Mechanical Properties of Al-based Amorphous Alloy Ribbons

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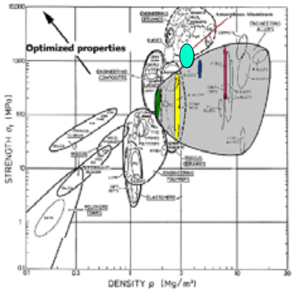
ABSTRACT

A well-balanced combination of strength and density is a necessary requirement for structural materials. Significant interest has arisen in amorphous aluminum alloys in recent years because of their high strength and light weight. The deformation behavior of Al-based amorphous alloys was characterized. A series of Al-based ribbons were produced via the melt spinning technique. High temperature microhardness indentation and uniaxial tensile tests were conducted over a range of temperatures to investigate the effects of changes in test temperature and chemical composition on the mechanical properties of these ribbons. Fatigue properties have been characterized via a fatigue ductility flex test. Furthermore, microstructural evolution and fracture surfaces were analyzed by a variety of analytical techniques, including X-ray diffraction, differential scanning calorimetry, laser confocal microscopy, and scanning electron microscopy.

DESIRED PROPERTIES FOR STRUCTURAL MATERIALS



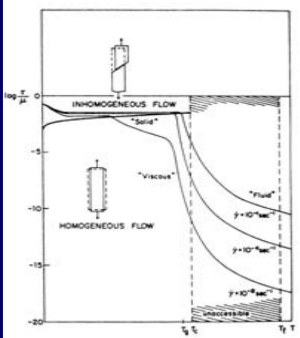
- Amorphous aluminum alloys
- Al alloys
- Ti alloys
- Mg alloys
- Steels

■ High strength ■ Good formability

■ Low density

M.F. Ashby, *Materials selection in mechanical design*. Permagon Press, New York, 1992.

DEFORMATION BEHAVIOR OF AMORPHOUS ALLOYS



■ Inhomogeneous flow:

- At temperature sufficiently below Tg
- Localized strain
- Shear bands formation
- Catastrophic failure

■ Homogeneous flow:

- At temperature around Tg
- slow strain rate
- Uniform deformation

F. Spaepen. *A microscopic mechanism for steady state inhomogeneous flow in metallic glasses.* Acta Mater. 1977; 25:407

MATERIALS

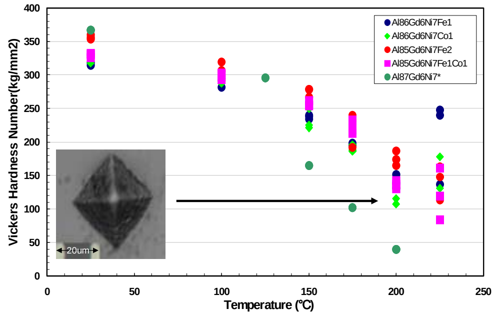
Al-RE-TM system amorphous alloy ribbons (at%):

- ■$Al_{86}Gd_6Ni_7Fe_1$
- ■$Al_{86}Gd_6Ni_7Co_1$
- ■$Al_{85}Gd_6Ni_7Fe_2$
- ■$Al_{85}Gd_6Ni_7Fe_1Co_1$

Materials were confirmed fully amorphous by XRD and DSC

As received specimen
Very high bend ductility was shown.

HIGH TEMPERATURE MICROHARDNESS



■ Chemistry changes to Al-Gd-Ni alloy by adding Fe/Co:

- ■ Increases VHN and strength vs. temperature
- ■ Reduces structure evolution at elevated temperature

HIGH TEMPERATURE TENSILE TEST

Test conditions:

RT, 100℃, 200℃

Heating rate=3K/min

Strain rate $\dot{\varepsilon} = 5\times10^{-4}\ sec^{-1}$ and $\dot{\varepsilon} = 1\times10^{-3}\ sec^{-1}$

Specimen geometry:

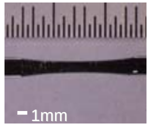
T=50μm

W=0.9mm

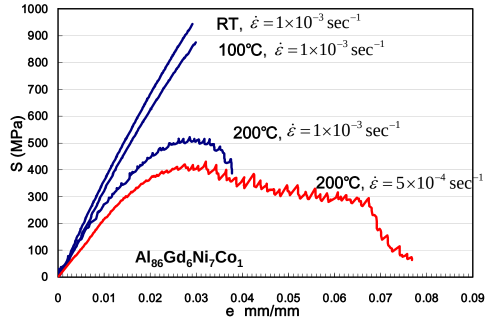
R=31mm

Gauge length=10mm

k_t~1



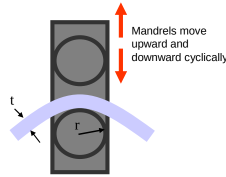
Specimen for tensile testing

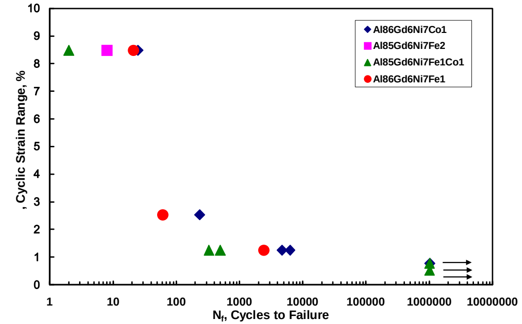


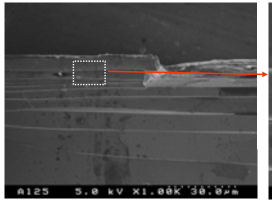
- ■ As T increases, elongation increases and flow stress decreases
- ■ As strain rate decreases, elongation increases and flow stress decreases
- ■ Transition from inhomogeneous to more homogeneous deformation

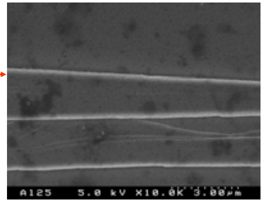
FATIGUE DUCTILY TEST

- ■ Bending over mandrels (ASTM E796-94)
- ■ Controlled cyclic strain
- ■ Stress ratio R=-1
- ■ Δ ε =t/r (t: ribbon thickness, r: mandrel radius)



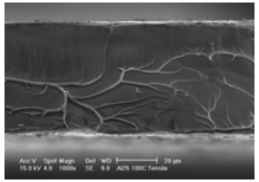


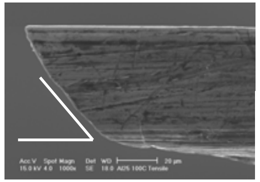




- ■$Al_{86}Gd_6Ni_7Co_1$ deformed at strain range=2.53%, specimen failed at 234 cycles
  - ■Cracks and shear bands were observed near fracture surface
- ■Fatigue limit was reached below a strain range of 0.78%
- ■Further investigation will utilize other cyclic strains

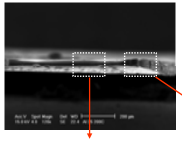
EXAMINATION OF FRACTURE SURFACES





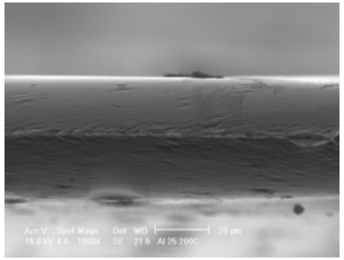
$Al_{86}Gd_6Ni_7Co_1$ deformed at RT, 100℃

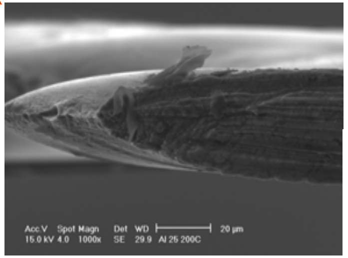
- ■ Specimens failed immediately after yielding
- ■ Specimens failed in shear
- ■ Vein fracture morphology



$Al_{86}Gd_6Ni_7Co_1$ deformed at 200℃ under $\dot{\varepsilon} = 5\times10^{-4}\ sec^{-1}$

- ■ Very high true fracture strain (> 250%)
- ■ Reduction in area > 99%
- ■ Ductile rupture





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