DFG-Project Schm 746/71-2

Determination of Residual/Internal Stresses, Stemming from Coherent Nano-scale Precipitations/Chemical Depositions

Begin of the Project: 01.12.2007
End of the Project: 31.01.2010

Aim

Nano-scale coherent precipitation process plays a major role in material strengthening of steel that could also be security-relevant. Coherent precipitation occurs due to micro-level residual stresses that are a cause for the existence of these internal stresses. This research project has as its goal the development of a micro-magnetic procedure with the help of Barkhausen noise measurements. The procedure is to enable the quantitive, disturbance-free, cost-effective and faster determination of the internal stresses of Type II and III caused due to nano-scale precipitation (for example, Cu in Fe). The combination of micro-magnetic test procedures and calculations based on atomistic simulations provides the possibility to determine such micro-level internal-stresses. On the basis of the developed procedure, it becomes possible to establish a relationship between such a micro-level internal-stress state, the precipitation status and the macroscopically measurable mechanical properties of the material related to the state.

Material

As a standard material, iron is considered that is used to form an alloy together with copper or/and nickel and through thermal precipitation, is allowed to grow in the desired average quantities and intervals.

Methodology

On change of the direction of magnetisation within a ferromagnetic material, the domain walls of the Weiss mean field, i.e., the Bloch walls, would be fixed-up by the precipitation and their movement would be blocked. The change in magnetisation directions results in the creation of an oscillating field of disturbed signals called the Barkhausen effect that can be taken as a measure of the status of the precipitation process.

From chemically pure elements, iron based alloys with Cu, Ni or Cu and Ni can be achieved. Ni is important as it plays a role in the precipitation process which cannot be neglected. By thermal processing the melts samples with different precipitation levels can be manufactured. These samples will then be analysed in the end with the help of techniques like electron-microscopy, small-angled-bending of neutrons and atom probe field ion microscopy/topographic atom probe methods. This is to be done so that the volume part and the average size of the precipitates can be known. Since these measurements and evaluations are not accurate, they are supported through additional atomistic simulations of the precipitation process using the Monte Carlo method. The results of these simulations would help confirm the results got for the precipitation process variables through statistical methods and through the other measurement techniques used.

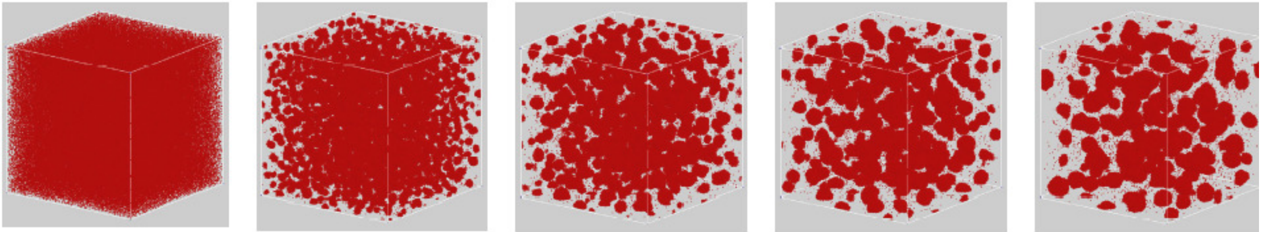

Figure 1: Example for a Monte-Carlo-Simulation showing the Building-Up, Growth and the Coarsening of Cu-Precipitates in Fe. Fe-Atoms are depicted by the transparent parts. The length of the edge of the cube is 46,3nm.

The micro-magnetically measured Barkhausen-noise on these samples would then be numerically evaluated and substantiated.

Parallel to it, atomistic simulations/molecular dynamic method would be used to simulate the micro-level internal stresses.

With the help of comparisons between the simulated internal stresses and the measured Barkhausen-noise-effects, a quantitive relationship between the Barkhausen noise and the precipitation status would be established. The final aim of the project is to be able to draw direct conclusions relating to the precipitation status by looking at the results of the Barkhausen-noise.

Partners

This project is to be carried out in co-operation with Dr. Iris Altpeter and Dr. Maddalina Pirlog of the 'Fraunhofer-Institute für Zerstörungsfreie Prüfverfahren (IzfP)' in Saarbruecken and Dr. Peter Kizler from MPA-Stuttgart.
At the IzfP, the sample preparation would be carried out alongwith the thermal treatment and the characterisation of the sample properties. Also, the measurements using the micro-magnetic measurements/Barkhausen-Rausch-Effect would be done.

The neutron-experiments would be carried out at the GKSS research centre at Geesthacht and the Atom Probe Field Ion Microscopy/Topographic Atom Probe measurements would be carried out at the University of Goettingen.

Furthermore, collaboration would be carried out with the Institut National des Sciences Appliquées de Lyon (France) in connection with the use of a new method to determine the contents/concentration of the dissolved part of the alloying elements with the help of thermal-power measurement techniques.

Acknowledgement

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