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# NUCLEAR RESEARCH AND TECHNOLOGY IN EAST GERMANY

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# FOREWORD

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## Chapter 6. Basic and Solid State Materials

The Department of Basic and Solid State Materials was created within the Central Institute for Nuclear Energy in order to combine the multiple tasks of physical, chemical and metallurgical research in the area of reactor materials into a uniform effort. Problems of basic research, especially that of irradiated solid state materials, and applied research, resulting from the GDR's contribution to the development of nuclear energy among the socialist countries, shall be based here.

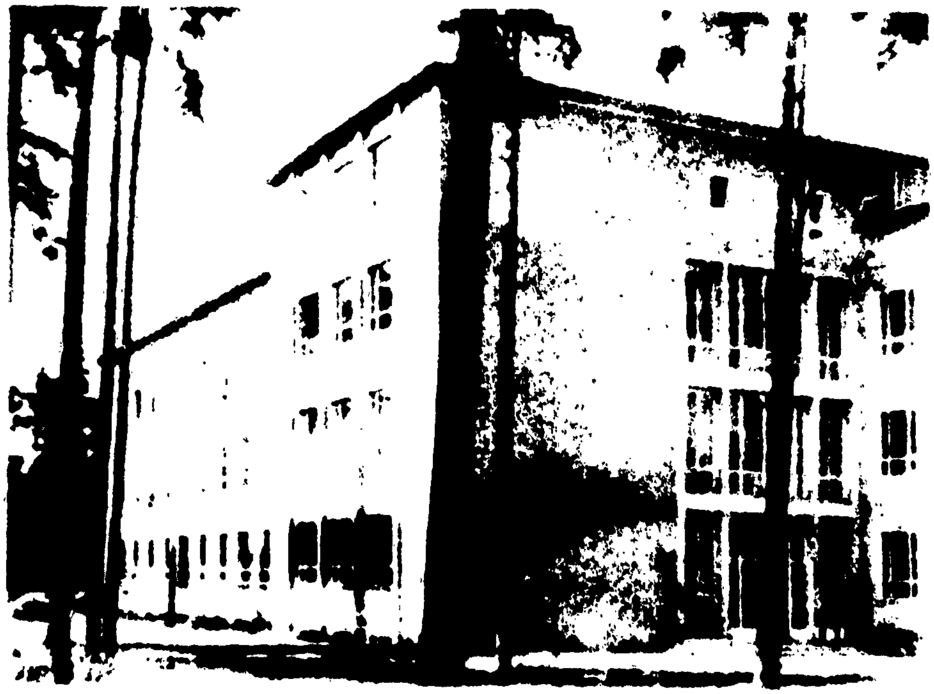

Fig. 1 Laboratory of the Department of Basic and Solid State Materials

Over the last four years a great effort has been made to provide all the equipment and documentation needed for this purpose. The main building of the department was occupied in the summer of 1959, as seen in fig. 1. In addition there are some smaller units for mechanical processing of uranium metal and metallographic research of irradiated fission materials.

The 90 employees of the department, of which there are about 40 scientists and engineers, have been assigned to three major sections, namely fuel technology chemical nuclear technology and solid state physics. The collective cooperation among metallurgists, chemists and physicists is an important prerequisite which will lead to the solution of the problems arising from the common task.

The development work on reactor fuel represents the main effort of the department. The collectives are grouped around this central task, and they will perform the basic work.

The section "Fuel Technology", as the name implies, is charged primarily with the solution of fuel production and testing probelms. This section is also in charge of metallography, uranium metallurgy and research on ceramic fission materials. Research on irradiated fission materials, especially as it concerns processing, is handled in the section for "Irradiated fissionable materials". Another section deals with reactor fuel corrosion. Experimental research on irradiated solid state materials in the section "Solid State Physics" forms the physical basis for the common problems of the department.

The work performed by the Department of Basic and Solid State Materials up to early 1962 has been publicized in 39 publications, 14 patent applications and numerous lectures at national and international conventions. The most important results will be dealt with briefly in this article:

## Fuel Technology

In addition to preliminary work on manufacturing and testing problems connected with fuel specimen, the first trial batches for a "zero-performance" (prototype) reactor were made and its construction in the Central Institute was initiated. This reactor will use dispersion fuel, consisting of $U_3O_8$ and Al covered by an aluminum alloy, as shown in fig. 2.

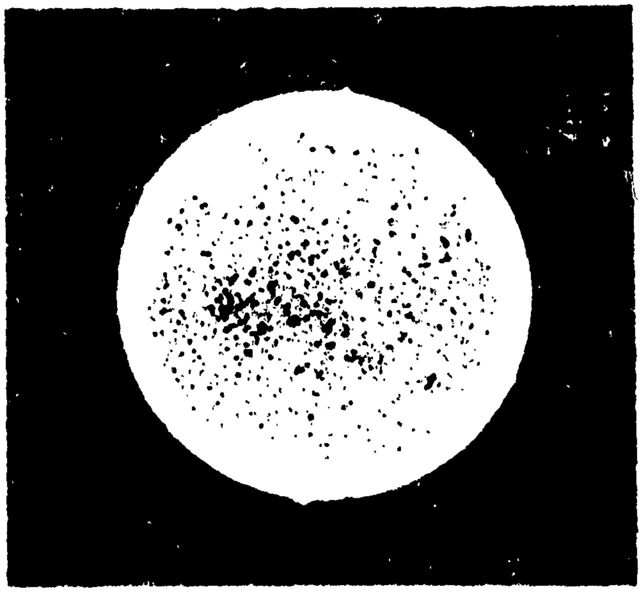

Fig. 2 Cross-section of a dispersion fuel element. Dark area $U_3O_8$, light area aluminum.

This element is manufactured using the process of pressing alloys together Simultaneously experiments are being conducted to make needle shaped fuel batches of $UO_2$ to be used as fuel and stainless steel to be used as an envelope, according to the process of hammer condensation.

In addition to uranium alloys with small amounts of zirconium, well known due to their temperature changing characteristics, other potential fission syste are being investigated, such as powder metallurgical elements combined with urani such as $U_3Si_2$ (Refs. 1 and 2.) Much attention is focused on developing technique of manufacturing this type of uranium combinations and the investigation of their interesting nuclear properties. Thus, for example, the behavior of the high tempe rature stable $U_3Si_2$ phase in water up to 300°C has been determined and compared with other corrosion-resistant uranium alloys for pressure and boiling water reactors (fig. 3).

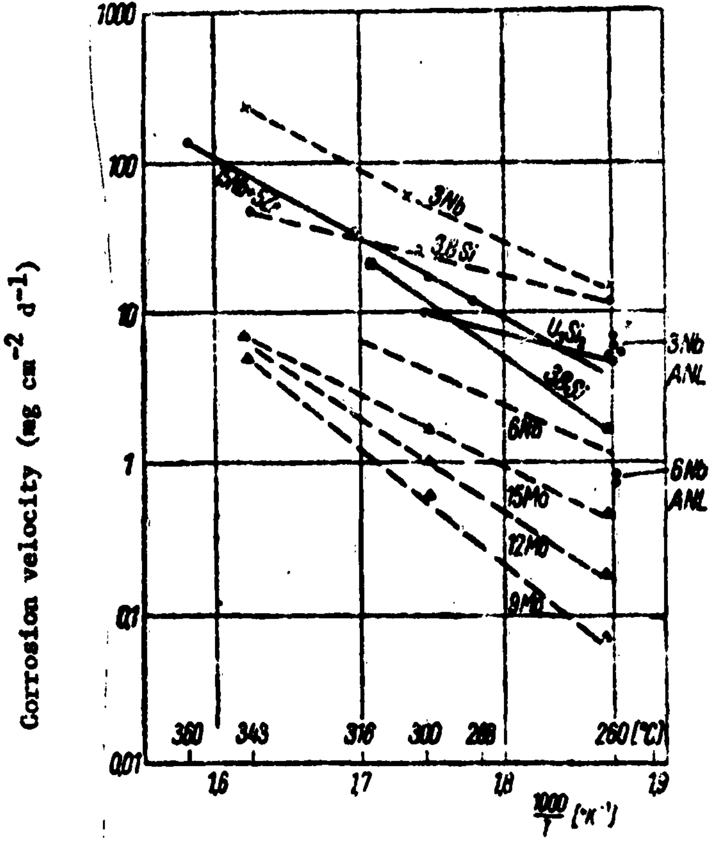

Fig. 3 Corrosion rate of $U_3Si_2$ as compared to corrosion rate of uranium alloys in stationary water, as determined by Foote (Ref. 35)
—— ANL (Argonne National Laboratory); --- WAPD (Westinghouse, Atom. Power Div.)
●$\overset{U_3Si_2}{——}$● ZfK (Central Institute for Nuclear Energy)

To ensure balanced production it is necessary to know the factors affecti sintering. In cooperation with the Research Institute for Non-ferrous Metals in

Freiberg and based on experimental results an efficient production process for powder has been found. Closely connected with this work research proceeds on a uranium-oxygen system. (Ref. 4). Furthermore, experiments with uranium oxide an mixed oxides are being conducted, aimed at improving the heat conductivity of sinter elements.

In connection with this work the compatibility between $UO_2$ and various A alloys at temperatures up to 620°C is being investigated. It has been shown th not only the grain size of the $UO_2$ powder but also the aluminum content, such alloy content and oxide content in aluminum sinter materials, as well as glow atmosphere have an effect on the $UO_2$-Al reaction. (Refs. 5 and 6.)

## Irradiated Fission Materials

A laboratory study for chlorine processing of irradiated uranium oxide revealed a new way of regenerating the burned up $UO_2$ by separating fission products from plutonium in the absence of water. This process provides for chlorination of $UO_2$ by means of $CCl_4$, followed by a gas chromatographic separation of the chlorination products through active coal at 700°C to isolate plutonium, followed by the absorption of $UCl_4$ in an alkali chloride smelter, from which uranium is again removed in the form of $UO_2$ in large concentration. (Ref. 7). Upon the conclusion of this work research in the field of salt melting chemistry becomes of greatest interest.

To provide the hot metallography the VEB Rathenower Optical Works develo a "hot" metal microscope (Ref. 8) and installed it in a hot cell on the reactor (Fig. 4).

Fig. 4 "Hot" Metal microscope

a. Inactive part in the observation area with comparison microscope, radiation ducts, light sources and service table

b. active part inside the "hot" cell

Maximum enlargement is x800. This instrument permits direct observation and photographs in the bright field and with polarized light, and micro measurements of hardness. There is also an inactive comparison portion. The picture is transmitted from the cell to the operator area by way of light optics.

To complete the research facility in dealing with irradiated fission materials an instrument to measure fission gas liberation has been added.

## Corrosion of Reactor Fuel

Research on silicon containing aluminum sinter fuel in stationary water at high temperatures (Ref. 5, 9) reveals a considerably more favorable corrosic behavior than that previously known from the literature on other aluminum alloy (Fig. 5.)

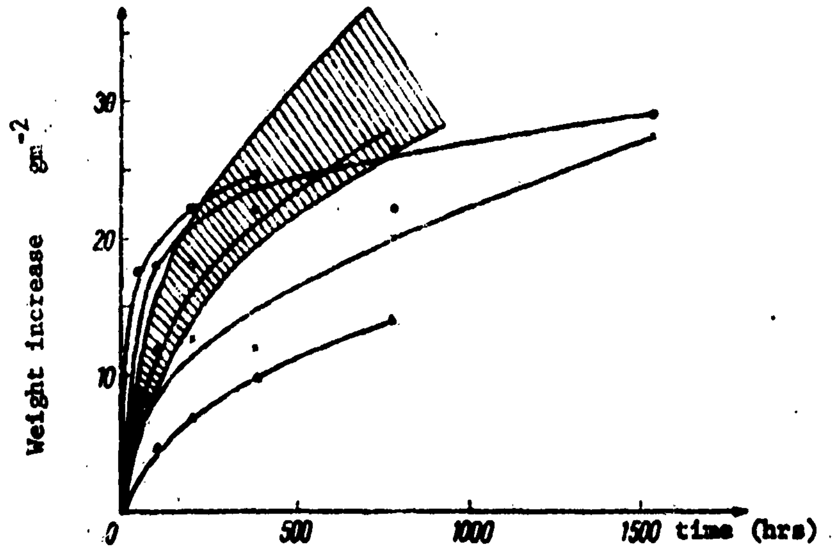

Fig. 5 Corrosion of aluminum fuel with high Si content in stationary distilled water ( $x = 5 \cdot 10^{-6}$ S cm$^{-1}$) at 300 and 350°C
⊘ Al Si 9 Ni 1 at 300°C; ● Al Si 9 Ni 1 Ti 1 at 300°C; ▲ ASW Si 9 Ni 1 at 300°C; ⧗ ASW Si 9 Ni 1 Ti 1 at 300°C; ■ ASW Si 9 Ni 1 Ti 1 at 350°C. Cross-hatched: Corrosion of Ni-Fe alloyed ASW in 300°C water according to ref. 36.

In the field of zirconium and zirconium alloys corrosion tests at high temperatures in water have been conducted primarily on certain materials and tl weld alloys manufactured in the GDR. Very good results have been obtained by m of electron beam welding. (Ref. 10). Weld seams proved to be corrosion resista to the same extent as the original material.

## Solid State Physics

A good deal of theoretical work deals with the mechanics of producing radiation effects (Ref. 11), their quantitative aspect (Refs. 12, 13), the experimental proof of radiation effects (Ref 14) and its cure (Ref 15).

In the experimental area non-fissionable materials have been examined almost exclusively in the department. For example, the effect of reactor radiation on carbon steel alteration has been investigated (Fig. 6, ref. 16). In addition experiments on the effect of mutation and neutron beams on electrical conductivity, the E modulus and attenuation of nickel (Ref 17) and copper (Ref 18 and 19) are being conducted. (Fig. 7). In order to be able to conduct these radiation experiments in the reactor even at low temperatures a nitrogen kreosate has been developed (Ref. 20), which is in the trial stage.

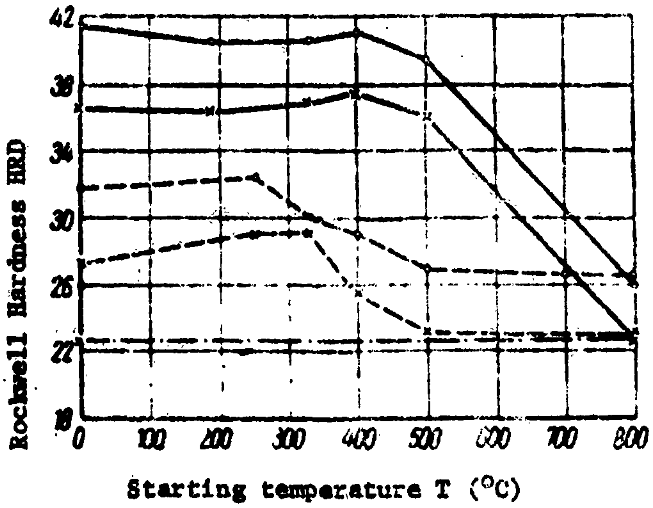

Fig 6. Rockwell hardness HRD as a function of starting temperature of only cold-formed (———) and only irradiated (-----) specimen.
Starting time: 20 min, Rolling percentage 30%; integral flow $3 \cdot 10^{18}$ thermal and $4.5 \cdot 10^{17}$ rapid neutr $cm^2$. Radiation temperature 40-50°C; Original status of irradiated specimen: normalized. 0 MSt 3b; x MSt 3u

Some interesting results were obtained in irradiating non-metals. For example, the so-called radiation dotting, i.e. the change in photo-conductivity of CdS (Ref. 21, fig. 8) and the change in electrical resistivity of insulators due to nuclear mutation caused by thermal neutron bombardment and reactor irradiation, respectively (Ref 22 and 23, fig. 9) has been determined.

Part of the research field of radiation effects is the electron microscop investigation of the effect of ion bombardment of metallic surfaces (Ref 24.)

To support work on fission material the electron-microscope laboratory further developed the process of vacuum etching (Ref. 25 through 28), which through relatively simple methods, allows considerable metallographic research on the interrelationships between uranium alloys and uranium sinter elements, which would have been very difficult or impossible with other etching processes

Up to the end of 1961 an analytical section was part of the department, which, however, for economic utilization of the instruments has been annexed to the corresponding section of the Department of Radio-chemistry of the Centra Institute for Nuclear Physics. In the Department of Basic and Solid State Mater most of the work centered around the determination of traces of contamination of reactor materials (Ref 29 through 32).

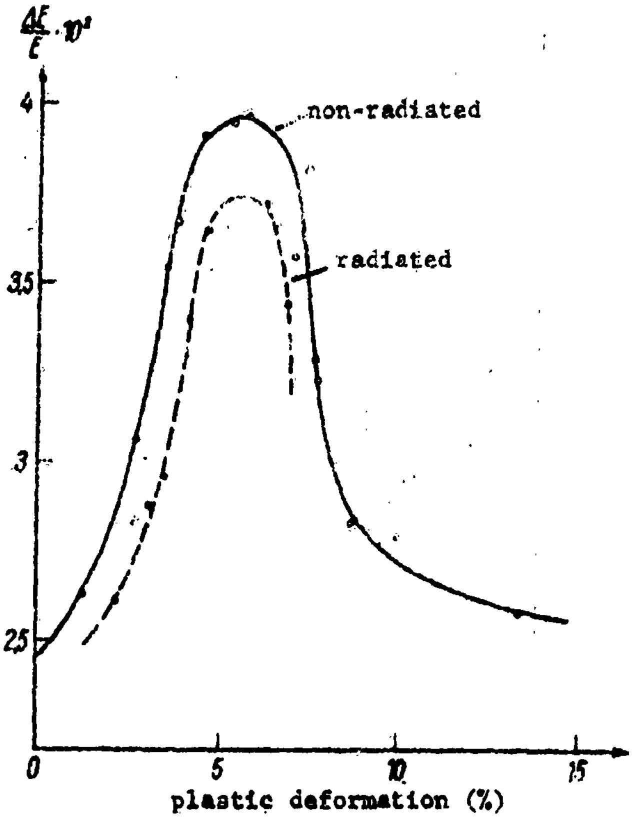

Fig. 7a Portion of modulus change as a function of amplitude

In this connection the newly developed 2-m plane grid spectrograph of the VEB Carl Zeiss Jena was used, and a spectral atlas was erected for this instrument. (Ref 33). To determine hydrogen and oxygen content in high melting temperature metals a vacuum hot-extraction apparatus was developed and built (Ref 34).

To solve the problems and tasks shown there has been a long-standing cooperation in existence with a number of GDR institutes and factories. For example, to develop fuels a supra-factory level work cooperative was established early in 1959. The close cooperation between scientists and engineers of various specialties within and outside the department and the generously lent work facilities at the Central Institute for Nuclear Physics assure us that in the important field of reactor fuels the GDR can also make a contribution.

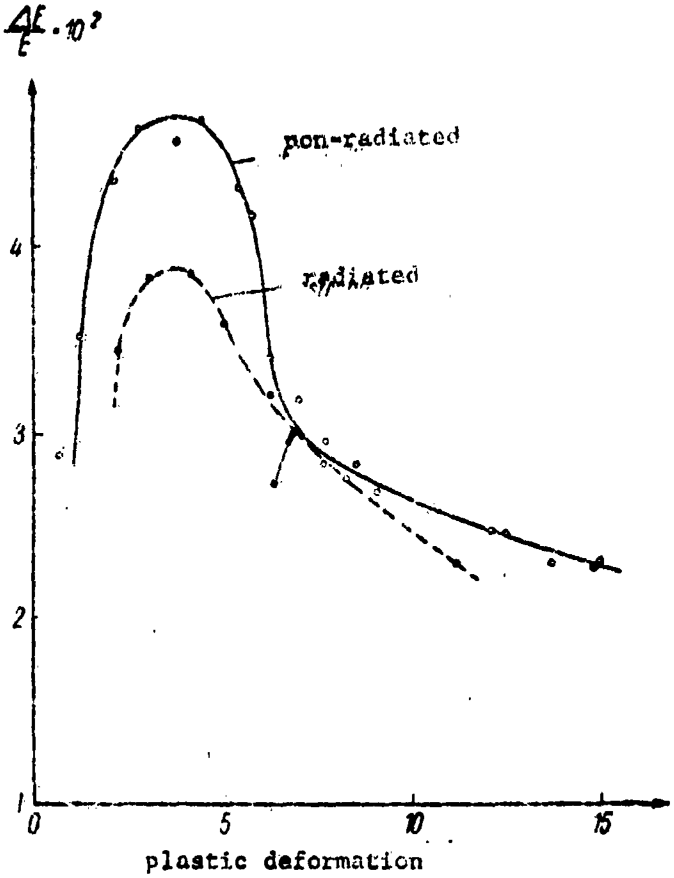

Fig. 7b Portion of modulus change as a function independent of amplitude
Figs. 7 a and b. Change of E modulus for copper following cold forming and irradiation with $1.3 \cdot 10^{15}$ rapid neutr./cm$^2$ Measurement made at room temperature

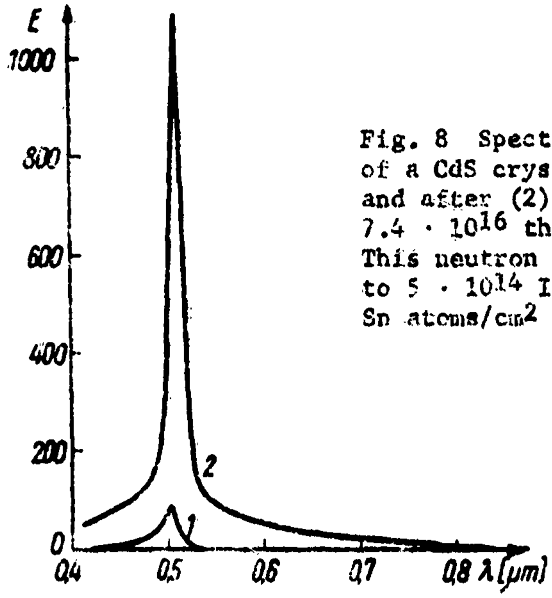

Fig. 8 Spectral sensitivity of a CdS crystal prior to (1) and after (2) irradiation wit $7.4 \cdot 10^{16}$ thermal neutr./cm$^2$ This neutron dosis correspond to $5 \cdot 10^{14}$ In- and $1.6 \cdot 10^{1}$ Sn atoms/cm$^2$

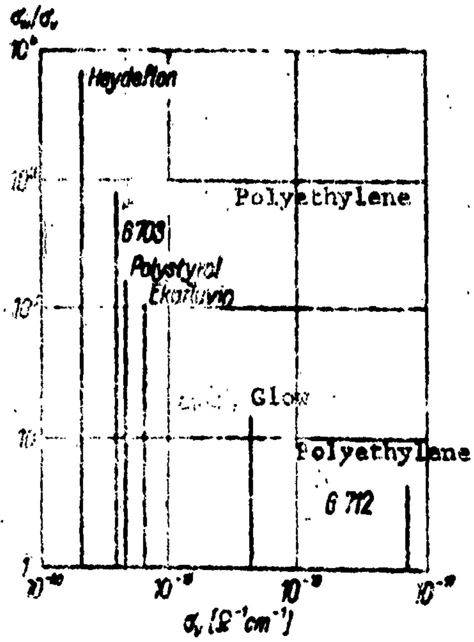

Fig 9. Electrical conductivity during reactor irradiation $\sigma_w$ vs. conductivity prior to irradiation $\sigma_v$ for various dielectrical materials

Materials are arranged according to their conductivity before irradiati

Measurements were made three hours after establishing an electric field of 6 kV/cm; Gama-dosis was 75 r/min, neutron flow 2.3 · $10^8$ neutrons/cm

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