# Education and training in preparation of rare-earth doped optical glasses

**J.Y. Ding, S. W. Yung, P. Y. Shih and H. J. Lin**
*Glass and Optical Fibers Research Center, Department of Materials Science and Engineering, National United University, Miao-li, Taiwan 360, Republic of China*

**Abstract:** For the first time in Taiwan, we have established an undergraduate training program for optical glass melting and applications. Incorporated with e-learning, we try to make the learning process and hands-on practice in preparation of optical materials more happy and efficient. Some ideas for course design, revised facilities and teaching tools have been proposed.

OCIS codes: (160.2750) Glass and other amorphous materials; (140.3510) Lasers, fiber

## 1. Introduction

Rare-earth doped optical glasses have been widely used in opto-electronic devices and optical communication systems. Although glasses can be prepared by a wide variety of methods, the majority are still made by melting of batch components at high temperatures. The melting process mainly involves the selection and calculation of raw materials in a batch-basis, mixing of these materials, dehydration and thermal decomposition of the metallic salts, melting the batch materials to obtain homogeneous liquid, and finally quenching the liquid to obtain glasses. Conversion of the high temperature melt into a homogeneous liquid requires to remove unmelted remnants, impurities, and bubbles. The melting process determines the quality of the glasses and should be treated as a key issue in the production of rare-earth doped optical glasses. In particular, when undergraduate students take the course of glass technology and its laboratory practice, it is recommended to show the students how and what has happened in a glass melting furnace. For these reasons, a continuous glass melting furnace with a sloping flow-channel in a laboratory scale has been designed for students to learn how to prepare high quality optical glasses. The objective of the course is to help students learning i) how to select raw materials, ii) how to design a glass melting furnace, iii) how to operate and control the glass melting process, iv) how to remove bubbles from the glass melts, and v) how to eliminate the thermal stress in a quenched glass sheet.

At NUU, we have also established fiber-drawing facilities, glass extrusion molding machine, glass rod pulling-up system, and glass lathe lamp work equipments. However, we will focus on the introduction of the sloping channel glass melting furnace as a useful teaching tool in glass workshop.

## 2. Course design

The course for rare-earth doped optical glasses is categorized into three parts:

i) the physical phenomenon of rare-earth ions interacted with amorphous oxides, including silicates, borates and phosphorous glasses;
ii) design and operation of a continuous glass melting furnace with a sloping channel, including how to remove impurities and bubbles; and
iii) characterization techniques of the rare-earth doped glass samples.

## 3. Design of the continuous glass melting furnace with a sloping channel

The furnace is a continuous type furnace with SiMo heating elements and maximum operation temperature is around 1550$^o$C. As shown in Fig. 1, the left part of the furnace is similar to a conventional tank furnace used in the glass melting factories. However, the right part is designed on purpose in a sloping manner for bubble removal. And it works well. The principle that an inclined surface can help removing bubbles form glass melts is based upon the Stoke's law:

$$V_b = [\, d_B{}^2 g(\, \rho_l - \rho_g)] \,/\, 18\mu \qquad (1)$$

where $V_b$ is the floating speed of a spherical bubble, $d_B$ is the diameter of the bubble, g is gravity, $\rho_l$ and $\rho_g$ ar the densities of liquid and vapor, respectively. M is the viscosity of the fluid. Thus, the time for a bubble to float through a liquid layer of depth H may be calculated by

$$t_B = H \,/\, V_b \qquad (2)$$

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Because of $\rho_g \rightarrow\rightarrow \rho_l$ , therefore the time required to remove those bubbles of diameters greater than $d_B$ will be

$$t \rightarrow t_B = 18\mu H / {d_B}^2 g\, \rho_l \tag{3}$$

When glass melts flow over an sloping surface with an inclined angle of θ, eq. (3) may be modified into

$$t_B = 18\mu H / {d_B}^2 g\, \rho_l \cos\theta \tag{4}$$

and

$$d_B^{\,2} = 18\mu q_v / g\, \rho_l \cos\theta L W \tag{5}$$

where $q_v$ is the volume flow rate of the glass melts ($m^3/s$), W and L are the width and length of the sloping channel, respectively. Based upon eq. (5), bubbles with diameters larger than $d_B$ will be removed by the sloping channel design.

Schematic illustrations of the continuous glass melting furnace with sloping channel are shown in Figs. 1-4. A simulated furnace has also been constructed for students to practice before they really start to operate the actual furnace, and simulation of the melting process is part of the e-learning program of the course.

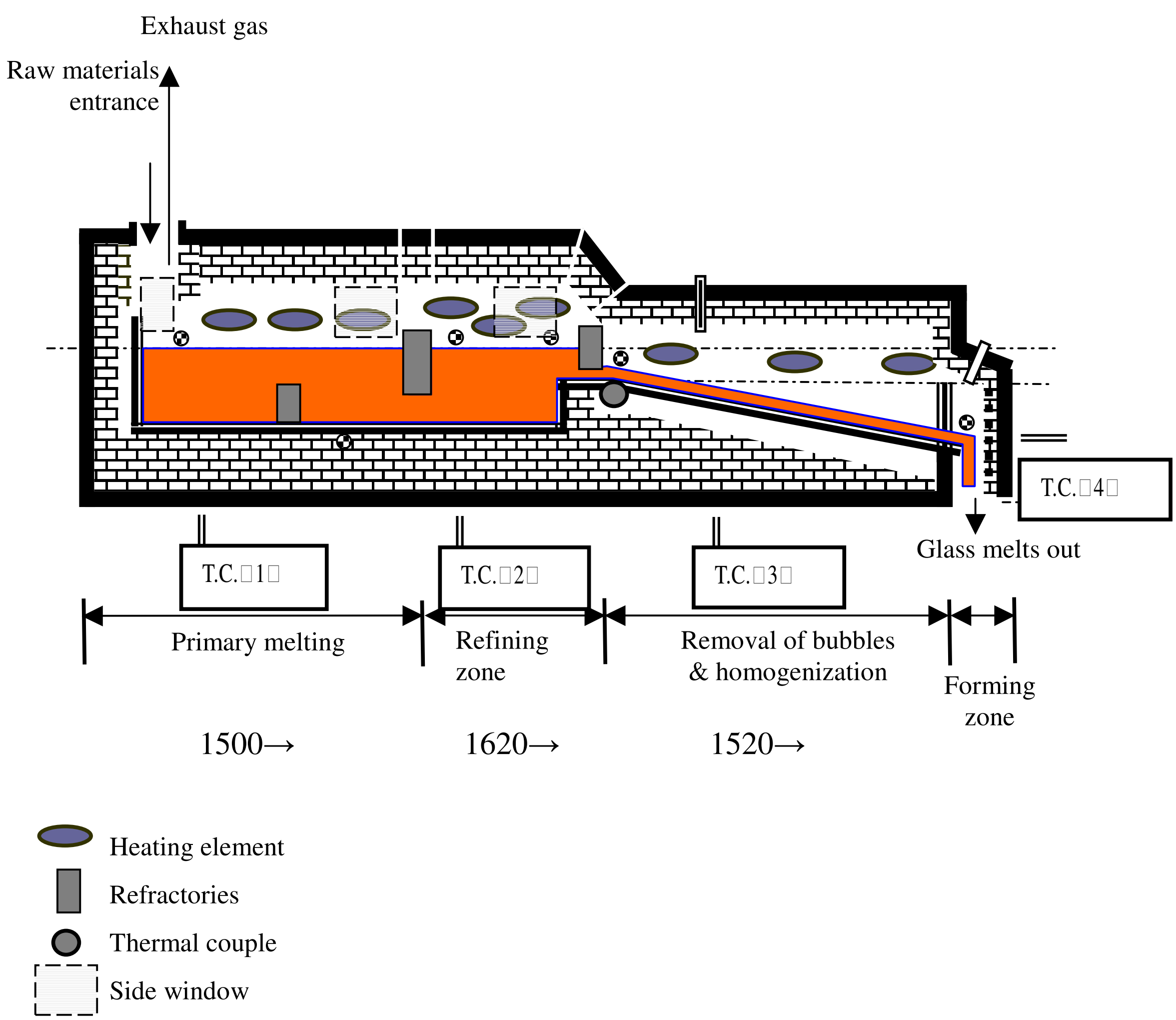


Fig. 1 Schematic illustration of a continuous glass melting furnace with sloping channel structure

## 4. Summary

A course and glass melting facility has been developed and rare-earth doped glasses have been successfully prepared. Simulation of the furnace has been incorporated into the course as part of the e-learning program.