Multi-Phase Materials

Determination of the Mechanical Properties

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A single phase can greatly influence the mechanical behavior of a bulk multi-phase material. The integral mechanical property of the material originates from the mechanical properties of all component phases and their distribution and interactions. Therefore, to test the mechanical property of each single phase is of significant importance for understanding and controlling mechanical behavior of the bulk multi-phase material. Due to the small size of it, a single phase could not be easily tested, until recent years. This is because classical metallography determines topography of the phases, while mechanical properties remain undetermined.

It is also extremely difficult to make a bulk sample of a single phase. In this study, mechanical properties of multi-phase materials have been tested *in-situ* using Hysitron's nanoindentation technique on the TriboScope®. The high post indent imaging resolution enables visualization of phases in the range of 50nm. Figures 1-5 show the results on hardness measurements of annealed steel.

It is evident that the mechanical behaviors of cementite and ferrite are different. Cementite has a hardness of 13.4 ± 2.4 GPa and ferrite a hardness of 2.4 ± 0.3 GPa.

Discontinuous deformation loading curves have been observed in Figure 2. Here, discontinuity of surface oxide film leads to high strain rates that cause typical plasticity steps.

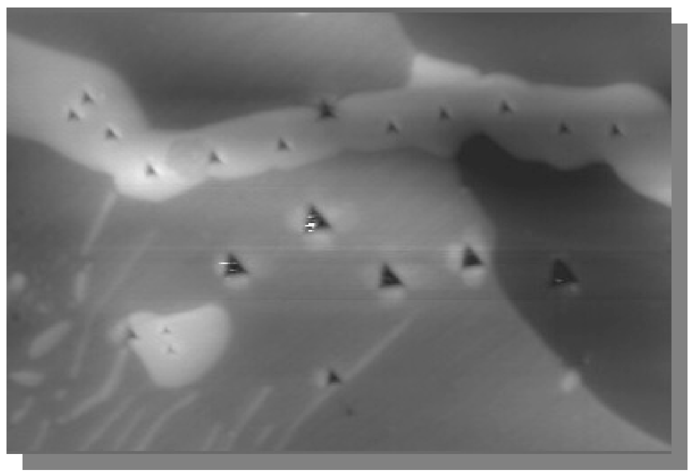

Fig.1: Indentation cups in ferrite (α-Fe) (dark) and cementite (light)

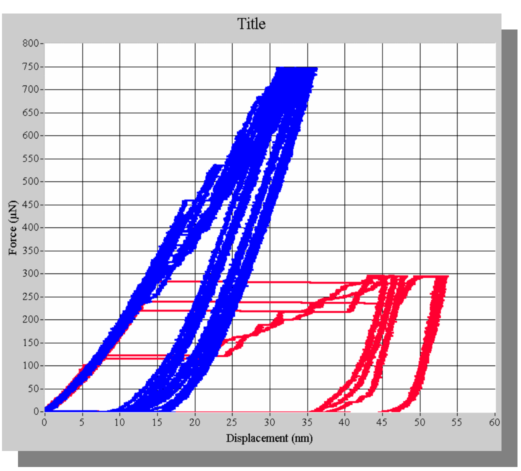

*Fig.2: Force-displacement curves of the indentation tests in ferrite (red) and **c**ementite (blue)*

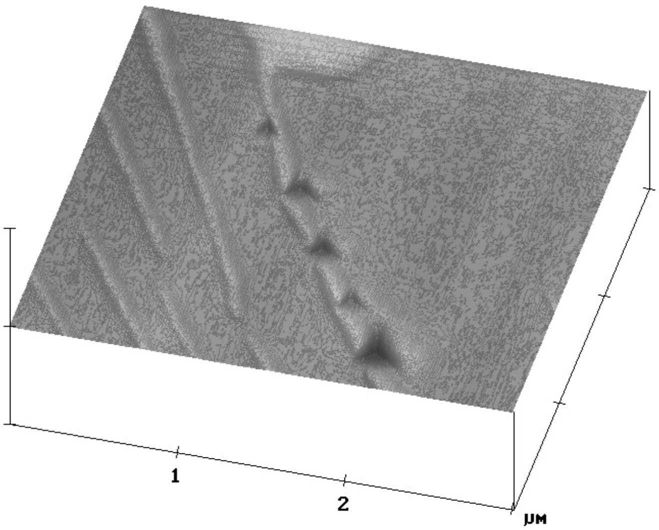

Fig.3: Indents on a cementite lamella imaged with the TriboScope®

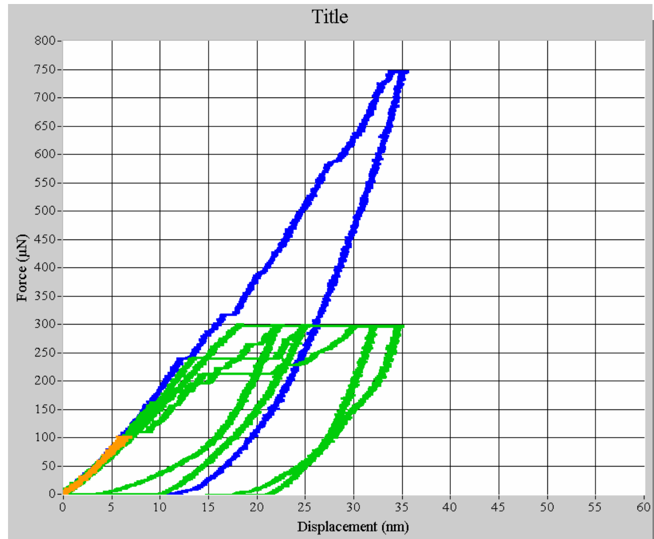

Fig.4: Force-displacement curves of a 200nm cementite lamella (green); elastic deformation observed for low load indents (orange); force-displacement curves of a thick lamella (blue)

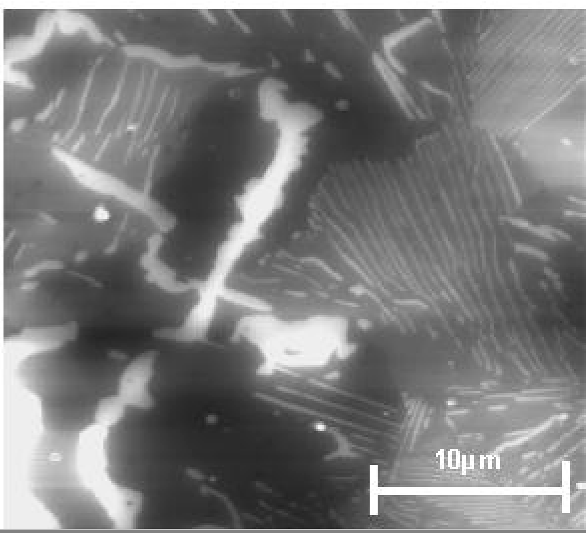

Fig.5: Scanning Force Microscopy (SFM) micrograph of annealed steel. Ferrite or α-Fe (C = 1.18%) (dark), cementite (light)

Hardness measurements have been performed even on very thin lamella. A Berkovich indenter was used in this study. Elastic behavior was found at low loads (Fig.4; orange). Plastic deformation was observed at high loads, where indents were in the size of the lamella. Due to the dull Berkovich probe tip used, cementite and ferrite phases were indented at the same time.

That is why the hardness of the thin lamella (green) is lower than the hardness of the thicker lamella (blue). To indent thin lamella only, smaller indents have to be performed with less indentation force and a sharper probe tip. The 90°-cube corner tip, that is available for the TriboScope would be a considerable choice.

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