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DAMPING CAPACITY OF ARTIFICIALLY MULTILAYERED THIN FILMS

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SUMMARY

The results of the research conducted during the first year of this program (12/90 - 8/91) are summarized below:

(a)   An electrodeposition system has been assembled which is capable of producing high quality multilayered thin films.

(b)   Cu-Ni multilayered films with bilayer repeat lengths of 2.5 and 22 nm have been produced.

(c)   These films have displayed unusually large damping capacity over the frequency range 0.1 to 10 Hz, compared to typical metallic behavior.

REVIEW OF WORK

This program involves an experimental investigation of the damping capacity of artificially multilayered metallic thin films. These materials possess a high density of interfaces which can have a profound effect on the anelastic properties By varying the as-deposited bilayer repeat length, as well as using post-deposition anneals, it is possible to introduce in a controllable manner different defect structures. In this way, we will be able to study in a systematic manner various relaxation mechanisms. Also, as is discussed below, these materials possess very large loss factors compared to conventional metallic materials. The films are prepared using a single bath electrodeposition process that can potentially be scaled up to produce materials for bulk structural applications.

The first year milestones for this program are summarized below:

(a)   The electrodeposition process would be perfected such that high quality Cu-Ni multilayered thin films could be produced.

(b)   Damping properties of films with bilayer periods near 2 nm would be investigated. During the first year of this program (12/90 - present), we have been able to achieve both of these objectives. We have perfected our electrodeposition system [based on the design of Lashmore and Dariel, (1988)] and have produced (100) textured Cu-Ni films with bilayer repeat lengths of 2.5 and 22 nm. The texture and quality of the layering have been characterized by x-ray diffractometry. Figure 1 is a θ-2θ diffractometer scan for a film with a bilayer repeat length of 2.5 nm. The main Bragg peak at 51° is a (200) peak, while the Bragg peak at 43.7^O is a (111) peak.. These peaks show that the film has a strong (200) texture. The superlattice peaks off of the main (200) Bragg peak are due to the layering. The diffraction pattern shown in Figure 1 is typical for Cu-Ni multilayered films possessing that bilayer period produced by more common deposition methods, such as sputtering.

The damping capacity of films with bilayer repeat lengths of 2.5 nm (sample 52) and 25 nm (sample 53) were measured using using a Dynamic Mechanical-Thermal Analyzer (DMTA). These measurements were made in collaboration with C.R. Wong of the David Taylor Research

Center. The real part of the bending modulus and the loss factor were measured in the frequency range 0.1 to 10 Hz and temperature range -20 to 500°C. Figure 2 shows the loss factor versus the bending modulus. The overall trends can be summarized as follows:

(a)   The higher the temperature and the higher the frequency, the smaller the real part of the modulus.

(b)   The higher the frequency, the smaller the loss factor.

These trends are as expected, with relatively small scatter in the data. However, while the values for the real part of the modulus are reasonable, the loss factors seem remarkably large (between 0.5 and 2). As a comparison, previous measurements by Berry and Pritchett (1976) on evaporated Cu-Ni multilayered thin films gave loss factors of about 0.1. Our results may suggest that electrodeposited films may have significantly larger damping capacity than films produced by other methods, perhaps due to a large defect concentration. Given that the measurements of the real part of modulus are consistent with values predicted using bulk properties, it is not evident what possible experimental difficulties may be present that would give erroneously large damping values. Gripping of the films in the DMTA presented some problems, and new samples are being prepared with geometries that are more convenient for measurement in the DMTA we are using. In addition, we plan to set up (funds permitting) a vibrating reed apparatus that will gives us a second measurement of the damping capacity.

FUTURE WORK

We expect that in the coming year we will be able to obtain the following milestones:

(a)   Prepare and measure the damping capacity of Cu-Ni artificially multilayered thin films over a range of bilayer repeat lengths and with different crystallographic textures. From these measurements, we will determine how the damping capacity depends on the bilayer repeat length..

(b)   Transmission electron microscopy and x-ray diffraction of the films will be performed in   order to characterize the defect structure in these materials.

(c)   The activation energy for the damping behavior will be determined for each film by measuring the loss factor as a function of temperature.

From (a), (b), and (c), insight into the mechanism for the rather large damping capacity in these materials will be obtained.

(d)   Low temperature anneals will be performed in order to induce grain growth, allowing the effects of grain size to be investigated.

(e)   High temperature anneals will be used to create diffuse interfaces, allowing the study of the effects of interface sharpness on the damping behavior.

REFERENCES

Berry, B.S., and Pritchett, W.C., Thin Solid Films 33, 19 (1976).

Lashmore, D.S., and Dariel, M.P., Journal of the Electrochemical Society 135, 1221 (1988).
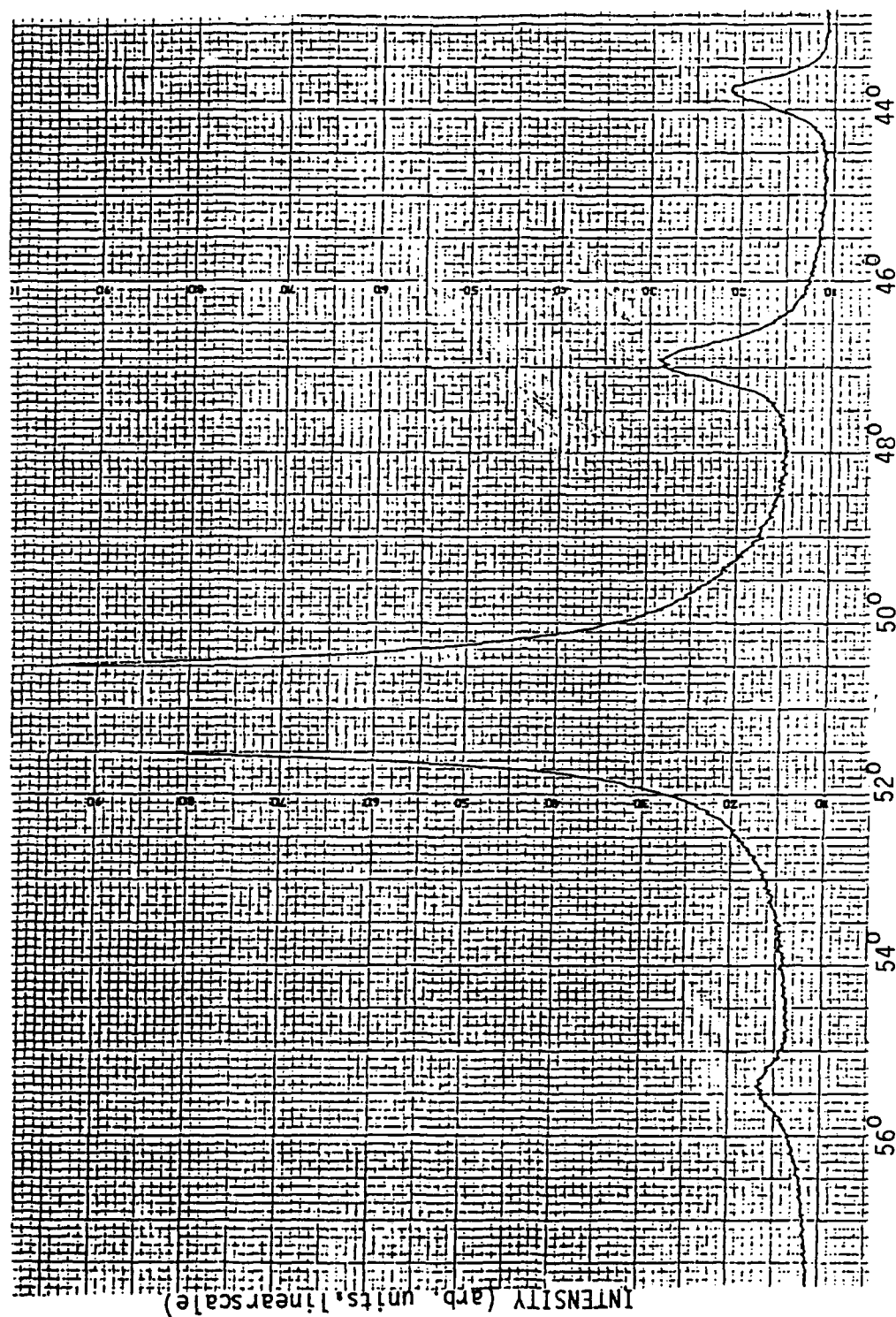
Figure 1. X-ray diffraction pattern for a Cu-Ni multilayered film with bilayer repeat length of 2.5 nm.

DAMPING CAPACITY VERSUS MODULUS FOR CuNi MULTILAYERED
FILM MEASURED FROM -20 TO 500°C AT 240 MICROSTRAIN.

Specific Damping Capacity (%)

Bending Modulus (MSI)

Bending Modulus (Pa)

Loss Factor (Tan delta)

- Sample 52 10 Hz first run
- Sample 52 1 Hz first run
- Sample 52 0.1 Hz first run
- Sample 52 10 Hz second run
- Sample 52 1 Hz second run
- Sample 52 0.1 Hz second run
- Sample 53 10 Hz first run
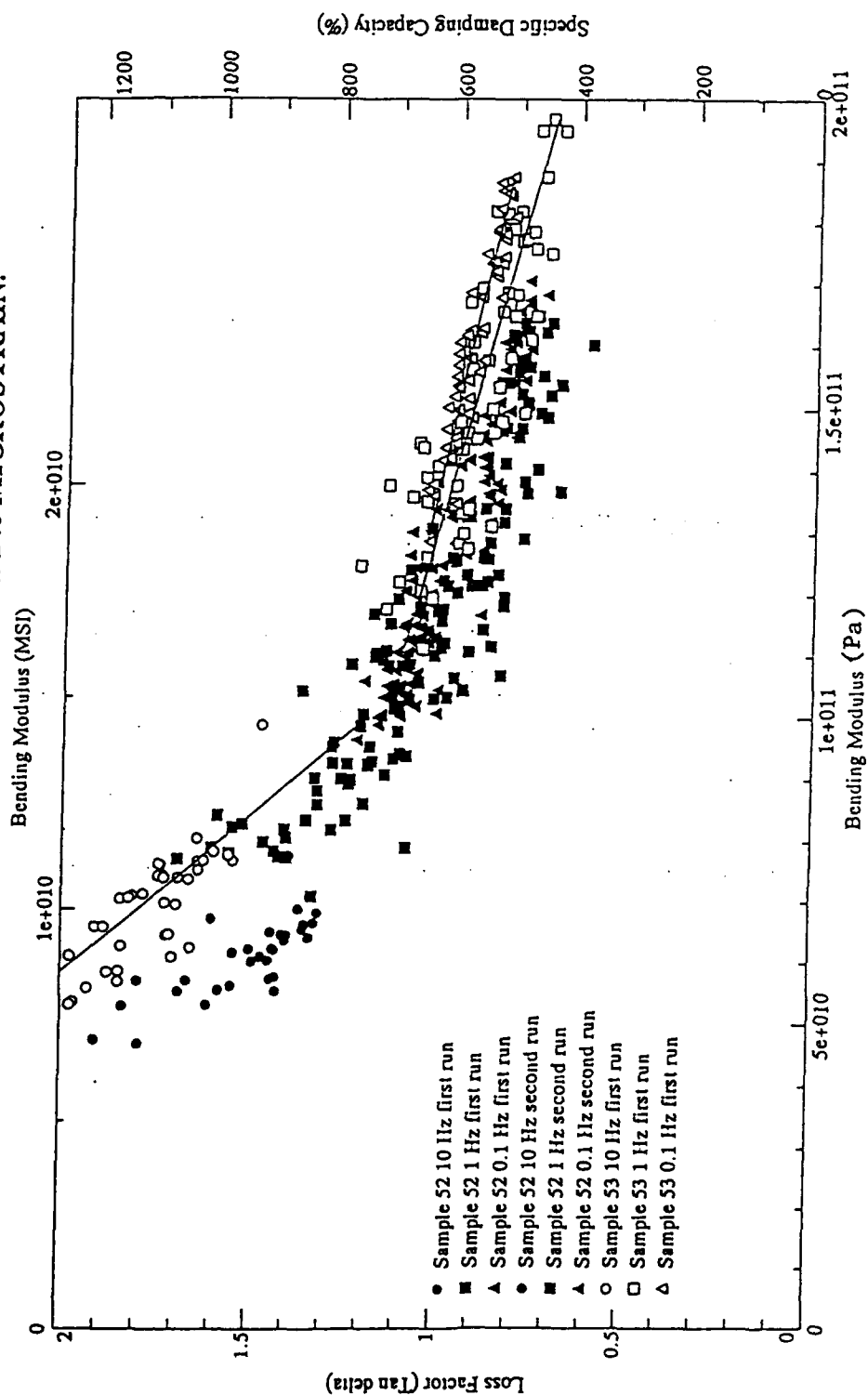- Sample 53 1 Hz first run
- Sample 53 0.1 Hz first run

Figure 2. Loss factor versus bending modulus for Cu-Ni multilayered thin films.