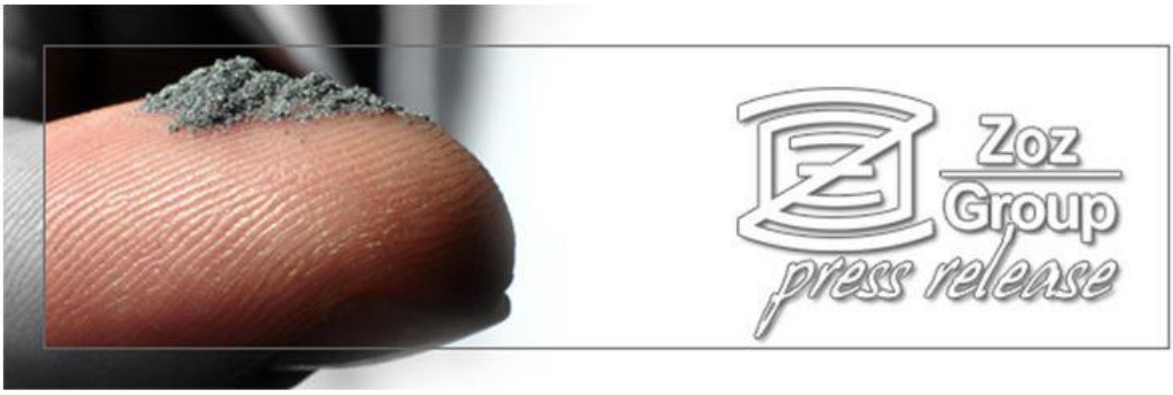


press release ZG-1702, Wenden, 12.04.2017

Zoz Group	KIT Karlsruhe Institute of Technology		logo not approved	logo not approved

Zoz launching PM2000

revitalization of Plansee's ODS-19YAT

ODS-20YAl (PM2017-AM) and NFA-14YWT (PM2018)

high-temp. & corrosion-resistant/irradiation-tolerant ODS/NFA-steels/powder from the shelf

Wenden/Germany

Any modern society considers sustainability, saving resources and increasing performance every day and our all future will be ruled by materials as never before. Based on general materials limitation, goal (a) is "making more with less" and since materials consumption contradicts with such limited resources, goal (b) is recycling. Both are leading to advanced materials processing with the utilization of larger surface and finer structures leading to nanostructures.

High Kinetic Processing (HKP) has been proven as a major route for reducing materials grainsize in large volume at economic manufacturing and cost capability where the “nanostructure-making-equipment”, the Zoz-Simoloyer® is well-known including technology and key advantages.

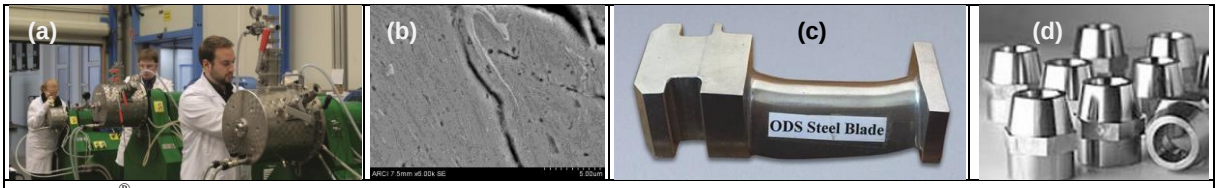
Nanostructure and innovative solutions in green-/cleantech manufactured with Zoz Technology

P2H® | P2G2F® | Hydrolium® | H2Tank2Go® | Zentallium® | ZoLiBat® | Simoloyer® are registered trademarks of Zoz Group, Taraxagum™ is so of Continental AG

oxide dispersion strengthening | ODS & Nanostructured Ferritic Alloys

One major focus at Zoz-customers is concentrated on the development and processing of Oxide Dispersion Strengthened Ferritic Steels (ODS). Due to their high temperature stability and strength along with a high irradiation tolerance, ODS-steels represent promising candidates for nuclear fusion and 4th gen. fission reactors likewise for components in gasturbines/aero- and combustion engines exposed to high temperature and high corroding environment [1-4].

This target does not at all contradict with the "green/cleantech-company" understanding of Zoz since the pure political German "no" to nuclear energy does not efficiently reflect global environmental responsibility.



Simoloyer® CM08 & CM20-ODS (a), Fe-0.03MOx after 4 h Zoz-HKP at Zoz-ARCI Center India (CM08), grainsize ~15nm (b), ARCI turbine blade (c) and PM-2000 burner nozzles [5] (d)

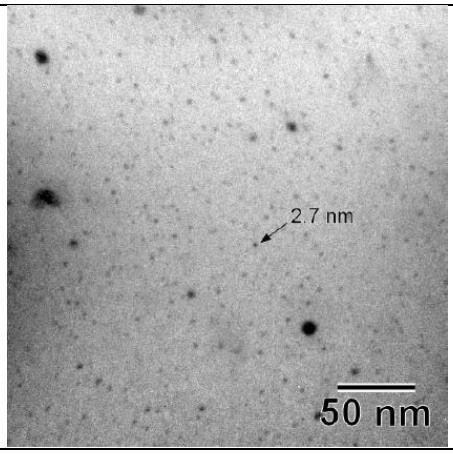
Particularly with the goal of achieving better resistance to radiation damage, Nanostructured Ferritic Alloys (NFA) with a dense dispersion of <10nm oxides occuring intra- and intergranulray as precipitates of complex oxides e. g. Y2Ti2O7 formed after a dissolution of starting Y2O3 under the presence of Ti during intense/extended HKP (>20h, >8m/s MRV) and subsequent heat treatment (>1.000°C), were developed [6, 7].

Due to a general renaisseance of powder metallurgy (PM) by additive manufacturing processes (AM, ALM...), also conventional ODS-materials, where coarser "original" oxides >10nm located predominantly on grain boundaries or former particle boundaries [6] homogeniously dispersed by HKP (<4h, >8m/s MRV) opened another focus. The naturally irregular/equiaxial particles after HKP can be modified in morphology by so called spheriodization (SPH) to better meet flowability requirements for AM or MIM [8].

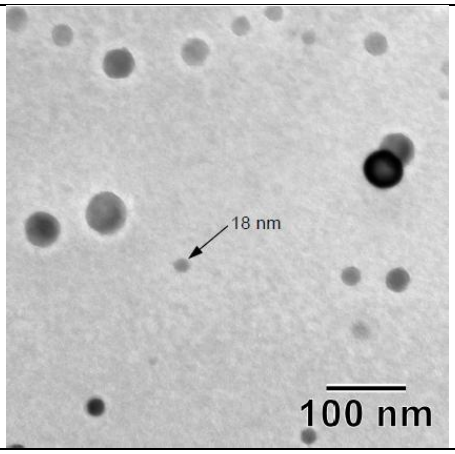
The difference in oxide character and location results in lower meachanical properties of the common ODS-material [6] where economics in processing cost do determine the proper material for the particular application.

Since Zoz has been providing not only the processing equipment but also most of the larger numbers of ODS/NFA-materials (powder, 2 t approx.) in recent years, in late 2016 it has been decided to invest into the semi-commercialization of 3 dispersion strengthened materials to on-shelf availability of powder and bulk (semi-finished). Under strict information and joint understanding/agreement policy towards all customers, partners, former manufacturer and future applicating industry, from whom Zoz has been and is learning a lot, a bilateral group USA/Germany has been formed [9]. A "geo-political" restriction appeared ultimate, since the Simoloyer® and its products as of 2016 are under full observation of BaFa (German Export Control) where e. g. military relevance of ODS and nuclear application of NFA are determining.

The goal of this joint undertaking between Zoz and core parters KIT in Germany and UCSB, ORNL as well as LANL in the USA is a commercial NFA from the shelf. Since this has never been done before, support from the US-DOE is on board and a joint submission within Euratom/INERI (International Nuclear Energy Research Initiative) based on DOE-NE's Advanced Fuels Program is planned as of August 2017.



ORNL 14YWT EFTEM Fe M Jump Ratio Map



Plansee PM2000 TEM Bright Field Image

14YWT contains significantly higher number density and smaller size of Ti-, Y-, and O-rich nanoclusters compared to YAG oxide particles in PM2000 (and other commercial ODS alloys) [4]

For at most eonomic "fast/safe resulting", two milestones have been fixed. In 2017, the former Plansee PM2000 alloy (ODS-19YAT, manufacturing by Plansee until 2006 [10]) is going to be relaunched in powder and bulk (D40xL250mm) based on the simplier fine-grain/HIP-consolidated type that e. g. the German car-manufacturer Porsche was utilizing for the injection nozzle of its GT4-engine [8] to serve under extremely high corrosive environment at high temperature. Under mutual understanding with Plansee [11], the name of PM2000 will survive. Also an immediate goal is a new material PM2017 (20YAl) with 1% more Cr and zero Ti (compared to PM2000) with a focus on AM consolidation routes including MIM.

brand	chem. composition (starting mat.)	ID	origin	t. b. on shelf
PM2000	Fe-19Cr-5.5Al-0.5Ti-0.5Y2O3	**19YAT**	ODS-PM	fine-grain/HIP only, D40xL250mm
PM2017	Fe-20Cr-5.5Al-0.5Y2O3	**20YAl**	ODS-RR	powder only (AM, ALM, MIM)
PM2018	Fe-14Cr-3W-0.4Ti-0.25Y2O3	**14YWT**	NFA-GE	t. b. d.
chemical (basic) compositions for on shelf (a) powder and bulk (b) powder only (c) powder and t. b. d.				

If the abitious schedule will be achieved, then the NFA-14YWT with the chemical starting composition Fe-14Cr-3W-0.4Ti-0.25Y2O3, demonstrated by GE with powder processing at Zoz [6] in large volume shall be available under the name PM2018 from that year in powder batches and small bulks.

ODS/NFA powder processing is done at the Zoz Technology Center (ZTC) in Germany, characterization of powder and bulk at core partners. For tolling HIP (PM2000) and starting materials supply, Zoz is searching for suppliers. For the upcoming (again after 10 years) availability of PM2000, Zoz is searching for the former and future customers and end user.

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[8] authors discussion with Prof. Gerhard Leichtfried, Innsbruck, 2017-03-02

[9] authors discussion with A. Moeslang (Karlsruhe Institute of Technology - KIT), G. R. Odette (University of California Santa Barbara), S. A. Maloy (Los Alamos National Laboratories), D. T. Hoelzer (Oak Ridge National Laboratory), 2016-11 through 2017-04

[10] Communication Plansee Nederland, 2017-04-05

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