1. Study of Properties of Materials used in Jewelry Casting Process

The understanding of the interactions between the different materials involved in the investment casting process is a key point for the optimization of the cycle, in order to get reliability in the product’s final quality. Though several different defects may occur, the main issues are related to the presence of pores, in terms of gas porosity caused by reaction with investment material or atmospheric conditions, as well as shrinkage porosity caused by inadequate combinations of feeding system geometries and casting process parameters are the predominant factors.

Limitations for process innovation of current gold jewelry casting quality are mainly given by the following factors:

- Limited knowledge about thermal stability and properties of investment mould material and how these properties depend on composition, mould preparation details and burnout schedules.
- Limited knowledge about thermal properties of gold casting alloys and how these properties influence susceptibility to gas and shrinkage porosity.
- Limited knowledge about complex interrelationships between the above mentioned material properties, casting process and equipment parameters, sprue and gating geometries and the desired outcome: optimized metal flow, minimized erosion of and reaction with investment mould material, dense and porosity-free castings with top quality surfaces.

As a consequence, the state-of-the-art procedure in identifying the source of casting defects in production at gold jewelry casting companies still is solely based on time-consuming and inefficient trial-and-error experimentation. These rarely lead to optimum results and casters usually have to compromise on quality, production efficiency and related costs.

Aim of this module is to provide an overview of the most important characteristics of the materials involved in the process (waxes, refractory/investments/metal alloys), both in terms of chemical and physical properties and to examine the mutual interlinking effects taking place during the entire process.

The theoretical part on the material properties will be coupled to practical examples of DOs and DON'Ts, which will also illustrate the typical defects arising from incorrect processing and eventual counteractions to be taken.

Duration of the course: one week
2. Computer Simulation of Jewelry Casting Process

Investment casting of precious metals is one of the manufacturing processes where the final product quality (and so the reduction of defects) is most critical, especially when taking into account the high costs related to raw materials and production. Process simulation, through the use of computational fluid dynamics (CFD), has been largely used in several industrial sectors, as an instrument for the better understanding of melting and casting processes and therefore for the reduction of production times and costs arising from casting defects. Additionally, the evaluation of the precious metal investment casting can benefit from the casting simulation, which is able to predict some of the defects, which will arise in the cast patterns. Several studies in literature demonstrated the applicability of computer simulation both on silver and gold alloys, with different karatages. Different software packages provide specific and valid support for the production, allowing to evaluate the influence of several different process parameters without the need of post production analyses, by means of the simulation of the mould filling and the following solidification.

The fundamental basis of CFD problem is the Navier-Stokes equations, which define any single-phase fluid flow. The most fundamental consideration in CFD is how one treats a continuous fluid in a discretized fashion on a computer. One method is to discretize the spatial domain into small cells to form a volume mesh or grid, and then apply a suitable algorithm to solve the equations of motion. Such a mesh can be either irregular or regular. In addition to the geometrical issues related to the pattern and to the trees, the use of the simulation software implies a deep knowledge of the entire set of materials used in the process and also of their dynamics. In fact it is needed to provide a precise geometrical description of the model (system) and make physical and chemical characterizations of materials.

Aim of this module is to introduce and describe the benefits provided by the use of computer simulation to the jewelry casting, starting from the object and tree design and leading to the final experimental validation. The course will provide some basic knowledge of fluid-dynamics and illustrate how the current research for the optimization of processing conditions can easily be fastened and made cheaper. Practical examples of the role of object sprueing and of other processing parameters (metal casting temperature, flask temperature, etc.) on the products’ final quality (simulated and practical) will be given.

Duration of the course: one week
3. Use of Rapid Prototyping Technology in Jewelry Prototyping and Casting Process

Jewelry CAD software is evermore used in the Design & Prototyping phase. In many manufacturing companies CAD data are transferred to Rapid Prototyping equipment which allows for fabrication of pattern by wax printing, UV resin curing (or comparable processes) directly from the CAD data. This CAD/CAM and Rapid Prototyping technology in principle allows for time-efficient realization of highly innovative, personalized and unique design. The CAD-driven printing or curing step allows building up of pattern geometries that are much more detailed and filigree than those that can be obtained by the traditional wax pattern fabrication technique. The transfer of this technology to production is, however, hindered by two main factors:

- The dewaxing/burnout step does not work for moulds where Rapid Prototyping waxes or resins are used; leading to ash-residues in the mould after burnout. The so-called ‘direct casting’ with Rapid Prototyping waxes/resins then suffers from severe porosity in castings, caused by reaction with the investment that is catalyzed by the ash residues in the mould. Another severe problem exists with cracking of mould material during heating due to incompatibility of thermal expansion of these types of waxes/resins and the investment.
- The design created by the technology is extremely difficult-to-cast with complete formfilling due to the detailed, filigree nature of the design. There is a lack of scientific knowledge about the complex interrelationships between casting process and equipment parameters, alloy and investment material properties, sprue and gating geometries and the desired outcome: laminar metal flow, minimum turbulences during pouring and complete pattern filling.

As a result, the innovative potential of the Rapid Prototyping technology is not exploited in the gold jewelry industry. Only RP patterns with reduced complexity are produced, which then have to enter the traditional process with its well-known limitations in terms of working efficiency and design limitation at its regular starting point: fabrication of rubber moulds and regular waxes.

Aim of this module is to describe the properties of the main resins commercially available on the market, illustrating the different PROs and CONs related to the different products/concepts. Resins differ one to the other in their chemical compositions, ranging from products with a high wax content to those totally resin based; the knowledge of their chemical and physical characteristics is therefore tremendously important for the understanding of their behavior in the entire process. A detailed focusing will be taken on the most critical steps both during the resin pattern building up (slicing, accuracy, UV curing, etc.) and on the entire production cycle (particularly in terms of the oxygen given during the flask burn out). An extended part of the course will be devoted to the analysis of case studies, with a set of practical tips and tricks for the direct casting of RP resins.

Duration of the course: one week
4. Innovative Materials and Production Techniques in Jewelry Production

New materials and innovative manufacturing processes, along with new design techniques, allow obtaining of precious articles that until recently were unlikely to be achievable.

Aim of this module is to give an overview on peculiar properties of materials (metals, polymers, ceramics and composite materials). The use of these materials is highly widening product’s horizons as well as the evaluation of innovative process for models and objects realization.

The introduction into the current production technique of high performing waxes, hydro-soluble resins, highly-conductive rubber moulds, as well as new machines derived from other industrial sectors, may strongly impact the final quality of the traditional investment cast patterns. Characterization and application of the aforementioned materials will be provided, as well as a basic training on their use in the traditional processing.

New production methods such as the use of precious metals powders applied to the jewelry production will extensively be introduced, described and characterized. The different Powder Metallurgy techniques will be compared in terms of processing features and characteristics, both of the starting materials and of the final products.

Duration of the course: one week