Project no. 018081

CUSTOCER

-Mass customization of ceramic and glass decoration

-A contribution to the future manufacturing industries –

Contract Number: COOP-CT-2005-018081

Instrument: Cooperative research

Thematic Priority: 3 ***"Nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices"***.

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D5

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Project coordinator organisation name: DECORKER

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1	19/10/2007	Addition of contents	Encarna Bou (ITC)
2	31/10/2007	Addition of the contribution of other partners	Encarna Bou (ITC)
3	13/11/2007	Modification of WP4	Kai Schulze (LZH)

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1.- Project Execution

1.1.- Introduction

CUSTOCER is the acronym for the project: “Mass customization of ceramic and glass decoration- A contribution to the future manufacturing industries”. This project started on the 5 of October of 2005 and finished on the expected date. All the project information is available in the web page: “150.128.190.210:8080/itc/opencms/custocer/en/index.html” which can be access also from the different web-sites of the partners: www.itc.uji.es/custocer.html

The objective of this project is to develop a decoration process, based on the use of laser technology, which enables customised manufacture of glass and ceramic tiles. To achieve this objective a study was made of several laser decorating techniques. These have been divided into two groups, respectively designated: deposition techniques and activation techniques. By analysis and development of the relevant materials, selection and adaptation of the laser, and development of a computer tool via the Internet, two demonstrators (deposition and activation) were elaborated that enable the client to customise the decoration of his products.

In order to achieve the objectives of the project, the research programme was divided into 8 workpackages (see Figure 1)

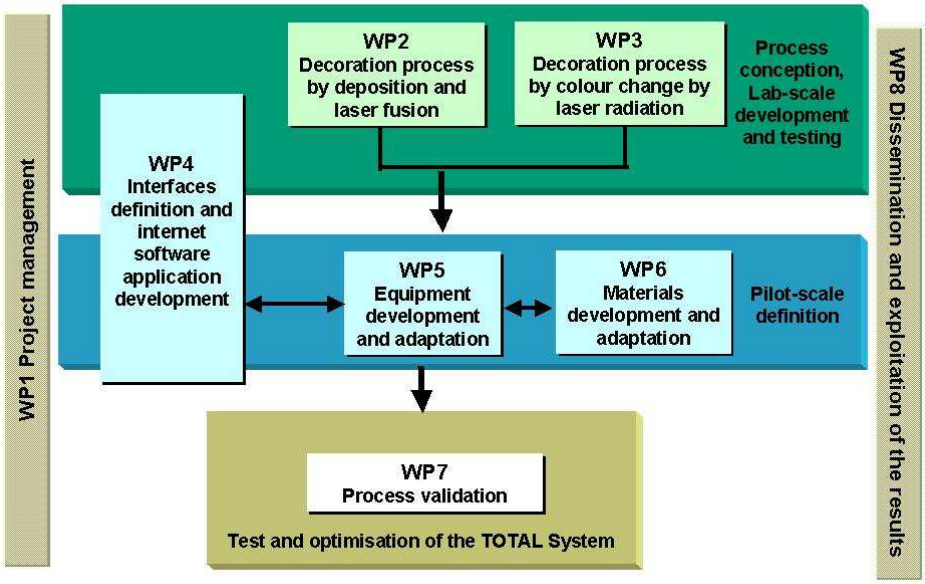

Figure 1. Structure of CUSTOCER project

The results obtained were so satisfactory for the SME’s that they decided to patent the results, because of that, the dissemination of the technical results depends on the patent submission.

1.2.- Specific project objectives

The project has three scientific and technical objectives:

1. Study of materials and adaptation to the technique used

   The objective of this project is to develop a decoration process, based on the use of laser technology, which enables customised manufacture of glass and ceramic tiles. To achieve this objective a study will be made of several laser decorating techniques. To obtain the appropriate prototypes, set out in objective 3, it is necessary first **to define** the most suitable laser techniques. Two prototypes will be developed In the CUSTOCER project based on two types of laser techniques, known as **deposition techniques** and **activation techniques**:

   a) With a view to obtaining the prototypes described in point 3 of the project objectives, a study will first be conducted of **laser deposition techniques**. The appropriate materials will be developed for this purpose, and the optimum processing variables determined. Two types of lasers are used in these techniques: HPLSS (high power laser scanning systems) and laser cladding. The former requires preliminary deposition of the material on the surface of the tile to be decorated; the subsequent laser scan then fuses the material on the tile surface. The second type of laser requires no previous application of material. In this laser technique the material is applied and simultaneously fused. The study of the materials and processing variables of the laser equipment will define the most suitable process, while also taking into account both the technical and economic aspects. The foregoing is all set out in the development and description of WP2.

      This task and the definition of the most appropriate decoration process by laser deposition techniques are expected to be accomplished by **month 9 (Milestone M4)**.

   b) In WP3 a study will be conducted of the **activation techniques**, based on the change in colour of the glazes used when these glazes are exposed to laser radiation. In this case as well, a study needs to be performed and suitable formulation is required of the pigments used in order to obtain the appropriate response to laser radiation. This will enable defining the most suitable types of materials and the appropriate processing variables for decorating ceramic tiles and glass.

      This task and the definition of the most appropriate decoration process by laser activation techniques are expected to be accomplished by **month 10 (Milestone M5)**

2. Development of communication systems between the end-user and the decoration process

   With a view to achieving a customised manufacturing process it is necessary to develop an Internet tool that will allow the client to prepare his own design and send it to the manufacturer. This will require creating a design tool that is easy to use, appropriate software for transmitting the design made by the client to the equipment that commands the laser, and the relevant communication protocols between the different equipment. This is all being done in WP4.

   The appropriate application software for the Internet tool is expected to be obtained by **month 14 (Milestone M6)**

3. Development and validation of prototypes

When the appropriate decoration processes have been defined, the ceramic materials to be used in the decoration process according to the relevant laser technique have been fabricated on a pilot scale, and the Internet tool has been developed, the process will be validated. For this, the individual elements that make up the prototypes will be assembled, and customised ceramic tiles and glass will be reproduced on a pilot scale using the deposition prototype and the activation prototype, generating the designs with the Internet tool that has been developed.

This task and the obtainment of the decorated products are expected to be accomplished by **month 23 (Milestone M10)**.

1.3.- Consortium

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Limatools Glas BV (LIMA). The Netherlands

Smalticeram Unicer S.p.a (SMALTICERAM). Italy

Technologia e Comunicazione di Grupo Ghelco srl (TCG). Italy

CERLASE (CERLASE). France

3D-Micromac AG (3D-MM). Germany

CAM-Service Gesellschaft Fur Software und Automationstechnik GmbH (CAM). Germany

RTD's

Asociación de Investigación de las Industrias Cerámica (ITC). Spain

ASOCIACION INDUSTRIAL DE OPTICA (AIDO). Spain

Istituto per le Ricerche di Tecnologia Meccanica e per l'Automazione s.p.a (RTM). Italy

Laser Zentrum Hannover e.v. (LZH). Germany

Netherlands Orgnisation for Applied Scientific Research (TNO). The Netherlands

1.4.- Work performed, partners involved

1.4.1.- Research activities

WP2: Decoration process by deposition of colouring materials and laser fusion

The aim of WP2 was in a first stage to evaluate the viability of decorative laser techniques to customise glass and ceramic tiles. Two techniques were industrially researched. The laser fusion technique by means of a high power laser scanning system (HPLSS) with a 2 kW CO_2 laser and a decorative laser cladding technique with two types of high power lasers CO_2 and Nd:YAG. The milestone set for WP2 was to define the most suitable decorative process the point of view of innovative, economical and technical aspects.

The laser fusion technique by means of a HPLSS consists of melting a pigment pre-deposited over the surface of different ceramic tiles varied in composition. Several pigments deposited in several conditions with different compositions were investigated.

The decorative laser cladding technique consist of melting a colouring powder pigments feeded over the tiles and glass and melted simultaneously with the laser beam. Several pigments like blue, black, yellow and red were researched. Successful results were obtained. Thus, the decorative laser cladding technique was defined as the most suitable technique due to economical, technical and innovative aspects to develop a decorative process in an industrial manner (M4).

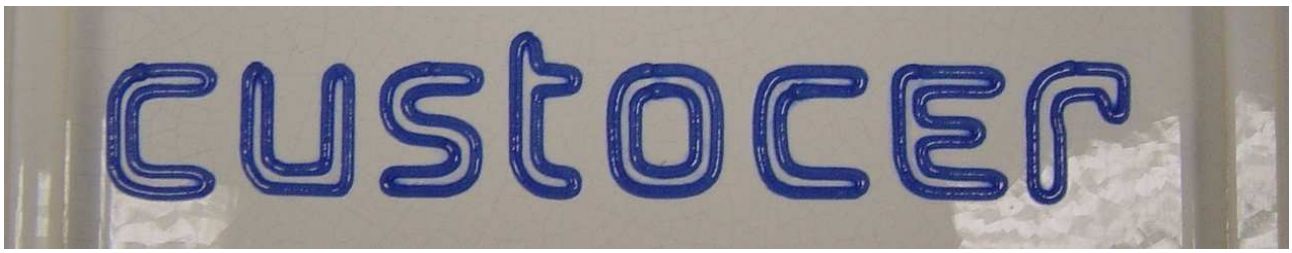
The WP2 was carried out in several tasks

Task 2.1 Decorative process using laser fusion techniques by HPLSS

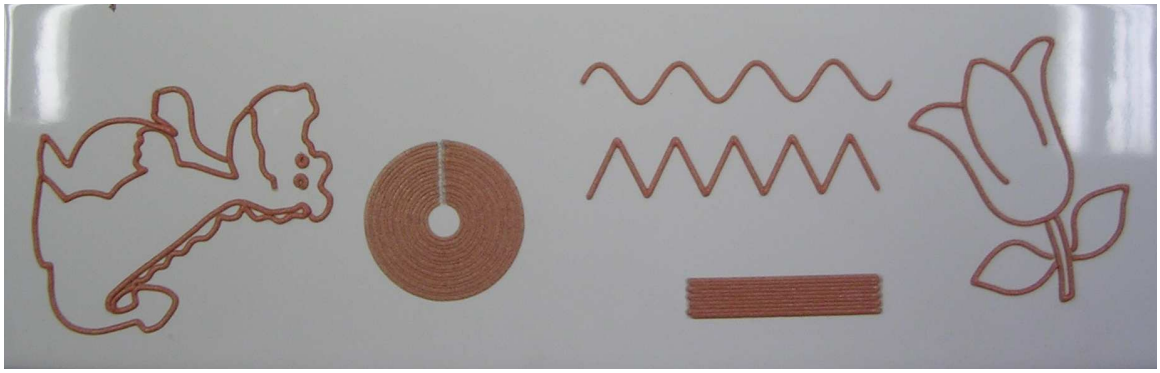
The partners ITC, TCG, SMALTICERAM, TNO, CERLASE, DECORKER, LIMA and SAVIO were involved in the development of deposition system, materials composition and standard analysis of the process. AIDO was in charged of optimizing the laser process.

Task 2.2 Decorative process using laser cladding techniques.

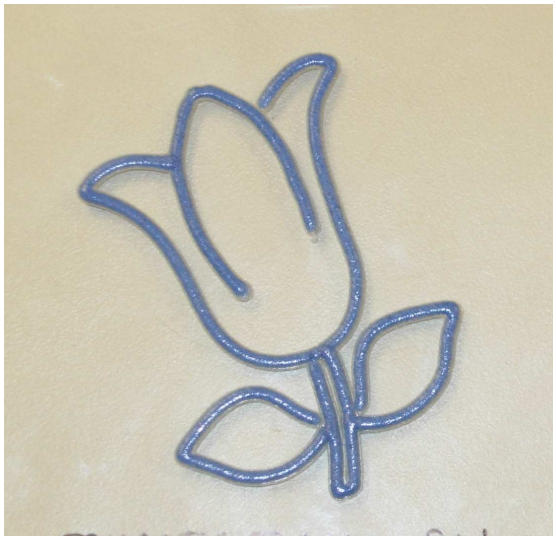
The partners AIDO, ITC, TNO, NTS, CERLASER, DECORKER. SAVIO and LIMA were involved in the development of materials, standard analysis and optimization of the process. AIDO was in charged of optimizing the laser process over glass and ceramic tiles. The result was the deposition a colouring ceramic layers with relieves. No extra heating was required except form the energy of the laser beam. The best results were obtained with a CO_2 laser. Several compositions and pigments concentrations of blue, black, yellow and red were tested under several CAD models.



Decorative process using laser cladding techniques. Blue pigment over ceramic tile.



Decorative process using laser cladding techniques.Red pigment over ceramic tile.



Decorative process using laser cladding techniques. Blue pigment over glass

Standard tests like crazing and thermal resistance were carried out by ITC with successful results.

WP3: Decoration process by colour change by laser radiation

The WP3 has got two main objectives:

1. Study of colour changing techniques on glass and ceramic tiles by laser, adding pigments to base material in appropriate ratio for colour change. The laser-mark must be good in contrast and not sensitive to touch, not an engraving but a decorative effect (colour change) that does not modify the properties of the glaze layer (smooth texture, water resistance and resistance).
2. Defining the most appropriate process, taking into account different aspects (technical, economic,…etc) for performing this type of decoration.

Both the proposed objectives have been well reached.

In order to obtain the best results the WP3 has been divided into three tasks: the goal of the first task was to study the laser-material interaction onto the commercial tiles (base material) without adding any pigments. In the second task, contrary wise, it has been necessary to study both laser-

material interaction and pigments' composition. The third task was important to establish the technical advantages and disadvantages of the decoration approach envisaged in the first two tasks and to analyze the results with complementary techniques i.e. optical microscopy, SEM analysis (electron microscopy), surface roughness measurement, and contrast evaluation devices. At the end of the WP3 it was necessary to define the most appropriate process.
Hereafter the work carried out is described briefly for each task:

Task 3.1:Laser marking tests on base materials:

Decorker, ITC, Limatools BV, TNO and Ceramiche Savio have selected the base material. All the tiles selected have been tested by RTM using different laser sources of different wavelengths.

To find the best laser parameters we have usually marked an array of square 5x5mm large, with a fill area, each square into array had got different laser parameters set: power laser, repetition rate, beam laser speed, space between two lines into fill area, repetition number of marking and focus plane position.

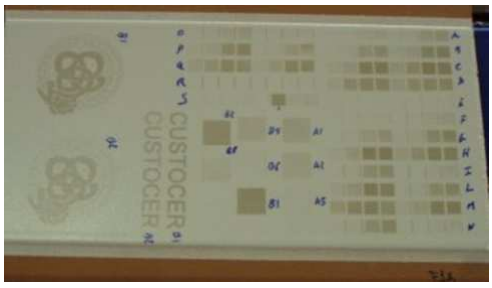
Task 3.2:Laser marking test on pigmented materials:

Different glazed tiles were prepared by ITC using different inorganic pigments. All the tiles prepared have been tested by RTM using the same diode pumped Nd:YAG lasers sources used in the task 3.1 and same testing plane.

Task 3.3:Marking quality characteristics: analysis and evaluation of the results.

Both base material and pigmented tiles, tested by laser, have been analyzed for evaluating the results: Surface roughness, Topographic maps, X-ray diffraction by ITC and Analytical tests using electron microscopy (SEM) by 3D-MM. Examination of the topographical maps indicates that laser marking of tiles does not give rise to any damage in the tile surface when laser parameters (power, speed, pulse frequency, etc.) are optimised. Designs with decorative applications can be made without modifying the original properties of the glaze layer (smooth texture, impermeability, and resistance). Based on these tests it has been possible to conclude that no change of glaze surface quality and structure is produced when the laser radiation strikes the glaze layer.

A good combination of pigments inside the glaze and he use of the green laser source has been defined as the most appropriate process.



WP4: Interfaces definition and internet software application development

The main objective of this workpackage was to develop a software tool to be used by the customer in order to design and send the product design to the manufacturing company, together with the implementation of all the software needed to generate and send the NC program of the designed product via the Internet to the manufacturing tools. The developed system offers and supports the following functionalities and activities:

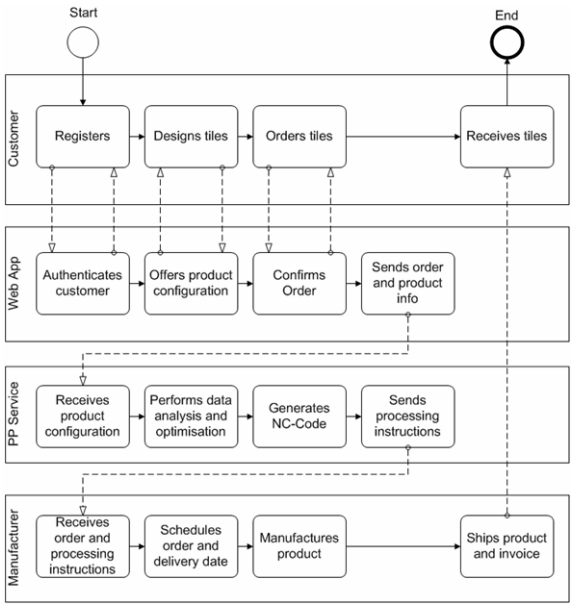
• Create an easy, user-friendly design tool that allows the customer to decorate a ceramic product. It limits the types of products to be designed. Moreover, it has implemented certain functions to limit the actions that the client can perform in order to avoid generating product designs that cannot be manufactured due the limitations of the manufacturing processes.

• Present to the customer pre-defined designs from a database.

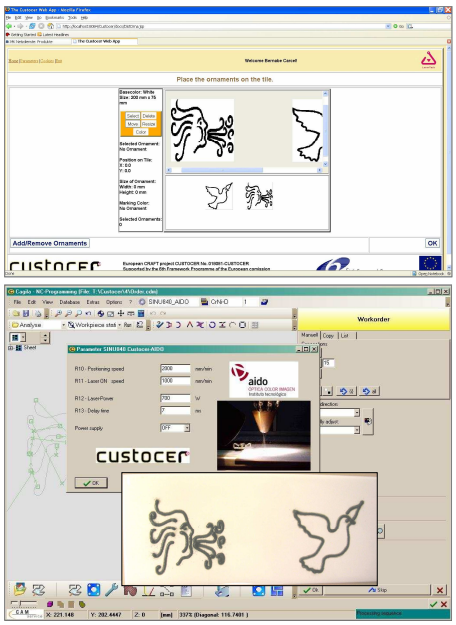
• Two special purpose NC-code generators that translate the customer's design into machining instructions useful for the both laser machines.

• A standard form to be completed by the customer and structured order information with all the production parameters such as lot size, product features and design information required by the manufacturer for production planning.

• The transfer the NC data program generated and all the other information via messaging services to the manufacturing site.



Business process and roles



Web application and CAM system

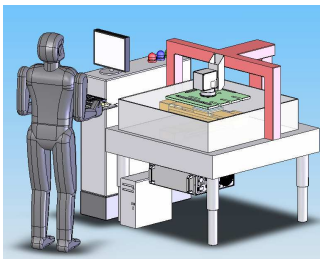
Along with the definition of the use cases and the modelling of the process chain, a novel software architecture has been investigated. The prototype system is based on the principles of service-orientation, loose-coupling and reuse of functionality and uses Web 2.0 technology. The NC-code generation and CAD-data transformations have been implemented as XML-based web services. The interoperability between Microsoft .Net WSE 3.0 services and Sun JEE JAX-WS 2.0 could be demonstrated. The customer front end is AJAX-based and is implemented with Google's web toolkit.

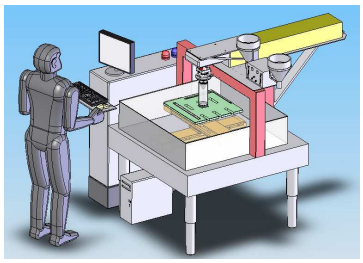
WP5: Development and adaptation of the laser for a pilot scale

The main objective of this WP was the creation of two prototypes for glass, tiles and stoves decoration by means of laser, one for laser deposition techniques and the other for laser activation techniques.

For the deposition technique the prototype was integrated and assembled in AIDO facilities. For the deposition technique the prototype was integrated and assembled in RTM facilities.

Moreover, Cerlase, based on the information of the project, designed two commercial prototypes one for each technique.





Each part of the prototypes has been quoted and a cost for the manufacturing of the prototypes has been determined. An excel file have been supplied with the production cost of a tile.

Preliminary fine-tuning was done mainly by AIDO and RTM in its facilities at the same time they were testing the materials developed in WP6.

The workpackage 5 have permitted to obtain two deliverables : D19 (deposition decoration prototype) and D20 (activation decoration prototype) and milestones 7 and 8 that they were the prototypes to use in process validation (WP7). The prototypes are able to mark following the specification from RTM and AIDO.

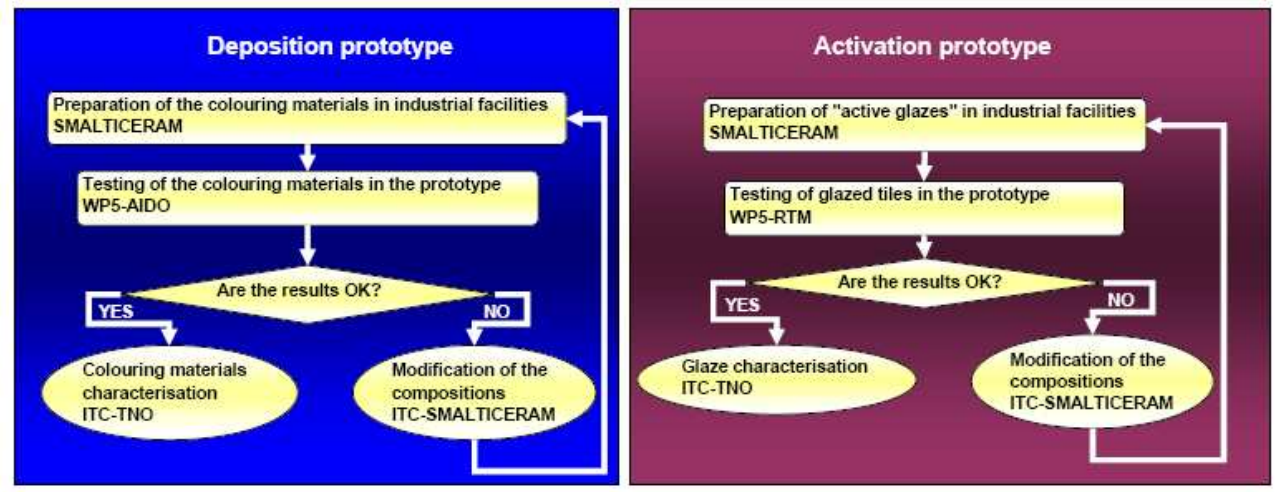
WP6: Development and adaptation of the materials for a pilot scale

The participants of this workpackage were Smalticeram, TCG, NTS, TNO and ITC. As TCG and NTS left the project Smalticeram took charge of the work that these two partners had to perform.

The main objective of this WP was to obtain the materials with the appropriate characteristics for using in the deposition and activation prototypes. The three specific objectives were:

- Adaptation of the characteristics of the materials developed on a laboratory scale for use on a pilot scale
- Determination of the characteristics of the materials
- Development of new compositions

Following scheme shows the main work carried out by each of the partners involved in this WP.



At the end of this workpackage it was possible to obtain the material characteristics for pilot use (Deliverable D21) and the materials that were used in WP7 for the demonstration stage (Milestone M9).

Some problems arise with both techniques, the main ones were:

In the deposition prototype the main problem was that some colours were difficult to obtain, mainly the colours, like red, that are not stable at high temperatures (produced by the laser fusion).

In the activation prototype the main problem was that the laser produces a change in the colour of the glaze, depending on the laser parameters different tonalities can be obtain but always in the same colour. Blue glazes are very difficult to decorate but with the development of new compositions it was possible to decorate this type of glazes.

From the glaze characterisation performed with the glazes used in the activation prototype it was possible to establish the mechanism by which the colour change is produced. These results have allowed having a more thorough knowledge of the interaction of the laser with the glassy materials. The results could be published in technical magazines.

WP7 Process demonstrator

In this workpackage the optimisation of both prototypes were carried out. The demonstration of both prototypes to the SME's was done during the last meeting held in AIDO facilities. Decorated samples were obtained by using both prototypes. SME's where very interested in the results.

1.4.2.- Use and dissemination and management activities

WP1 Project management

The main activities of this workpackage are focussed in the following issues:

- To provide sound project management and coordination.
- To provide monitoring of the RTD progress, planning of future activities, control and distribution of budget, legal support, reporting to the Commission and overall administrative management.

DECORKER developed the Project Coordinator role for the CUSTOCER project. With the help and advice of qualified ITC technical staff, DECORKER assumed the responsibility for the technical, financial and administrative management on a day-to-day basis. The ITC has been the responsible for the Communication with the Commission. The CUSTOCER Project Manager at the COORDINATOR is the chairman of the Steering Committee and the official contact point for the European Commission.

WP8: Exploitation and Dissemination,

Task 8.1 Intellectual property rights protection

During the project, the companies defined where and when the new technologies developed will be exploited, without adversely affecting the interests and competitive advantages of each of the partners.

Two SMEs, CERLASE and 3D-MM, expressed their interest in patenting some results of the project. Currently, they are working on an agreement in order to establish the conditions for the exploitation of the results.

Task 8.2 Dissemination activities beyond the consortium

The dissemination activities represent a very important part of the CUSTOCER project. In this activity, the RTD performers play an important role. Specific tools and strategies are foreseen, to be implemented starting in the first year of the project when interesting results become available for all fields of society: industrial, scientific, and educational.

Among the most important such activities envisaged in the project, the following key dissemination actions may be noted:

- Project Web site
- Technical workshops
- Press conferences at trade fairs
- Newsletters and scientific papers.

During the first stages of the project, dissemination of information about the project remained limited to the distribution of publishable abstracts, such as those contractually required by European Union collective research project. Nevertheless, some press articles were published in the local press, in order to inform to the general public about the stating of this project. More

widespread publication was considered once the project becomes mature enough for the results to be sufficiently comprehensive. Discretion was required during the first part of the project in order not to endanger the industrial interests of partners who face competitive pressure from external interested companies.

2.- Dissemination and use

The results of the project have been very interesting for some SME's, because of that they have decided to patent some of the results. This implies that no technical dissemination can be done until the patent submission has been done.

A Web site dedicated to the CUSTOCER project has been created (www.itc.uji.es/custocer.html), More than ten general articles about the project have been published in different Journals. A project leaflet and a flyer have been prepared; they have been used as project publicity in different trade fairs and congresses related with ceramics, glass and laser (more than 15 events). A general conference titled "Evolución de la aplicación del laser en la decoración de vidrio y baldosas cerámicas" was held on the 18 of October of 2007 in the "IV Taller Nacional de Procesado de Materiales con Láser" in Valencia (Spain). Three technical articles can be publish with the results after the patent submission.