Development of Pt-IrO_2 Thin Films by an Internal Oxidation Process

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Introduction and Motivation

Common bulk alloy systems have been internally oxidized in the past for a variety of applications. Thin film systems have been successfully oxidized when there is a large driving force. Here, the possibility of oxidizing Pt-Ir thin films is explored. Both Pt and IrO_2 are used as electrode materials for MEMS applications, but each have reliability issues. Pt suffers from high residual stress and IrO_2 from a suspected brittle nature. Solid solution alloying has been successful at raising the strength of Pt, but not in reducing residual stress. A successful Pt-IrO_2 films, which would be Pt with conductive IrO_2 particles, might provide enhanced mechanical properties as a dispersion strengthened thin film.

Pt - (Ir or Ru) *Solid solution*

Pt - IrO_2 *Oxide dispersion*

Goals

- Identify a *new alloy system* that will improve the performance of a PZT-based MEMS device
- Develop the processing steps to obtain an oxide dispersion strengthened film, Pt - IrO_2.

Processing

Pt-Ir alloy films
- Sputtering co-deposition, 4.5 mtorr Ar
- Power varied to obtain different compositions
- 375 µm Si wafer (4" dia) / 300 nm SiO_2 diffusion barrier

Pt-IrO_2 films
- Sputtering co-deposition, 1.6 O_2 / Ar ratio
- Power varied to obtain different compositions
- Post annealing, 700°C for 4 hrs
- 375 µm Si wafer (4" dia) / 300 nm SiO_2 diffusion barrier

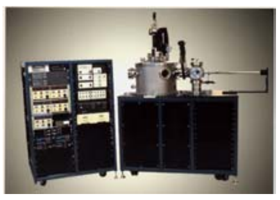
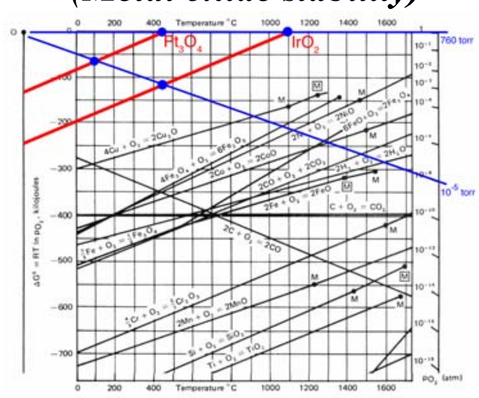



Image courtesy of AJA International

Ellingham diagram (Metal oxide stability)



- IrO_2 formation is thermodynamically favored.
- Kinetic limitations unknown.

Sample Characterization

X-ray Photoelectron Spectroscopy (XPS)
- Indicates bonding characteristics
- Depth sensitive

X-ray Diffraction (XRD)
- Indicates crystal structure
- Volume average

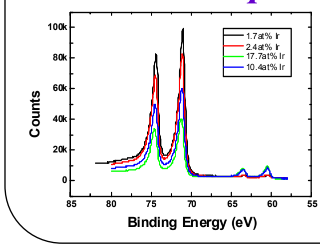
Atomic force microscopy (AFM)
- Measure film thickness
- Estimate grain size

Scanning electron microscopy (SEM)
- Film structure and estimate grain size

Transmission electron microscopy (TEM)
- Measure grain size
- Film structure, including information on dispersion alloying

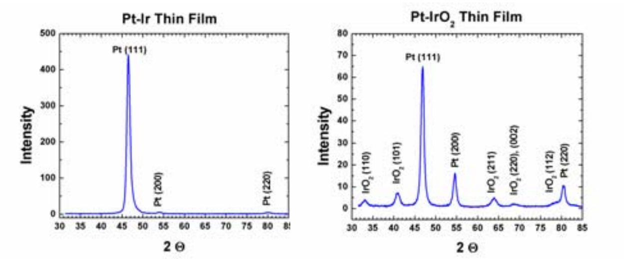
XPS Results

Sample Composition



- Sensitivity factors measured for pure films of Pt and Ir
- Compositions of alloy films measured
- Oxygen examined in Pt-IrO_2 films

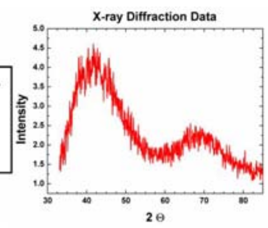
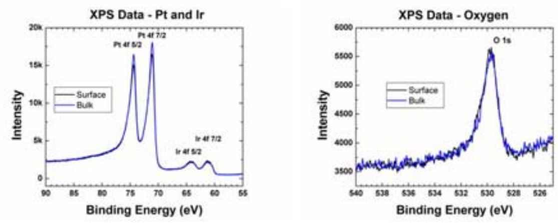
X-ray Diffraction – Texture Results



- The Pt-Ir films exhibited a strong (111) texture.
- Pt - IrO_2 films exhibited a random texture.

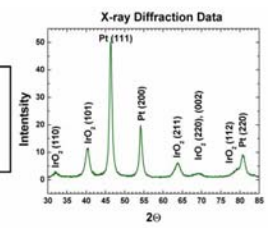
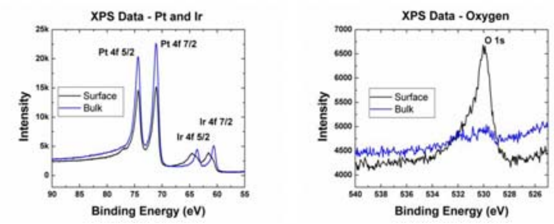
Sample Characterization for Pt-Ir-O film, 24.6 vol% Ir

As prepared

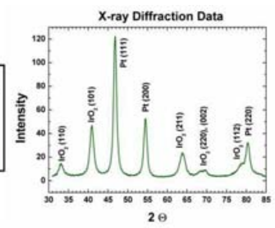
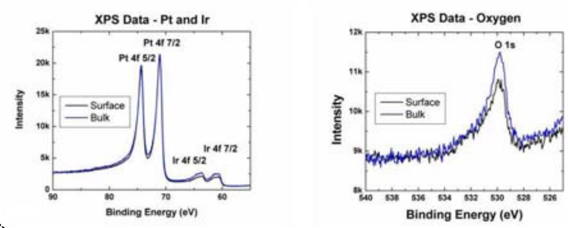
Sample Characterization for Pt-Ir-O film, 24.6 vol% Ir

Annealed, 600°C, Air, 1 hr

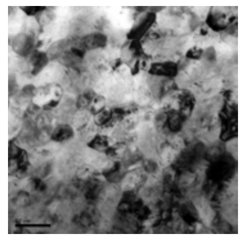
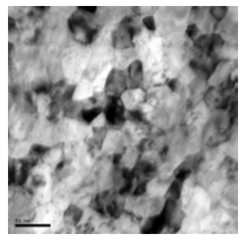



Sample Characterization for Pt-Ir-O film, 24.6 vol% Ir

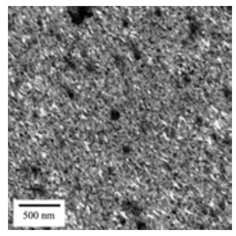
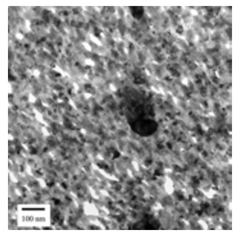
Annealed, 700°C, O_2, 4 hrs

Transmission Electron Microscopy (TEM)

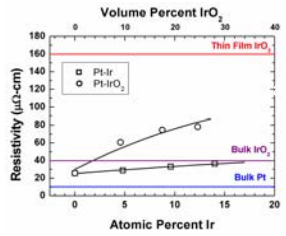
Pt- 4.8at%Ir   Pt- 9.6at%Ir

Pt- 24.6vol%IrO_2

Sheet Resistivity

Pt, Pt-Ir and Pt-IrO_2 Thin Films

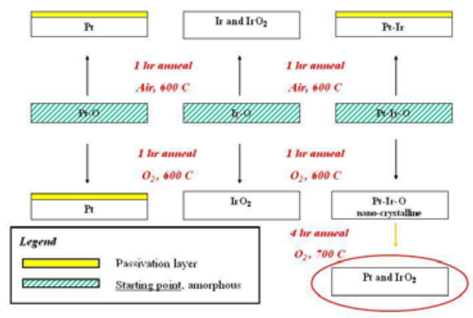


- The Pt-IrO_2 films have lower resistivity than pure IrO_2 films and are better suited for PZT/MEMS applications.

$$\rho_{alloy} = \rho_{Pt} + A\,(C_{Ir})\,(1-C_{Ir})$$

where, C_{Ir} = atomic fraction of solute Ir,
A = Nordheim coefficient for Ir in Pt = 230 µΩ-cm

Processing Paths



Conclusions

- A unique fabrication technique for Pt-IrO_2 "dispersion" strengthened films has been demonstrated.
- Electrical resistivity is slightly higher than bulk IrO_2.
- Pt-IrO_2 thin films have potential application as hybrid electrodes for MEMS applications.

References

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- Richard R. Chromik, Thirumalesh Bannuru and Richard P. Vinci, "Internal oxidation and mechanical properties of Pt-IrO_2 thin films." *Mater. Res. Soc. Symp. Proc.*, Vol. 795, 2004, P. U 8.13.1-U 8.13.6

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