Conference Reports

Martensitic Transformations in Bochum

By Norbert Jost*

The European Conference on The Martensitic Transformation in Science and Technology held on March 8.–10. 1989 in Bochum, was a sequence of more or less informal meetings of researchers from western European countries interested in martensitic transformation.** It was organized by *E. Hornbogen* and *N. Jost* from the Institute of Materials at the Ruhr University, Bochum, and *V. Schumacher* from the German Society of Materials (DGM), Oberursel.

The martensitic transformation is a particular type of first order structural phase transformation in crystalline solids. Among its characteristics are its diffusionless nature and the rather large amount of shear displacement associated with the change in crystal structure. Consequently, its onset and course is not only determined by thermodynamic equilibria and nucleation, but also by internal and external shear stresses. It has been found in all types of crystalline materials: ceramics (ZrO_2), polymers (PTFE), and metals (steels, shape memory alloys). The differences in the characteristics of the martensitic transformation from similar transformations in crystalline solids are shown in Table 1.

Table 1. Definition of the martensitic transformation in comparison with some similar solid state reactions.

characteristics / transformation	no diffusion $D \approx 0$	no change in chemical composition $\Delta C \approx 0$	first order transformation 1. Order	large lattice variant shear $\gamma_{\beta\alpha} \gg 0$
martensitic	+	+	+	+
pre-martensitic (and similar)	+	+	○	○
bainitic	○	○	+	+
massive	○	+	+	○

Due to the strong response to the conference announcement two parallel oral sessions in addition to posters were necessary. The topics of the conference were subdivided into four large groups: 1) Fundamentals; 2) Iron Based Alloys, Steels; 3) Shape-Memory Alloys; and 4) Mn-, Ti-, Zr-Alloys and Ceramics.

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Five invited lecturers summarized recent research interests and 75 contributed papers covered a wide range of more specialized subjects. Additionally, two workshop discussions dealing with "Residual Austenite and Measurement Techniques" and "Future of Shape Memory" were held.

The aim of the conference was to bring together the various interested groups in western European research institutes and industry in order to review the present situation, to assess the prospects, and to define tasks for the future.

For about 3000 years mankind was baffled by the phenomenon of the hardening of steel. About 100 years ago the first successful scientific efforts were made for the scientific clarification of this problem by *Sorby* (1865) in Sheffield. *Adolf Martens* (1850–1914), the ex-president of the Royal Institute for the Testing of Materials, Berlin, gave his name to the main theme of the conference, and an introductory lecture ("*Adolf Martens* and Early Research on Martensite") commemorated the 75th anniversary of his death. This was given by *H. Czichos*, the vice-president of the present Federal Institution for the Testing of Materials (BAM) in Berlin. He recalled some of the highlights of the fundamental work of this great researcher and presented some very interesting original drawings made by *A. Martens* in the 19th century using a specially developed microscope.

The sessions on shape memory alloys (SMA) were led off by three keynote lectures. In the first one, *L. Delaey* (Katholieke Universiteit Leuven, Belgium) gave a review of the potential shape memory alloys. Because SM-effects are not shown in all martensitic alloy systems, all SME "candidate" systems were pointed out, and three groups of technologically important SMA were highlighted. Besides the characteristics of copper- and nitinol based alloys, two recently developed iron based alloys (Fe-Mn-Si and Fe-Ni-Co-Ti) were discussed. The subjects of the second keynote presentation by *R. Gotthardt* (Ecole Polytechnique Federale de Lausanne, Switzerland) were the TEM mobility of austenite-martensite interfaces as well as hysteresis and internal friction. *G. Guenin* (Institut National des Sciences Appliquees, Villeurbanne, France) discussed the two way memory effect in relation to the nucleation and growth of martensite.

The session on the fundamentals of the martensitic transformation was started by a paper by *W. Krauss, S. K. Papi* and *H. Gleiter* (Universität des Saarlandes, Saarbrücken, FRG) in which the mechanism of martensite nucleation was

reviewed. *I. Müller* (Technische Universität Berlin, West) discussed a model for the simulation of shape memory behavior after which the session was concluded by *J. Ortin* and *A. Planes* (University of Barcelona, Spain). They pointed out the thermodynamics of the thermoelastic martensitic transformations in relation to calorimetric measurements.

The second session on shape memory alloys was concerned with thermal and thermomechanical aspects. It was led off by *M. Sade* (a von Humboldt fellow on leave from Centro Atomico Bariloche, Argentina) who gave a report on the thermal and mechanical fatigue of shape memory alloys. The other papers in this session discussed the effect of aging and the thermal and thermomechanical stability of Cu-based SMA.

Many contributions were presented on alloy development and applications, most of them concerned with Ni-Ti alloys. The report of *P. M. Kleinherenbrink* and *J. Beyer* (Univerisity of Twente, Enschede, Netherlands) dealt with the control of the transformation temperatures of Ni-Ti alloys by ternary additions and *T. Duerig* and *K. Melton* (Raychem Corp., Menlo Park, USA) presented details of a very effective way to obtain wide hysteresis in Ni-Ti alloys by the addition of niobium. *J. Beyer, E. J. M. Hiensch* and *P. A. Besselink* from the university of Twente, Enschede, Netherlands reported work on the possibility of the resistance welding of Ni-Ti SMA. The results of this work may be very interesting for the future, especially for new industrial applications of SMA. In the same way this could be said for the "CADSMA", the computer aided design of SMA. A large group of authors from the university of Leuven and *N. V. Proteus* (Kortijk, Belgium) outlined the special problems concerned with construction using SMA. In the next three lectures *P. Tautzenberger* (G. Rau GmbH, Pforzheim, FRG) and *D. Stöckel* (Raychem Corp., Menlo Park, USA) gave an overview of the industrial application of SMA and drew a comparison to the properties of thermobimetals. *J. M. Welter* and *P. Naudot* (Trefimetaux, Serifontaine, France) reported about the development in industrial scale fabrication of Cu-based SMA.

A whole session was concerned with new iron based SMA. It was led off by *M. Sade* who gave a review of the SME in Fe-Mn-Si alloys. *Y. Vanderveken* and his coauthors (Katholieke Universiteit Leuven, Belgium) continued the session with a report on the influence of thermomechanical treatment on the one way effect in Fe-Mn-Si alloys. *P. Donner* and *E. Hornbogen* (Ruhr-Universität Bochum, FRG) described the production of Fe-Mn based SMA by melt spinning and discussed the results in relation to the influence of rapid solidification on the SM behavior. The session was concluded by two papers from *N. Jost* and *K. Escher* (Ruhr-Universität Bochum, FRG) in which the effect of the austenite microstructure on the martensitic transformation and the mechanical properties of Fe-Ni-Co-Ti SMA were analyzed.

The last session on SMA was concerned with special transformation characteristics and hysteresis. It began with a paper by *L. Lu, E. Aernoudt* and *L. Delaey* on the modeling of hysteresis in martensitic transformations after which *J. Stoiber, J. van Humbeeck* and *R. Goithardt* described the hysteresis effects during martensitic transformation in Cu-Zn-Al SMA. The report of *G. Airoldi* and *G. Riva* (Universita di Milano, Italy) dealt with the stepwise, stress free, martensitic transformation in the Ni-Ti system. The last paper of this session was presented by *L. Manosa* (University of Barcelona, Spain) who had studied the origin of acoustic emission during thermoelastic martensitic transformation.

In addition to these oral sessions 21 posters concerned with SM and a workshop on the future of shape memory held by *E. Hornbogen* gave the participants of the conference the opportunity to discuss more of the fundamental as well as specialized subjects. A systematic survey of shape memory effects and applications in the different fields of engineering was given by *E. Hornbogen* as a basis for the workshop discussion. It can be seen from Table 2 that a large field of applications exist.

Table 2. Systematic survey of shape memory effects and applications in engineering.

technology \ SM effect	one-way	two-way	pseudo-elasticity
connecting, fastening	couplings, pipe connections expanding rivets		seals, spectacle frames
control		valve control, temperature protection greenhouse opener	
motor vehicle		opening of fog lights gear adjustments	high noise absorption
data processing	plug connections for circuits	head/disc system magnetic data memory color changes for optical storage	
engines/ power		rotating machines, solar battery control	
automation	manipulators	robot hands	
medicine	implants (osteosynthesis)	endoscope control	dental braces
clothing	fabric reinforcement		rubber substitute

Besides the sessions on SM, the second large group of contributions was concerned with new developments in steels. It was begun by the keynote paper from *I. Schmidt* (Zahnradfabrik Friedrichshafen AG, FRG) who gave an overview of metastable ferrous austenites and the consequences on fracture and tribology.

The session was continued by *B. Skrotzki* and *E. Hornbogen* (Ruhr-Universität Bochum, FRG) who described a volume fraction vs. temperature function of the martensitic transformation in iron based alloys. *H. Weiland, L. M.*

ADVANCED MATERIALS

Matthews and *H. J. Bunge* (Technische Universität Clausthal, FRG) reported work on the texture and microstructure of lath martensite and *H. Berns* (Ruhr-Universität Bochum, FRG) traced the development of new martensitic nitrogen steels, discussing his results with special reference to the technological applications of this steel. *D. Löhe, R. Bartels* and *E. Macherauch* (Universität Karlsruhe, FRG) then dealt with the interaction of dynamic strain aging and the transformation of retained austenite to martensite, after which *K. Ullako* and *J. Pietikäinen* (Helsinki University of Technology, Espoo, Finland) reported their results on the carbon redistribution in low temperature deformed and aged martensite. Fe-Ni-C alloys were the subject of a paper by *X. M. Zhang* (Institute of Metal Research, Shenyang, China) who had studied the effect of plastic deformation on the lenticular martensitic transformation. *T. Abe* and *C. M. Sellars* gave an overview on the effect of thermo-mechanical treatment on the reverse transformation behavior and micro-duplex formation in Fe-Ni alloys. The last lecture of this session was given by *H. Vetters* (Institut für Werkstofftechnik, Bremen, FRG) who discussed the influence of unidirectional and cyclic loading on the martensite formation in austempered ductile iron.

The second session on steels was concerned with the mechanical properties. It began with a paper by *E. Gautier* and coauthors (Laboratoire de Science et Genie des Materiaux Metalliques, Nancy, France) on the transformation plasticity and resulting microstructures for strain induced martensitic transformation in Fe-Ni-C alloys. *Y. Zhang* (on leave from Shangai Iron and Steel Institute, China) reported on reverse austenite and its effect on mechanical properties. The microstructure-strength relationship of low carbon bainite and martensite was discussed by *W. Österle* (BAM, Berlin, FRG), and then *A. Schulz-Beenken* and *H. P. Hougardy* (Max-Planck-Institut für Eisenforschung, Düsseldorf, FRG) reported on a development of high strength martensite. They have shown that the age hardening of coherent intermetallic precipitates is a very effective way to obtain such martensites. In the last paper of the session *J. B. Vogt* and his coauthors (Universite de Lille, France) discussed the influence of nitrogen on the low temperature stress induced martensitic transformation of stainless steel.

In the workshop "Residual Austenite and Measurement Techniques" held by *I. Schmidt* and in five additional posters, interesting aspects on the development of steels were discussed in detail.

The session on transformations in Mn-, Ti-, Zr-alloys and ceramics was led off by *H. Warlimont* and coworkers (Vacuumschmelze Hanau, FRG). They gave an overview of displacive transformation phenomena in high-T_c-superconductors. The lecture by *G. Vogl* and coauthors (Universität Wien, Austria) dealt with the martensitic phase transition and soft phonons in the pure metals Ti and Zr. *M. Humbert* and coworkers (University of Metz, France) explained a simulation model for the texture transformation which occurs during the martensitic $\alpha-\beta$ transformation of Zr sheets. The fractal aspects of the martensitic transformation in Zirconia were discussed by *W. Wunderlich* (MPI-Düsseldorf, FRG) who made special reference to the study of fractal geometry as a new method for the characterization of microstructures. *S. Schmauder* (MPI Stuttgart, FRG) discussed the nucleation of the martensitic transformation of ZrO_2 in the system Al_2O_3-ZrO_2 before *M. Ellner* (MPI Stuttgart, FRG) closed the session by describing the structure of the high temperature phase $Mn_{0.8}Al$ (h) and the martensitic transformation of this phase to Mn_5Al_8.

The last contribution of the conference was the presentation of an educational film by *S. Keller* (Gewerbeschule Hamburg, FRG) and *J. F. Edgar* (Stockport College of Technology, England) in which the crystallographic characteristics of the martensitic transformation in steels were shown with hard sphere models.

The conference was an exciting and important meeting and provided an excellent opportunity for researchers from academic institutions and industry to meet and discuss problems and aspects of martensitic transformation.

Composites and Particle Technology in Las Vegas

By Wolfgang A. Kaysser *

The 118th TMS Annual Meeting and Joint TMS/SME (The Minerals, Metals and Materials Society/Society of Metallurgical Engineering) Exhibition from February 27 to March 2, 1989 in Las Vegas, Nevada, USA confirmed the growing importance of particulate technology as the major production route to new high performance materials. It is increasingly accepted that the required property combinations such as high temperature strength, creep resistance and toughness at low temperatures are not achievable in mono-

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