Wetting behavior of sintered nanocrystalline TiO_2 by Armco Fe and 22CrNiMoV5-3 steel grade using sessile drop wettability technique

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The study of the wetting behavior at elevated temperatures constitutes one of the most important scientific aspects of high temperature liquid phase materials processing stimulated by the needs of modern metallurgy and foundry industry. [1]

The wettability of sintered TiO_2 nanocrystalline powder by liquid Armco Fe and by 22CrNiMoV5-3 steel grade was studied using sessile drop wettability technique. The liquid deposited on the solid surface under gravity, has tendency to spread until the cohesion (internal forces) of the liquid, the gravity forces and the capillary (surface tension) forces are in balance, and an equilibrium state is reached. [2] The relationship between the contact angle and the respective interfacial tensions acting at the triple point is given in the Young equation [3] which is as follows: $(\gamma_{SG} - \gamma_{LS}) = \gamma_{LG} \cdot \cos\theta$ where θ is the contact angle and $\gamma_{LG}, \gamma_{LS}, \gamma_{SG}$ are the liquid/gas, liquid/solid and solid/gas interfacial tensions respectively.

The nanometric powder was pressed and sintered under different pressures, heating rates and holding times. The later grinding and polishing surface treatments were characterized by infinite focus microscope. The wetting experiments were carried out under pure argon atmosphere in the wettability furnace (Figure 1). A small piece of Armco Fe and steel grade was melted on sintered nano oxides, heating up to 1600ºC with a holding time of 10 minutes for each experiment.

The contact angles were measured (see drop morphological evolution in Figure 2) and chemical analyses were conducted on tested samples to characterize the wetting reactions. The chemical compositions were studied for Electron Probe X-ray microanalysis (EPMA) supported by wavelength dispersive spectroscopy (WDS) It was found that sintered nano TiO_2 not only suffered considerable wetting by Armco Fe (Figure 3) and 22CrNiMoV5-3 steel in both cases, but also reacted with the substrate to form ilmenite and pseudobrookite.

From this experiment it is concluded that sintered nano TiO_2 shows high and reactive wetting for both low alloyed iron matrix and steel grade matrix. In both cases, a reaction layer formed by Fe-Ti-O solid solutions with various stoichiometries was observed.

The preliminary results of this investigation may help to determine the suitability of the nanoparticle to be added in a liquid iron based matrix in order to influence the microstructure evolution improving mechanical properties by a fine distribution in the metallic alloy.

References

[1] N. Sobczak, M. Singh, and R. Asthana: *Curr Opin Solid State Mater Sci*, 9 (2005), 241.

[2] K.J. Kubiak, M.C.T. Wilson, T.G. Mathia and Ph. Carval: *Wear* Article in Press.

[3] T. Young: *Phil.Trans. R. Soc.Lond.*, 95 (1805), 65.

Figures

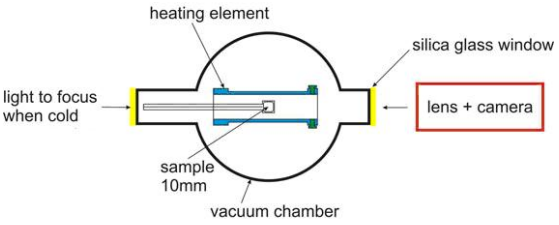


Figure 1. Schematic diagram of the experimental set up

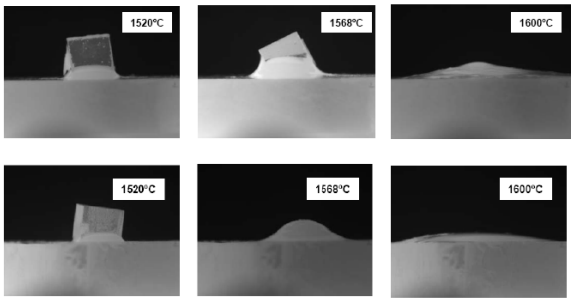
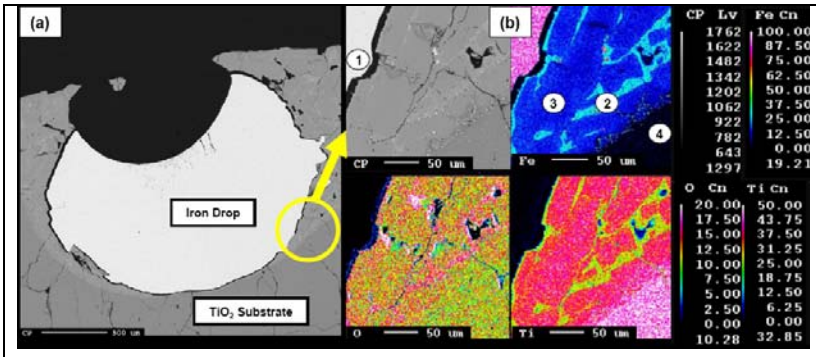


Figure 2. Morphologycal evolution of the Armco Iron (top images) and 22-CrNiMoV-5-3 (bottom images) on the TiO_2 substrate.



	Atomic ratio			
Element	Point 1	Point 2	Point 3	Point 4
Fe	914.281	188.094	88.211	
Ti		200.468	279.426	328.375
O		576.443	602.453	638.269

Figure 3. (a) The cross section backscattered micrograph of the solidified Armco Iron drop on sintered nano TiO_2 substrate and (b) the element distribution of the reaction layer obtained by EPMA. Left table: Atomic ratio of elements in the drop phase (point 1), reaction layer (points 2 and 3) and TiO_2 substrate (point 4) in the vicinity of the reaction layer for Armco Fe-sintered nano TiO_2 wettability experiment.

Figure caption

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