N87-16410

CREEP OF WEB RIBBONS

CORNELL UNIVERSITY

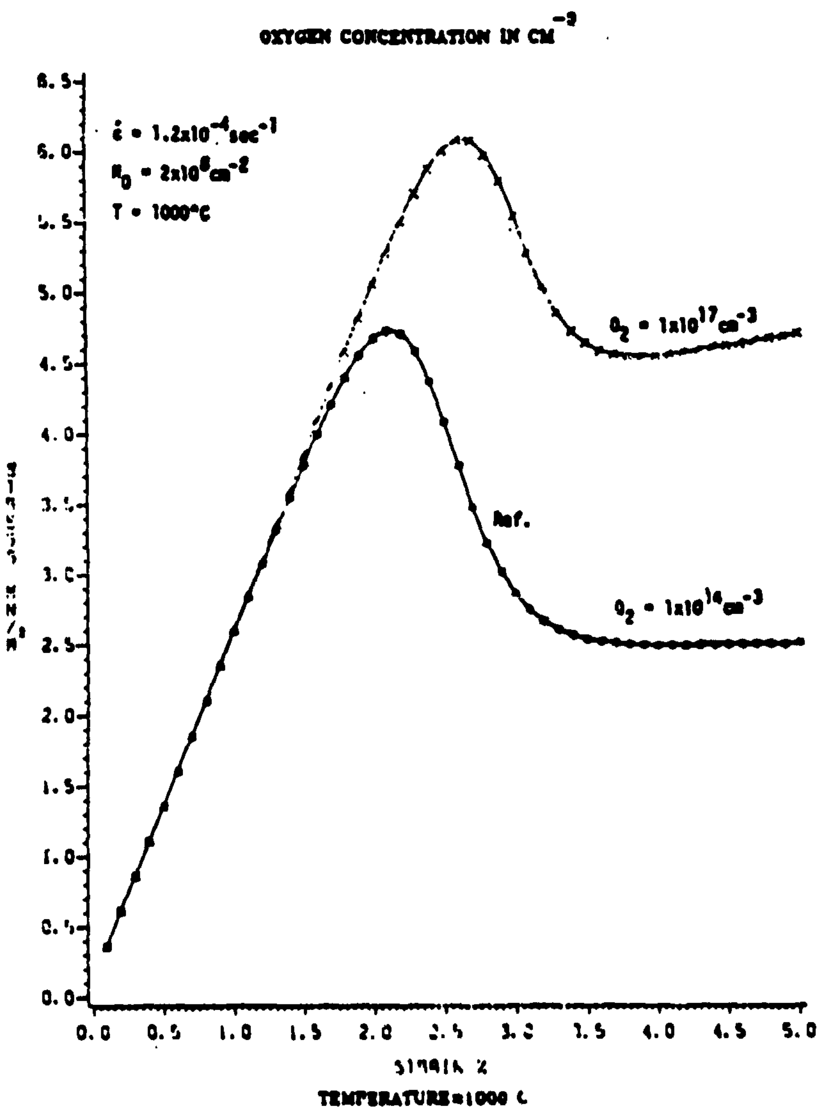
S. Hyland and D. G. Ast

1. Oxygen Content

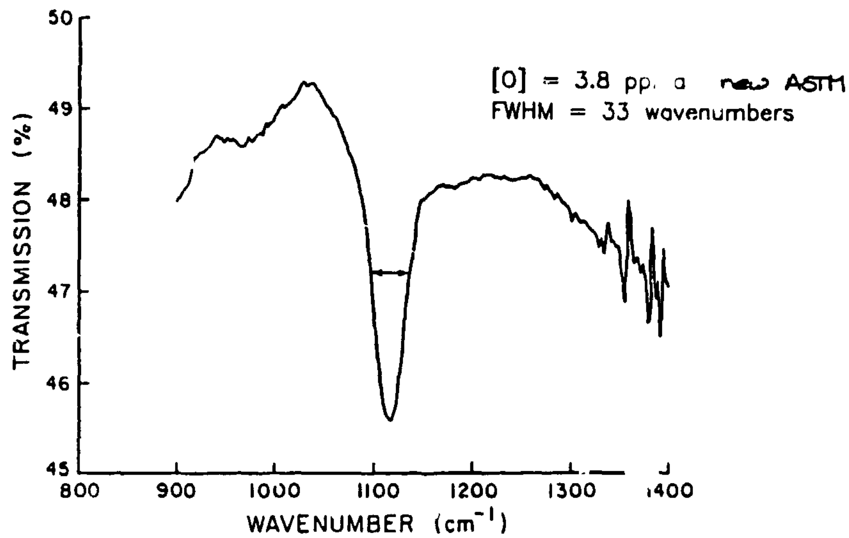
2. Creep Law

3. Microscopic Mechanisms

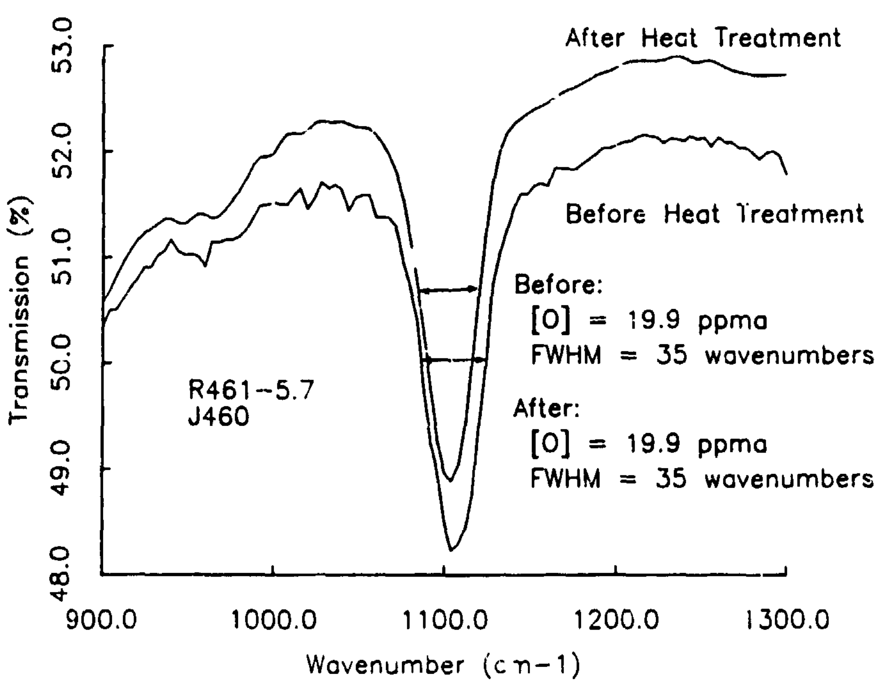
Silicon Sheet Growth and Characterization



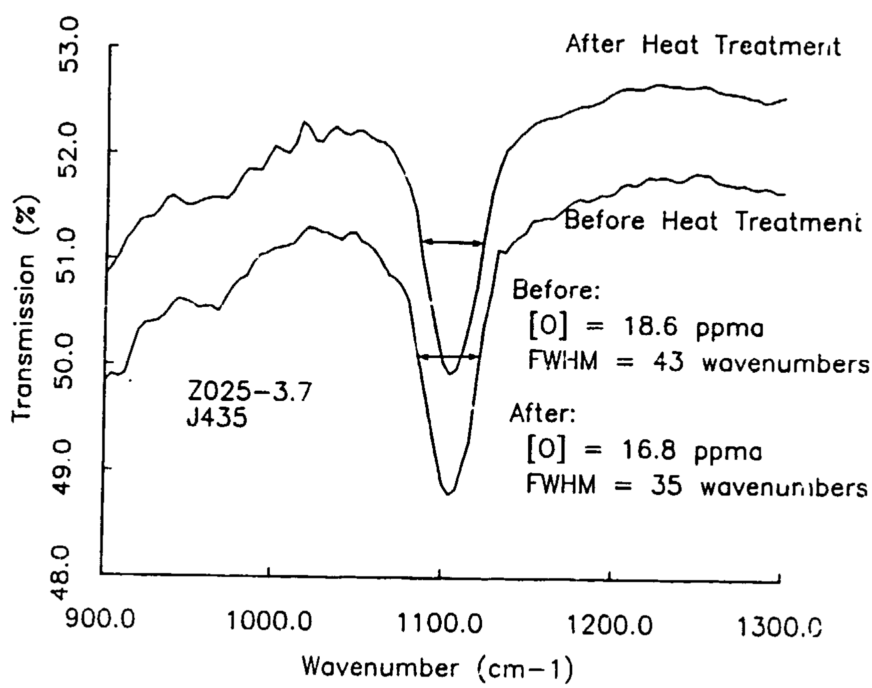
IR Transmission Versus Wavenumber for Cz Silicon



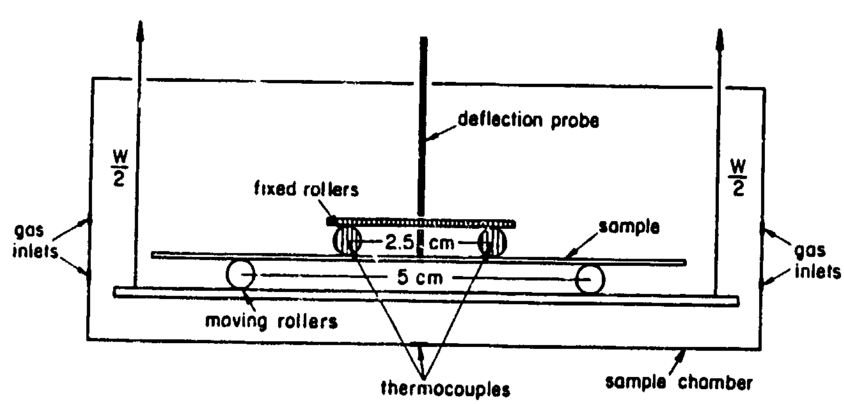
IR Transmission Versus Wavenumber for Low Stress Web
Before and After 850°C, 24-Hour Heat Treatment



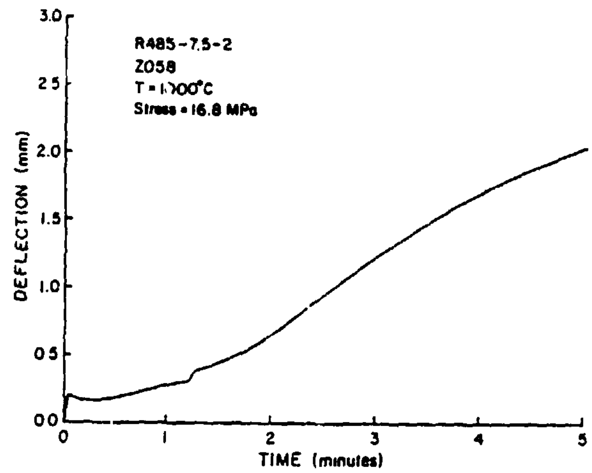
IR Transmission Versus Wavenumber for High Stress Web Before and After 850°C, 24-Hour Heat Treatment

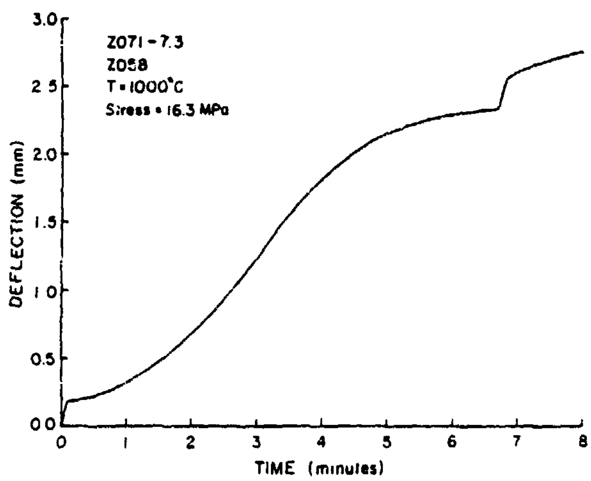


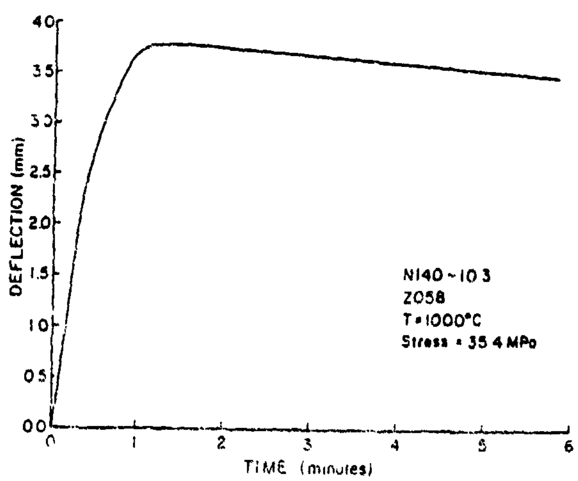
Four-Point Bending Rig at MSEC



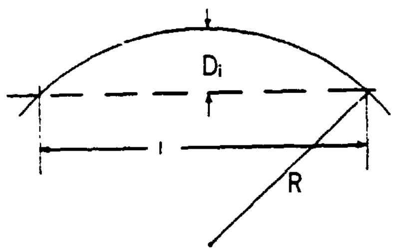
Deflection Versus Time for Web Silicon
Four-Point Bending







Preliminary Analysis of Four-Point Bending



h = sample thickness
B = sample width
ε_s = surface strain
σ_s = surface stress

$$R = h/(2\varepsilon_s)$$

$$D_i = R - R\cos[\arcsin\{l/(2R)\}] = l^2/(2R)$$

$$\text{for } D_i \ll R$$

combining:

$$\dot{\varepsilon}(z) = \frac{8\dot{D}_i}{l^2}\, z$$

Assuming a Power Law Creep

$$\dot{\varepsilon} = \dot{\varepsilon}_o\, \sigma^n$$

therefore, $\sigma(z) = [(8\dot{D}_i z)/(\dot{\varepsilon}_o l^2)]^{1/n}$

The stress can be determined from the slope of the deflection vs. time curve.

The moment is obtained from the stress:

$$M = 2B\int_0^{h/2} \sigma(z) z\,dz$$

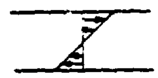
$$= 2B[(8\dot{D}_i)/(l^2\ \dot{\varepsilon}_o]^{1/n}$$

$$[n/(2n+1)][h/2]^{(2n+1)/n}$$

Preliminary Analysis of Four-Point Bending (Cont'd)

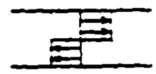
Under elastic loading:

$$\sigma_s = 6[M/(h^2B)]$$



Under plastic loading:

$$\sigma_s = 4[M/(h^2B)]$$



Kalejs uses an intermediate factor of 5.
We will use the plastic factor of 4.

experimentally,

$$\dot{D}_l = \frac{1}{7000}\,\sigma^3 \qquad l = 25\text{ mm},\quad h = 0.153\text{ mm}$$

leading to: $\dot{\varepsilon}_o = 8.8\text{x}10^{-8}\ \text{sec}^{-1}$

Creep Law:

$$\dot{\varepsilon} = 8.8\text{x}10^{-8}\ \sigma^3$$

σ in MPa, T = 1000°C

Data from Web Bending Tests

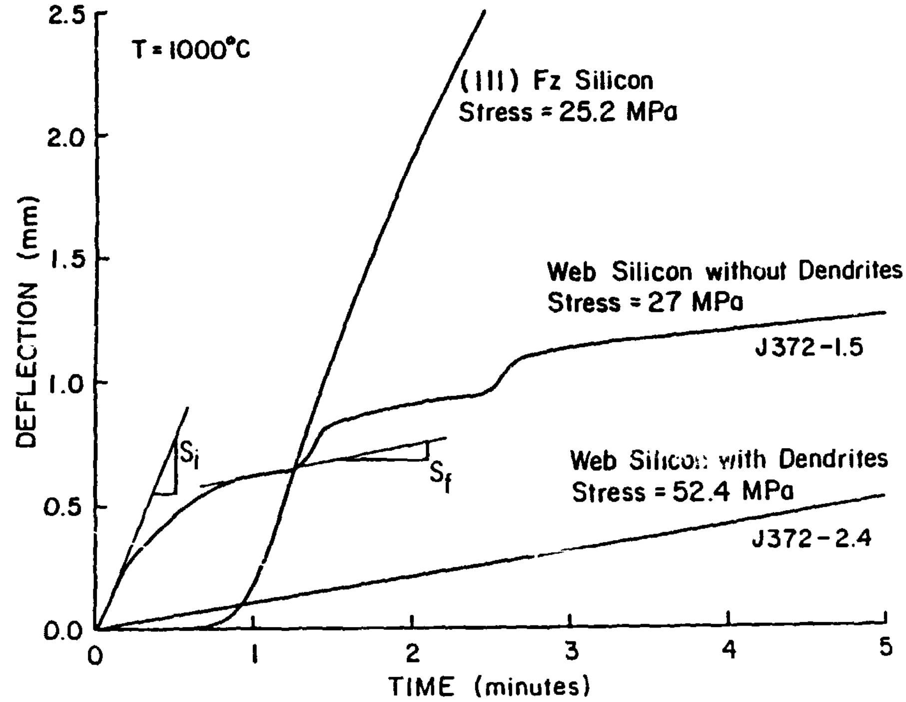
APPLIED STRESS (MPA)	EXPERIMENTAL S_I (MM/MIN)	POWER LAW FIT (MM/MIN) N=3
27	2	2.8
16.3	0.5	0.62
35.4	6	6.3
16.8	0.5	0.68
16.8	0.5	0.68
13*	0.1	0.3

* WEB WITH DENDRITES ON ASSUMING LOAD IS CARRIED BY SQUARE DENDRITES ONLY.

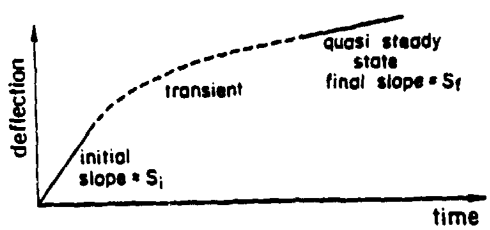
POWER LAW FIT. $S_I = \frac{\sigma^3}{7000}$

FROM FIT TO DATA

Deflection Versus Time for Web Silicon
Four-Point Bending



Predicted Deflection Versus Time Curve



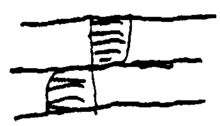
$S_F = S_I\ (1.5)^{-N}$

APPROXIMATELY = 0.3 TO 0.36 S_I FOR N = 2.5 - 3

ASSUME THAT THE MATERIAL DOES NOT CHANGE DURING THE TEST.

Initial stress distribution:

Final stress distribution:



Analysis of Strain Transition

Elastic: $D_i^e = [i^2/4Eh]\ \sigma_s$

Plastic: $D_i^p \cong \frac{1}{7000}\ \sigma_s^3 t$ (experimentally)

When does the elastic load distribution change to a plastic load distribution?

$$D_i^p = N\ D_i^e$$

assume $N = 5$:

a) $\sigma_s = 27$ MPa $h = 0.153$ mm
$i = 25$mm $E(111) = 1.9 \times 10^5$ MPa

$$t_{transition} = 15.5 \text{ sec}$$

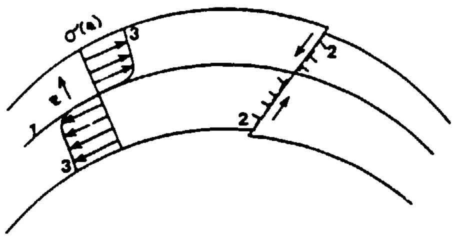
b) $\sigma_s = 16$ MPa

$$t_{transition} = 44 \text{ sec}$$

This order of magnitude seen for transition from S_i to S_f.

Load redistribution is responsible for the transition.

Analysis of Strain Bursts



There is no stress on a dislocation at the neutral axis(1).

A dislocation at the neutral axis will experience a stress due to the long range stress fields of following dislocations(2).

If the following dislocations are located in a part of the sample where they are under an applied stress(3), they may generate enough stress on the leading dislocation to push it through the neutral axis.

Therefore, if the length of a dislocation pile-up is some fraction of the thickness of the sample, such as in the case of Web silicon ribbons, there may be enough stress on dislocations at the neutral axis to cause them to move through, resulting in "strain bursts".

References

1. Change of misorientation with deformation due to trapped reaction products (Ge): J.J.Bachmann, M.O.Gay and R.Touremine, Scripta Met. 16 (1982) 535.

2. Influence of coherent twins on mechanical behavior (Ni): L.C.Lim, Scripta Met. 18 (1984) 1139; L.C.Lim and R.Raj, Acta Met. 32 (1984) 727ff and 1183ff.

3. General discuccion on interaction between grain boundary dislocations and lattice dislocations and their role in mechanical properties: L.C.Lim and R.Raj, Journal de Physique Colloque C4 (1985) 581.

4. Reactions between lattice dislocations and twins studied by TEM (Si): R.Gleichmann, M.D.Vaudin and D.G.Ast, Phil. Mag. A 51 (1985) 449.

Summary

4–Point Bending

Data consistent with
- –transient due to load redistribution
- –creep law, at 1000 deg C: $\dot{\epsilon} = 9 \times 10^{-8} \sigma^3$ (σ in MPa)

Observed creep slower for Web than for Cz

Oxygen Measurements

High Oxygen content of 20 ppma

Width of IR absorption peak greater for Web

Low stress ribbons–no change with annealing

High stress ribbons–width of peak decreases with annealing

Appearance of shoulder on IR peak is not predictable