the analysis of materials in vacuum by Rutherford backscattering spectrometry (RBS), proton elastic scattering (PES) spectrometry, nuclear reaction analysis (NRA), and proton induced X-ray emission (PIXE) spectroscopy. In the C6 channel one will be able to perform the analysis of materials in air by PIXE spectroscopy.

CONCLUSION

We hope that in a few years the upgraded FAMA should become regional user facility for different basic and applied research programs in the field of nanotechnologies and investigation of new materials with improved properties, offering advanced techniques for modification and analysis of materials with ion beams.

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