In-situ high temperature confocal laser scanning microscopy: introduction and applications in metallurgy

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High temperature confocal laser scanning microscopy (HT-CLSM) provides the opportunity to perform in-situ direct observations of e.g. crystallization, solidification, phase transformation at high temperatures for materials, such as metals and ceramics. The investigated sample is positioned in a crucible, placed on a specimen stage with thermocouples attached for temperature control. The furnace is heated by a halogen infrared lamp, and the sample is placed at the focal point of the infrared beam which is reflected by the gold coated ellipsoidal furnace chamber. The imaging of the sample surface is conducted with the use of a He-Ne scanning laser beam and a confocal pinhole aperture enabling excellent contrast and resolution along the laser beam direction (Z direction). The laser power is about 1.5 mW in general and operates in the red, blue and violet wavelength range. When performing Z scans 3D reconstructions of the surface can be constructed, but for fast imaging of e.g. phase transformations Z scanning is not adjusted much, instead the surface relief between parent and product phase is observed at the almost fixed Z distance in real time. An image of a modern HT-CLSM microscope and its working principle is presented in Fig. 1 [1].

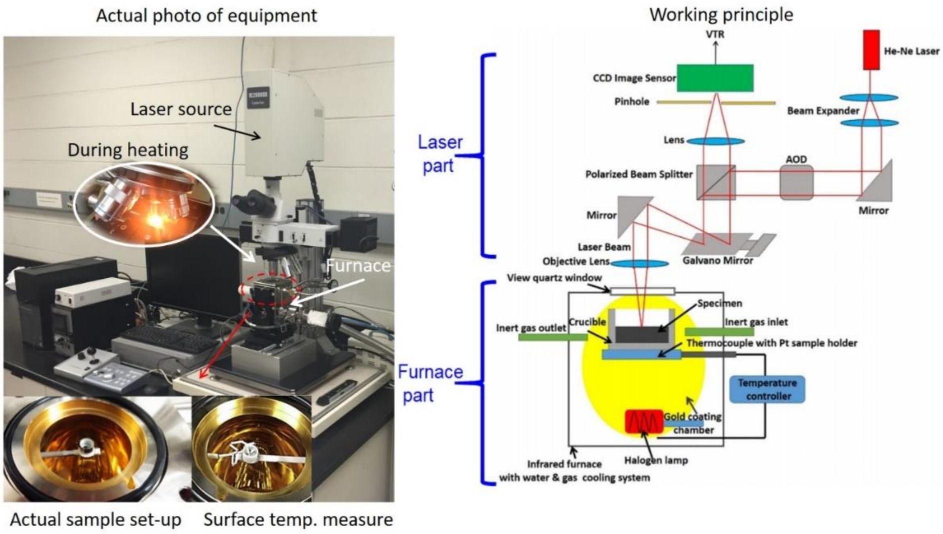

Figure 1. Photo of modern HT-CLSM equipment and illustration of its working principle.

The modern HT-CLSM instruments can reach maximum temperature of 1700 ºC using heating rates up to about 1200 ºC/min. Rapid cooling at a certain temperature range with a maximum rate of 3000 ºC/min is enabled by He gas flushing. These thermal testing capabilities means the HT-CLSM is suitable for analysis of various high temperature processes, for example, in metallurgy. The first application of HT-CLSM was for the study of planar to cellular and cellular to dendritic transformations in solidification of Fe-C alloys [2]. Thereafter, it has been applied to observe the collision and agglomeration behavior of non-metallic inclusions at the liquid metal surfaces, crystallization of mold flux during non-metallic inclusion solidification in continuous casting of steels, inclusion/refractory dissolution in steelmaking slags, initial solidification in undercooled steel melts, etc. An example of an inclusion chain cluster bending process in liquid steel is shown in Figure 2 [3]. Besides the research on liquid steel, HT-CLSM has been widely used in solid-state phase transitions, e.g. to observe the formation of acicular ferrite transformation in inclusion-engineered steels, bainite transformation in low alloy steels, etc. Furthermore, other metallic materials have also been investigated by this technique, for example, incipient melting behavior at the intermetallic cluster/matrix interface in cast Al-alloys (319 type, 206 type, etc.) has been studied, see Fig.3 [4]. This presentation aims to provide an introduction to HT-CLSM and to illustrate application examples in metallurgy. The aim is furthermore to stimulate novel experimental ideas outside of the metallurgy field. Such applications are still rare and could provide new insights in high temperature processes for materials in both liquid and solid state.

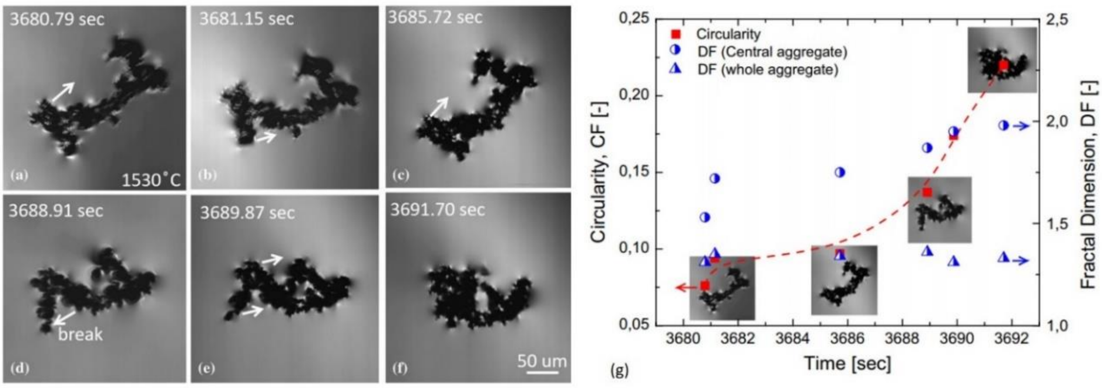

Figure 2. An application of HT-CLSM in steel, to observe the non-metallic inclusion cluster bending [3].

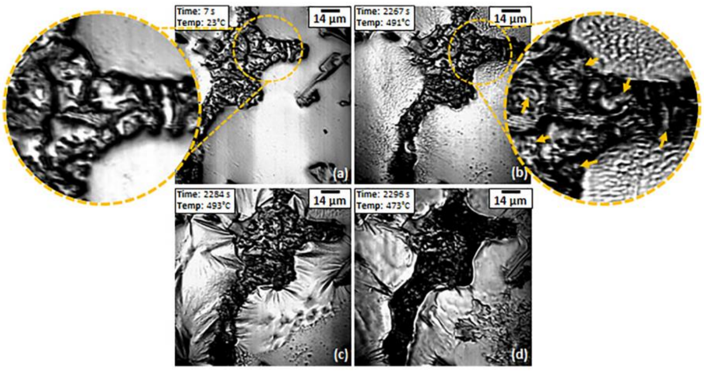

Figure 3. An application of HT-CLSM in a 319 Al-alloy. Liquid film formation from a eutectic cluster/matrix interface is observed [4].

References
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