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IMPURITY EFFECTS ON THE CREEP OF POLYCRYSTALLINE
MAGNESIUM AND ALUMINUM OXIDES AT
ELEVATED TEMPERATURES

Technical Progress Report

December 19, 1968 to December 18, 1969

Atomic Energy Commission

Contract No. AT(11-1) -1591

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Division of Materials Science and Engineering
University of Utah
Salt Lake City, Utah

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TECHNICAL PROGRESS REPORT

December 18, 1969

PROJECT TITLE: Impurity Effects on the Creep of Polycrystalline Magnesium and Aluminum Oxides at Elevated Temperatures.

CONTRACT: AEC AT(11-1)-1591

CONTRACTOR: University of Utah
Division of Materials Science and Engineering

PERIOD REPORTED: December 19, 1968 to
December 18, 1969

PROJECT PERSONNEL: Principal Investigator
Dr. Ronald S. Gordon
Associate Professor
Graduate Research Assistants
Mr. Glenn H. Hollenberg
Mr. Randolph T. Tremper
Undergraduate Assistant
Mr. David D. Marchant

I. INTRODUCTION

The research activities under Contract AT(11-1)-1591 during the period December 19, 1968 to December 18, 1969 are summarized in this report and in the attached reprint (1) and preprints (2-4).

Major effort was devoted to the following:

- (1) A complete reconstruction of the vacuum hot press for operation at temperatures higher than were possible with the previous equipment. (5)
- (2) A redesign and reconstruction of the creep testing facilities.
- (3) Preliminary experiments on the effects of oxygen partial pressure on the creep of polycrystalline magnesium oxide doped with Fe_2O_3 .
- (4) Completion of the grain growth studies in magnesium oxide and magnesiowüstite (3).
- (5) Completion of the analytical study on the calculation of strains and strain rates in the inelastic bending of beams (4).
- (6) Continued analysis of grain size distributions.

Since most of these activities are described in the reprint and preprints submitted with this report, a brief account will be given only on (1) the construction of new facilities (2) preliminary experiments on the effect of atmosphere (P_{O_2}) on the creep of Fe_2O_3 doped MgO and (3) the analysis of grain size distributions.

A complete listing of the Bibliography of papers and theses prepared under this contract is given at the end of the report.

II. NEW HOT PRESSING FACILITY

In the previous hot pressing studies on magnesium oxide, pure and doped with Fe_2O_3 , two problems were encountered.⁽⁵⁾

1. Small amounts of residual porosity were present ($\sim 0.1 - 0.5\%$) in the billets.

2. Impurity distributions in the doped samples were not uniform, particularly at dopant levels over about $1\% \text{Fe}_2\text{O}_3$ by weight.

It was believed that both of these problems could be solved if the hot pressing temperature was raised above 1200°C , the upper limit of the existing facility⁽⁵⁾.

This past year a new hot pressing facility has been constructed. A schematic of the furnace chamber is shown in Figure 1. The chamber can be evacuated to at least 10^{-4} Torr with a six inch diffusion pump. Specimens are pressed in graphite dies which are inductively heated with a 20 KW Lepel induction power supply. In Figure 2 a photograph of the entire hot pressing facility is given showing the furnace chamber, the hydraulic press, the vacuum pumps and the Lepel unit.

It is expected that relatively pore free, homogeneous doped specimens of magnesium and aluminum oxides (doped and undoped) can be hot pressed at temperatures up to 1700°C .

Figure 1 Schematic - Hot Pressing Furnace

Figure 2 Hot Pressing Facility

Figure 3 Creep Testing Facility

III. NEW CREEP TESTING FACILITIES

Early in this contract year the existing creep testing facilities were critically evaluated. A number of problems were identified. These included:

1. Difficulties in aligning the equipment because the furnace, specimen stand, and the table upon which the stand was placed were all independent of each other.
2. The susceptibility of the furnaces themselves to slow oxygen leaks, which caused premature loss of the molybdenum windings.
3. High sensitivity to fluctuations in the room temperature which caused scatter in the creep data, particularly when the creep rate was small.
4. Temperature fluctuations within the furnaces.

With these factors in mind and with the new SCR temperature controllers authorized in the budget, it was decided that it was time to redesign and rebuild new creep testing facilities which would overcome the foregoing difficulties. One of these facilities is completed and is operational. The other is nearly completed, and it will be operational shortly.

A schematic drawing of the creep testing facility is presented in Figure 4; while Figure 3 is a photograph of the actual equipment illustrating the electronics used for measuring creep rates and temperature control.

The frame of the structure consists of two steel I-beams welded to the sides of a length of 12 inch steel pipe, which is used as the measurement chamber. This enclosed chamber is maintained at nearly constant temperature by water cooling. The enclosed measuring equipment at the micrometer head is fairly insensitive to ambient temperature changes, thus minimizing thermal expansion errors.

The specimen stand rests on top of a steel plate which is attached to the top of the chamber. It can be leveled by means of three cap screws which are

Figure 4. . . . Schematic Creep Testing Facility

threaded up through the base plate. The stand is secured in place by three bolts through the base of the stand and the base plate.

The furnace itself is suspended above the preceding assembly using pulleys and counterweights. The furnace is constrained from horizontal motion by the use of ball bushings which track the furnace vertically over ground steel shafts.

A change in the design of the specimen stand, as shown schematically in Figure 4, is soon to be incorporated. The support and load points will be applied to the creep specimen through the use of small sapphire rods which are kept in place by notches machined in the weight support rod and the specimen support tube. Several advantages are present with this modification:

1. reduced friction of the specimen over the load and support points during bending
2. easy replacement if the rods become damaged
3. much harder sample support and loading points (useful for the projected studies on the creep of polycrystalline alumina).

The creep data which are being obtained with these facilities are relatively free of the scatter that plagued many of the earlier experiments.

IV. PRELIMINARY RESULTS ON THE EFFECT OF ATMOSPHERE ON THE CREEP OF POLYCRYSTALLINE MgO DOPED WITH Fe_2O_3

With the completion of the new creep testing facilities, preliminary experiments were begun at 1400°C on studying the influence of atmosphere on the creep of polycrystalline magnesium oxide doped with 1.0% by weight Fe_2O_3 . A summary of the experimental results to date follows:

All experiments were conducted on specimens which were cut from a dense billet which had been hot pressed at 1470°C at a pressure of 5000 psi. Prior to creep testing the specimens were all preannealed at 1400°C in air for one week to stabilize the grain size at 14 microns (linear intercept value). Creep tests at 1400°C were then conducted in three different atmospheres: air ($\sim .18 \text{ atm } P_{\text{O}_2}$), dry commercial nitrogen ($\sim 10^{-5} \text{ atm } P_{\text{O}_2}$), and nitrogen passed over titanium filings at 830°C . For each atmosphere several stress change experiments were performed over a range of stresses between 200 and 307 kg/cm^2 .

A. Air

The results of a creep test in air at 1400°C over a stress range between 209 and 266 kg/cm^2 are given in Figure 5. (Stresses were calculated by the method of Timoshenko as reported earlier⁽²⁾). Stress change experiments were conducted to determine the stress exponent N in the relation $\dot{\epsilon} \propto \sigma^N$. The first stress change (209 to 230 kg/cm^2) yielded a value of $N = 1.0 \pm 0.1$ which indicated creep was occurring by a viscous mechanism⁽²⁾. The second stress change to 266 kg/cm^2 conducted later in the test yielded a value of $N \sim 4$, an indication of a strong non-viscous contribution to creep. Shortly after this stress change, creep rapidly proceeded into the final or tertiary stage with fracture occurring after 75 hours. It is apparent that the high stress

Figure 5. Creep in Air at 1400°C

exponent of 4 is due probably to a mechanism contributing to the onset of fracture.

B. Dry Nitrogen

Another specimen from the same billet was creep tested in commercially pure (dry) nitrogen over a stress range between 201 to 307 kgm/cm². The results of this experiment are presented in Figure 6. Three stress change experiments were performed. The first two yielded stress exponents $N \approx 1.0 \pm 0.1$, again assuring that the creep mechanism was viscous. The last stress change to 307 kgm/cm² yielded a value of $N = 2.1$, indicating again the presence of a non-viscous mode.

C. Pure Nitrogen Gettered by Titanium at 830°C

A third specimen was tested in pure nitrogen which had been passed through titanium filings at 830°C thus scrubbing the gas to a very low oxygen partial pressure. The results of this experiment are shown in Figure 7. Two stress changes were conducted yielding values of $N \approx 1.0 \pm 0.1$ again indicating the predominance of viscous creep.

D. Steady State Creep

By referring to the creep data in Figures 5 - 7 it can be seen that in the regions of viscous creep, i.e., $N \sim 1$, steady state creep is occurring except during a short transient (4 - 7 hours) which occurs after each stress change.

Steady state creep has not been observed in previous experiments presumably due to the occurrence of simultaneous grain growth⁽²⁾. The steady state conditions observed in the present tests consequently imply that no grain

Figure 6 Creep in Dry N₂ at 1400° C

Figure 7 Creep in Scrubbed N₂ at 1400°C

growth was occurring. This conclusion can be verified by referring to the photomicrographs in Figure 8. Figure 8A is a photomicrograph of the specimen prior to creep testing. Figure 8B is a photomicrograph of the tension side of the specimen which had been tested in air and had fractured. Figure 8C shows a specimen that had been tested under reducing conditions. All three specimens possess the same grain size ($\sim 14\mu$) revealing that, indeed, no grain growth had occurred during the creep tests. Thus it is possible to preanneal specimens at the 1% dopant level and stabilize the microstructure. It is also apparent from Figure 8 that the specimens are completely dense, except for the sample which had proceeded to fracture. In this case large voids between the grains in the tension direction were formed as might be expected⁽²⁾.

E. Effect of Oxygen Partial Pressure on the Creep Rate

The results shown in Figures 5 - 7 prove conclusively that the creep rate of Fe_2O_3 doped polycrystalline magnesium oxide is sensitive to the partial pressure of oxygen in the atmosphere. A preliminary indication of this effect had been demonstrated previously.⁽²⁾

Data from the present and previous experiments⁽²⁾ are summarized in Table I. Bulk diffusion and grain boundary ($D_b w$) diffusion coefficients were calculated from the Nabarro-Herring and Coble diffusional creep relations⁽²⁾. Calculations were performed only when the strain rate ($\dot{\epsilon}$) was proportional to the stress (σ), i.e., when $N = 1$. Good agreement exists between the present data at 1400°C and the previous data at 1300°C on 0.94% specimens in that the creep in air is slightly faster at 1400°C .

It is readily apparent from the results presented in Table I that the creep of $\text{MgO} - \text{Fe}_2\text{O}_3$ solid solutions (1% Fe_2O_3) at 1400°C is faster (by a factor of 6) in air than in a reducing atmosphere with some low level oxygen

Figure 8A Before Creep and After Preannealing at 1400°C

Figure 8B Tension Side after Creep in Air

Figure 8C After Creep in Reducing Atmosphere

Figure 8 Microstructures Before and After Creep Testing - Average Grain Size - 14 microns

TABLE 1
SUMMARY OF EXPERIMENTAL RESULTS ON 1% Fe₂O₃ CREEP SPECIMENS AT 1400°C

<u>Specimen</u>	<u>Dopant Level (%)</u>	<u>Atmosphere</u>	<u>Stress (σ)</u> kgm/cm ²	<u>Steady State $\dot{\epsilon}$ at given σ</u> x 10 ⁴ /hr	<u>Relative Rate</u>	<u>D Nabarro-Herring</u> cm ² /hr	<u>D_bw Coble</u> cm ³ /hr
1.0-A-4	1.0	air (P _{O₂} ~.18 atm)	208	2.68	6	4.5 x 10 ⁻⁹	2.7 x 10 ⁻¹²
1.0-A-6	1.0	dry N ₂ (P _{O₂} ~10 ⁻⁵)	200	1.31	2.9	2.3 x 10 ⁻⁹	1.4 x 10 ⁻¹²
1.0-A-7	1.0	N ₂ (passed over) Ti at 830°C P _{O₂} = ?	200	0.45	1.0	7.9 x 10 ⁻⁹	4.7 x 10 ⁻¹³
D-E ⁽²⁾	0.94	air (1300°C)				2.6 x 10 ⁻⁹	1.4 x 10 ⁻¹²

partial pressure. A factor of two increase is observed between the rate in dry nitrogen and air.

These results are consistent with the early observations⁽²⁾ that viscous creep in $\text{MgO} - \text{Fe}_2\text{O}_3$ increases with increasing concentrations of trivalent iron. Since increasing the $\text{Fe}^{+3}/\text{Fe}^{+2}$ ratio increases the concentration of magnesium ion vacancies in the lattice, it is apparent that the creep rate is sensitive to the $\text{Fe}^{+3}/\text{Fe}^{+2}$ ratio (i.e., magnesium vacancy concentration). These results are consistent with the proposal that viscous creep of $\text{MgO} - \text{Fe}_2\text{O}_3$ solid solutions is controlled by cation (magnesium) diffusion.

If in fact the creep rate (i.e., $\dot{\epsilon}$) is proportional to the cation diffusion coefficient (D_{Mg}), then

$$\dot{\epsilon} = k [V_{\text{Mg}}''] \quad (1)$$

$[V_{\text{Mg}}'']$ = concentration of cation vacancies

k = proportionality constant

A question of interest, therefore, is the following. Is the magnitude of the observed increase in creep rate consistent with pressure dependence of the vacancy concentration? In order to answer this question one must resort to a model for the defect structure. For the purposes of argument let us assume that the trivalent and divalent iron impurities substitute for magnesium ions and that the trivalent iron impurities are compensated by unassociated magnesium ion vacancies. Thus the incorporation of oxygen into the lattice can be described by the following quasi-chemical reaction:

in which

$\text{Fe}_{\text{Mg}}^{\text{x}}$ = divalent iron on cation site

$\text{Fe}_{\text{Mg}}^{\circ}$ = trivalent iron on cation site

O_0^{x} = oxygen ion site

$\text{V}_{\text{Mg}}^{\text{''}}$ = cation (magnesium) vacancy

Since 1% by weight Fe_2O_3 is a dilute magnesiowüstite solid solution, equation 2 may be a good representation of the mechanism of oxygen incorporation.

Using the law of mass action the following expression can be written for the incorporation reaction.

$$\frac{[\text{Fe}_{\text{Mg}}^{\circ}]^2 [\text{V}_{\text{Mg}}^{\text{''}}] [\text{O}_0^{\text{x}}]}{[\text{Fe}_{\text{Mg}}^{\text{x}}]^2 P_{\text{O}_2}^{1/2}} = K \quad (3)$$

in which

K = equilibrium (mass action) constant

P_{O_2} = partial pressure of oxygen

$[]$ = denotes concentrations

The overall electrical neutrality condition is

$$2 [\text{V}_{\text{Mg}}^{\text{''}}] = [\text{Fe}_{\text{Mg}}^{\circ}] \quad (4)$$

From a mass balance of iron one can write

$$[\text{Fe}_{\text{Mg}}^{\text{x}}] = [\text{Fe}]_{\text{T}} - [\text{Fe}_{\text{Mg}}^{\circ}] \quad (5)$$

$[\text{Fe}]_T$ is the total concentration of iron.

Substituting equations (4) and (5) into (3) gives

$$\frac{[V_{\text{Mg}}'']^3}{([\text{Fe}]_T - 2[V_{\text{Mg}}''])^2} = \frac{k}{4} P_{\text{O}_2}^{1/2} \quad (6)$$

For highly reducing conditions

$$[\text{Fe}]_T \gg [V_{\text{Mg}}'']$$

and

$$[V_{\text{Mg}}''] \propto P_{\text{O}_2}^{1/6} \quad (7)$$

Since the vacancy concentration (reducing conditions) varies as $P_{\text{O}_2}^{1/6}$, only small increases in the vacancy concentration (or creep rate) would be expected to accompany rather substantial increases in the oxygen partial pressure. This prediction is borne out by the results in Table I in that the creep rate increases by only a factor of 6 for many orders of magnitude change in P_{O_2} .

As P_{O_2} increases $[\text{Fe}]_T$ is no longer much greater than $[V_{\text{Mg}}'']$ and the vacancy concentration is given by equation (6).

If the viscous creep rate ($\dot{\epsilon}$) is assumed to be proportional to the vacancy concentration (i.e., equation (1)), then equation (6) can be rewritten as

$$\frac{(\dot{\epsilon})^3}{(A - \dot{\epsilon})^2} = B \cdot P_{\text{O}_2}^{1/2} \quad (8)$$

in which

$$A = \frac{k[\text{Fe}]_T}{2}$$

$$B = \frac{k^5 K}{16}$$

In order to see if equation (8) is a reasonable description of the pressure sensitivity of the steady state viscous creep rate, the data for experiments in air ($P_{O_2} = .18$ atm) and in dry nitrogen ($P_{O_2} \sim 10^{-5}$ atm) were used to calculate the constants A and B. A was $\sim 3 \times 10^{-4}$ and $B = 4.55 \times 10^{-2}$. Using these values and the creep rate ($.45 \times 10^{-4}$ /hr), the partial pressure of oxygen in the titanium gettered nitrogen was estimated to be $\sim 9 \times 10^{-10}$ atmospheres. This value is quite reasonable in view of the nature of the experimental system and outgassing effects which will cause the oxygen pressure in the N_2 to increase after it leaves the getter furnace.

In view of the preliminary success of this type of analysis, additional experiments are underway over a wide range of oxygen partial pressure, temperatures and dopant levels. The oxygen pressure will be controlled by CO_2/CO gas mixtures, mixed gases, and coexistence equilibria. Oxygen pressures will be measured with a stabilized zirconia probe (galvanic cell) at the specimen position in the furnace. In this way the steady state (viscous) creep rate will be determined as a function of P_{O_2} , $[Fe]_T$, and T . These data will be treated theoretically along the lines of the foregoing development.

F. Summary

A number of tentative conclusions can be drawn from the preliminary experiments which have been conducted on the effect of atmosphere on the creep at $1400^\circ C$ of polycrystalline MgO doped with 1% by weight Fe_2O_3 .

1. Steady state viscous creep (i.e., $\dot{\epsilon} \propto \sigma$) can be obtained over a range of stresses and atmospheres ($10^{-9} < P_{O_2} < 1$ atm) in specimens which have been

preannealed in order to stabilize the grain size.

2. Creep rates in air are approximately 6 times faster than those in highly reducing atmospheres (i.e., $P_{O_2} \sim 10^{-9}$ atm). These preliminary results are consistent with the concept that the creep rate is proportional to the cation vacancy concentration.

3. Non-viscous behavior (i.e., $\dot{\epsilon} \propto \sigma^N$ with $N > 1$) becomes important in the latter stages of the creep experiments particularly at high stress levels. In this stage the occurrence of void formation on tensile grain boundaries is consistent with the hypothesis that non-viscous grain boundary sliding processes may be important. The relative contributions to creep of the viscous and grain boundary sliding modes need to be evaluated.

V. THREE DIMENSIONAL GRAIN SIZE DISTRIBUTIONS

Measurements of the average grain size and distributions of grain sizes in a polycrystal are commonly performed by lineal analysis on a planar polished section. A problem of practical interest is finding the relation between the average grain size on a planar section ($\bar{L}$) with the actual average in three dimensions ($\bar{D}$). In order to obtain this relationship grain size distributions must be measured on a planar section in addition to average grain sizes^(5,7).

In connection with the recent study on the effects of impurities and porosity on grain growth in magnesium oxide,⁽³⁾ an extensive amount of grain size (linear intercepts) distribution data was collected. As a result it was decided that it would be useful to determine from these data the relationship between $\bar{L}$ and $\bar{D}$ in typical magnesium oxide microstructures.

If, in fact,

$$\bar{D} = K \bar{L} \quad (9)$$

how is K related to the properties of the grain size distribution (e.g., standard deviation)? In hot pressed magnesium oxide the initial grain size distributions are wide⁽²⁾. However, upon annealing they normalize rapidly. Does K vary with time during the normalization? Finally how does K vary with time if grain growth is not normal (i.e., $GS^2 - GS_0^2 = kt$ does not fit the data⁽³⁾)? To find answers to these questions it was decided to adapt the analyses of Cahn and Fullman⁽⁶⁾ and Mendelson⁽⁷⁾ to the grain size distribution data obtained on MgO. This analysis will comprise the senior thesis (presently under preparation) of Mr. David Marchant. In this report a brief outline of the procedure will be given.

In Figure 9 a typical histogram of linear intercepts is given for magnesium oxide doped with 0.10% Fe_2O_3 which has been annealed 189 hours in air at 1400°C . Approximately 270 intercept lengths (L) were measured by the method of chords⁽⁸⁾. In order to construct a smooth distribution curve, a cumulative probability plot versus $L/\bar{L}$ was constructed in Figure 10 from the raw data in Figure 9. A second degree equation was fitted to the data by least squares. Using this smooth curve a continuous frequency versus intercept length (L) plot was constructed in Figure 11.

In order to obtain a three dimensional grain size distribution the method of Cahn and Fullman⁽⁶⁾ was used. If $N(D)$ is the number of spheres of size D and $n(L)$ is the number of intercepts of length L , then according to Cahn and Fullman⁽⁶⁾

$$N(D)_{D=L} = \frac{-2}{\pi} \frac{d[n(L)/L]}{dL} \quad (10)$$

$$= \frac{2n(L)}{\pi L^2} - \frac{2}{\pi L} \frac{dn(L)}{dL}$$

These values, which were calculated by computer, are plotted in Figure 12 as the true three dimensional distribution.

Finally a cumulative probability versus $D/\bar{D}$ plot is constructed in Figure 13 from the data in Figure 12. A straight line passing nearly through $D/\bar{D} = 1$ at 50% probability is obtained. A distribution of grain sizes is said to be log-normal if on log probability paper a straight line is obtained which passes through $D/\bar{D} = 1$ at 50% cumulative probability⁽⁷⁾. Note that the distribution of intercepts was not log-normal (Figure 10). Assuming the distribution to be log-normal the standard deviation of $D/\bar{D}$ can be picked off the plot at 16 and 84% probability (i.e., $\log \sigma = 0.104$). Using this value for $\log \sigma$ the constant K relating $\bar{D}$ and $\bar{L}$ can be evaluated from an equation developed by Mendelson⁽⁷⁾

Figure 9 Histogram - Intercepts

Figure 10 Cumulative Probability Plot of Linear Intercepts

Figure 11 Smooth Distribution Curve of Linear Intercepts

Figure 12 Three Dimensional Distribution of Grain Sizes

for a log normal distribution of grain sizes with a tetrakaidecahedral shape, i.e.,

$$K = 1.7756 \exp (-2.5 \ln^2 \sigma) \quad (11)$$

For this particular distribution $K = 1.54$ which is remarkably close to 1.50 a value based on a two dimensional distribution obtained by cutting a plane through single sized spheres⁽⁷⁾.

In Table 2 a summary is given of σ and K for all grain size distributions which have been evaluated to date. Most of the K values for well annealed samples lie between 1.4 and 1.6 close to the commonly used 1.5. The K values are low (0.9 - 1.1) and the σ values are high (1.5 - 1.6) for the as hot pressed magnesium oxide (undoped, 0.10 and 0.48% Fe_2O_3 by weight) and for some of the annealed samples. These low values of K are probably due to abnormal grain growth situations⁽⁷⁾.

From the present data no systematic variation in K with time has been observed with the exception of an initial increase and an occasional decrease at some later time. It is known that in the initial hot pressed material the distributions are wide. The normalization (i.e., narrowing of the distribution) which occurs in the first 10 - 20 hours is probably responsible for the rise in the K values (~ 1 to ~ 1.5).

The isolated drops in K at later times (e.g., undoped 189 hours at 1400°C) are due probably to abnormal grain growth which was known to occur in these situations⁽³⁾.

In summary the methods of Cahn and Fullman and Mendelson in characterizing grain size distributions are proving to be informative particularly with respect to the identification of abnormal grain growth.

Figure 13 Cumulative Probability Plot of Grain Sizes

TABLE 2
SUMMARY OF GRAIN SIZE DISTRIBUTION PARAMETERS
IN MAGNESIUM OXIDE

<u>Temperature °C</u>	<u>Time (hours)</u>	<u>σ</u>	<u>K</u>
<u>Undoped</u>			
-	0	1.61	1.01
1400	49	1.31	1.47
	118	1.28	1.51
	189	1.61	1.01
1500	80	1.27	1.54
	80	1.39	1.35
	96	1.28	1.52
	159	1.35	1.42
<u>0.10% Fe₂O₃</u>			
-	0	1.69	0.89
1400	25	1.25	1.57
	118	1.29	1.49
	189	1.28	1.52
1500	80	1.28	1.52
	120	1.27	1.53
<u>0.48% Fe₂O₃</u>			
-	0	1.53	1.13
1400	25	1.25	1.56
	49	1.33	1.45
	118	1.28	1.52
	189	1.68	0.90
1500	80	1.23	1.59
	80	1.24	1.58

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