EUREKA PROJECT E!2214 - EUROCARE MOUSE

1. General description

Project	E! 2214 - EUROCARE MOUSE	**Status**	Announced - 23-JUN-2000
Title	**Nuclear Magnetic Resonance Mobile Scanner For On-Field Non- Invasive Diagnosis Of Porosity/H20 Infiltration In Materials**		
Class	Sub-Umbrella	**Technological area**	Environment
Start date	01-JUL-2000	**End date**	01-JUL-2004
Duration	48 months	**Total cost**	4.5 Meuro
Partner sought	Yes		
Summary	The Aim Is To Produce An Nmr Mobile Universal Surface Explorer To Perform Non-Destructive Analysis Of Surface- Near Volume Elements Of Arbitrarily Large Objects To Characterize Macro And Micro Defects Such As Porosity.		

Budget and duration

Phase	Budget(Meuro)	Duration (Months)
Definition phase	1.5	12
Implementation phase	3	24
Total	**4.5**	**48**

Member contribution

Member	Contribution	Position	Since
Italy	**51.00%**	**Contact Member**	**16-JUN-2000**
Germany	34.00%	Participating Member	23-JUN-2000

Participants

Company	Country	Type	Role
Bruker Italiana S.R.L.	**Italy**	**Large company**	**Main**
Universita Di Roma "La Sapienza"/ Dipartimento Di Fisica	Italy	University	Partner
Bruker Analytik Gmbh	Germany	Large company	Partner
C.N.R. - Istituto Di Chimica Nucleare	Italy	Research Institute	Partner
Rwth-Lehrstuhl Fuer Makromolekulare Chemie Sammelbau Chemie Rheinisch-Westfaelische Technische Hochschule	Germany	University	Partner

2. Project outline

Project description

Radio frequency waves are known to penetrate non-conductive materials such as wood, stone and cementitious materials. Nuclear magnetic resonance (NMR) is a method of radio frequency spectroscopy in strong magnetic fields which is used for the chemical analysis of fluid matter, the analysis of material properties of solid matter and medical diagnostics, where the the method is known as Magnetic Resonance Imaging (MRI). In any of their applications, NMR techniques are not invasive because the sample remains unchanged: Radio Frequency does not produce any known effect on it.
By NMR, the peculiar properties of a fluid in porous media and the topological properties of the porous media themselves, such as pore-size distribution, pore connectivity and microfracture, can be investigated. The NMR approach is non-invasive and sensitive to molecular events which characterize the behaviour of a fluid trapped in a porous matrix. The peculiar aspects which make NMR sensitive to the confinement state of a fluid are based on the dramatic difference in dynamics and interactions that molecules experience in the vicinity of a solid wall with respect to the bulk. The effects induced by the wall are reflected on measurable NMR parameters like the relaxation times (T1, T2, T1r) and line shape. It is well known that the ageing of polymers like paint or the ones used for the conservation of Cultural Heritage or the alteration to texture in paper and canvas as well as the degradation of solid structure in frescoes and other fine arts materials (marble, wood, etc.), are strictly related to the role of trapped water, so that the NMR approach can be very powerful for the evaluation of the state of such materials.
For standard NMR applications, the sample must be placed inside the poles of a magnet exhibiting high homogeneous magnetic field. That places strong restrictions on the shape and size of the sample which cannot be larger than one metre and must be transportable inside the magnet. Single-sided applications of the NMR technique are also known. This approach forms the basis of the MOUSE (MObile Universal Surface Explorer) which is an NMR device designed for measurements on surfaces and surface-near volumes of arbitrarily-shaped objects.
This means that MOUSE makes it possible to perform non-destructive analysis of surface-near volume elements of arbitrarily-shaped objects. Useful results in material characterization have already been achieved in the field of soft matter relaxation and liquid components in solids, like oil in objects from plastics with measurement depths commonly up to 3 mm.
The main key features of the existing MOUSE can be summarised as follows:
a) it permits the collection of information on water content and its molecular mobility (relaxation times, line shape);
b) it retains small dimensions and weight (of the sensor) in such a way as to allow it to be moved into buildings like churches, museums, palaces and libraries by a single person;

c) it operates without producing damage or negative effects on people and objects;
d) it has sensors that can be tailored for particular object shapes. By default we assume planar objects;
e) its moderate equipment cost is of the order of 75,000 - 100,000 Euro.
The main aims of the project are:
1. Realization of a MOUSE-10 having 10 mm penetration depths, that hsould be suitable for the following applications to objects of cultural heritage:
* Humidity and water concentrations in building materials and wood;
* Degradation of canvas and oil in paintings;
* Characterization of paper quality;
* Porous structure of marble and building materials;
* Porous structure of stone with intrinsic high porosity;
* Detection of holes under fresco surfaces;
* Monitoring of porosity during and after restoration;
* Characterizsation of materials' wettability.
2) Study of feasibility of utilization of hyperpolarized 129Xe NMR technique for the analysis of open porosity fo dry materials through MOUSE-10.
3) Study for the determination of properties and transport parameters of water in building materials.
Conseuqently, the project also focuses on improving the following aspects of the existing mouse:
* increasing its sensitivity
* improving its measurement depth
* increase its spatial resolution
* correlation of measurement results with amterial properties (water content, ageing/degradation processes, porous structure, etc.)
* easy handling of the MOUSE for different measurement depth and materials of investigation
* easy data processing.
Keywords: movable NMR, fine arts, diagnosis.

Technological development envisaged

We propose to construct a mobile NMR sensor, which is portable to objects of cultural heritage for the analysis of water content and porosity. The penetration depth will be variable from 0.5 mm to 10mm. The device will be used for screening analysis of structural damage in many buildings and objets d'art from wood and stone before invasive restoration work begins. In addition, after restoration, the device can be used again to assess the success of the preservation measures including consolidates. Accompanying work will focus on establishing a database of NMR parameter characteristics of different types of materials and material damage. In addition, other than normally measured signals from protons, Xenon gas can be hyperpolarised causing the sensitivity of the measurement to be improved by several orders of magnitude, which can also be of great significance in determining the structure and quality of the wood and stone behind paintings and frescoes.
Note under Relationship to other EU Programmes:
Our project follows the 5th Framework Programme: Title: Energy, Environment and Sustainable Development: Key Axtion: the City of Tomorrow and Cultural Heritage.

Markets application and exploitation

Due to human activity and damaging environmental influences, many historical monuments and objets d'art are threatened by decay. Given the current extent of the damage, a joint effort by research, industry and administrative bodies is required to successfully save buildings, monuments and works of art. Apart from cultural and environmental repercussions, the decay of our cultural heritage also has an enormous economic impact. Tackling its effects offers a rapidly expanding market for new materials, technologies and services developed by industry.

Project codes

BSI

B	measurement, testing and instruments
BA/BK	measurement
BCB.M	detectors

NACE

73	Research and development
7430	Technical testing and analysis

3. Main participant

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Organisation type	Large company
Participant role	Main

Contribution to project

Carrying out of theoretical studies on MOUSE-10 construction, development of some software to control MOUSE-10, carrying out of part of the tests on built prototypes, project coordination.

Expertise

Partner company of BRUKER, which is a well known worldwide company in the field of instruments implementation.

4. Partner

Company	**Universita Di Roma "La Sapienza"/ Dipartimento Di Fisica** Piazzale Aldo Moro, 2 00 185 Roma Italy Tel +39 06 49 91 34 68 Fax +39 06 44 63 158
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Organisation type	University
Participant role	Partner

Contribution to project

Theoretical approach to the development of the new instruments.

Expertise

Expertise: considerable research regarding this project.

4. Partner

Company	**Bruker Analytik Gmbh** Am Silberstreifen, 76287 Rheinstetten Germany Tel +49 721 5161-0 Fax +49 721 516 1297 www.bruker.de
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Organisation type	Large company
Participant role	Partner

Contribution to project

Will perform many tasks related to the development of the MOUSE-12 prototypes.An RF circuit covering a frequency range of about 3-5 MHz and a Static Field Circuit will be built. Lateral resolution of the existing Mouse should be improved.

Expertise

Expertise: Well known worldwide company in the field of instruments implementation. Contribution: 1. They will construct an RF circuit covering a frequency range of about 3-5 MHz (depending on the BO-field gradient), showing mechanical stability and non-sensitivity to susceptibility and dielectric constant of samples. It should be possible to pre-select a penetration depth using a switch without re-tuning the circuit. Moreover, dead- time and background signals should not exceed 6-7 ms. Up to a penetration depth of 10 mm, measurement time should be shorter than 10 minutes and frequencies corresponding to penetration depths of 5-10 mm should be adjustable. 90 degree pulse-length at maximum penetration depth should not exceed 10 ms (about 250 W) in order to irradiate solid polymers as well. 2) A Static Field Circuit will be

constructed, to obtain the desired volume and there the regions of well defined discrete field lengths should be as large as possible. The preferred geometry of these regions are plain slices to guarantee an exact correlation of resonance frequencies to measurement depths. The depth resolution should be in the order of 0.5 mm. Magnet materials should be mechanically robust, and the field strength must be non-sensitive to temperature fluctuations in the range of about 15-40 degrees C. 3) the laterial resolution of the existing MOUSE, that currently cannot detect small changes in the samples within the diameter of the coil, must be improved.

4. Partner

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Organisation type Research Institute
Participant role Partner

Contribution to project

Theoretical approach to the development of the new instrument. Xe measurements. Confined H20 relaxation properties.

Expertise

Expertise: considerable research regarding this field.

4. Partner

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Organisation type University
Participant role Partner

Contribution to project

Realization of the MOUSE-10 prototypes, sensitivity of existing MOUSE must be improved. NMR characterization (relaxation times/line shape) must be done on model systems to identify polymer state before and after restoration.

Expertise

Well known research group in the field of applied technologies. The effects due to the static field gradient of the NMR surface device influence the detected moisture signal. So the minimum detectable moisture must be studies with the relative accuracy and reproducibility of the meausre, which is also influenced by conducting and paramagnetic particles that can be contained in the materials under examination. The second goal is to achieve an NMR characterization of polymeric solutins in stones: the research in the field of suitable products for the conservation Cultureal Heritage, both with consolidation and protective purposes is currently intended to set up new polymeric materials which could show better performances and longer durability. Nevertheless, to obtain such results and characterize the state of the polymer evolution from the NMR point of view, a deeper knowledge of polymer behaviour in the crystalline matrix is needed.