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Propagating Exothermic Reactions in Al/Pt Multilayers of Varied Composition

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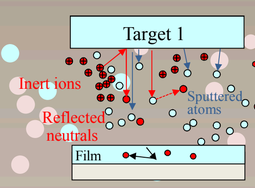
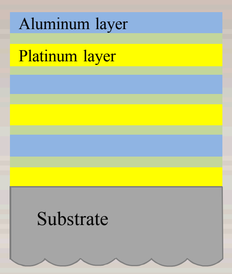
Process parameters and initial deposited multilayer structure

Sputter deposition of reactive films



Sputtering process used for Al/Pt

- Chamber base pressure: 10^{-7} Torr
- Throttled chamber pressure: 10 mTorr ultra-high purity Ar
- Each material was sputtered at rates in the range from 200-400 Å/min.
- DC magnetron sputtering for both sources
- No deliberate heating or substrate cooling.
- Estimated deposition temperature ~ 50°C.



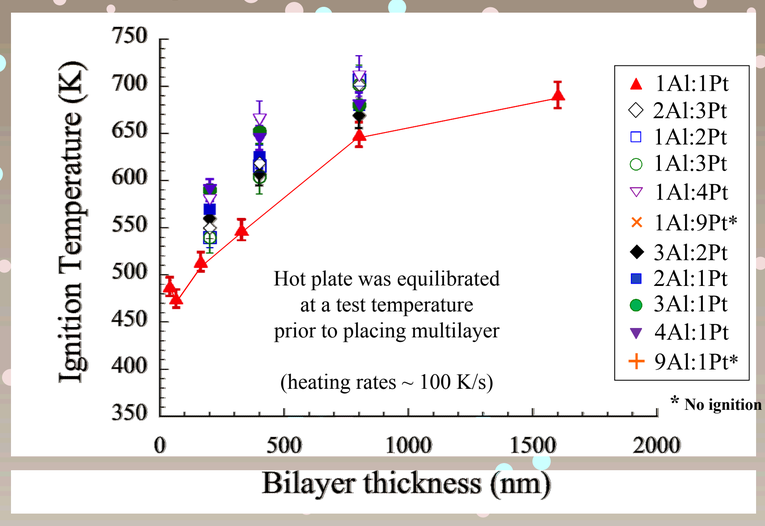
Characteristics of Al/Pt Multilayers

- Aluminum and platinum are grown in alternating thin film layers.
- Single periodicity (bilayer thickness) for
- The reactive layers undergo intermixing at the Al/Pt interface during film growth.
- The intermixed layer (documented below) has been shown in prior work to have an effect on stored chemical energy and propagating reactions.

Abstract

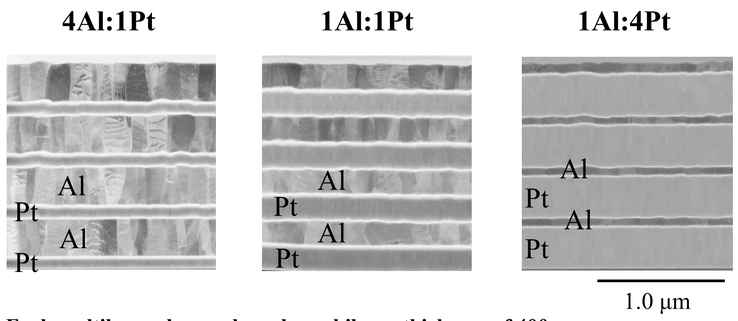
The propensity of sputter-deposited Al/Pt multilayers to undergo rapid, self-propagating formation reactions has been evaluated across broad ranges of stoichiometry and reactant layer thickness. Experiments demonstrate self-propagating, high temperature reactions in ~1.6 μm-thick Al/Pt multilayers when the molar ratio of reactants is in the range of 4Al:1Pt to 1Al:4Pt (includes specified limits). High-speed videography shows that equimolar Al/Pt multilayers undergo the most rapid reactions with wavefront speeds as large as 80 m/s. Al- and Pt-rich multilayers react at reduced rates with speeds as low as 1 m/s. Nearly all of the tested multilayers undergo stable, propagating reactions characterized by a smooth, reaction wavefront morphology. Only multilayers made with a 1Al:4Pt molar ratio and large bilayer thickness (800 nm) exhibit a 2-D (spin-like) instability. Ignition temperatures and flame temperatures also show related bilayer thickness dependencies.

Ignition Temperatures



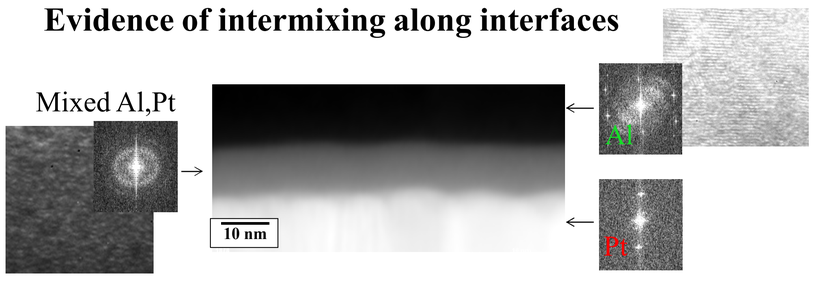
Observations prior to ignition

Sectioned Al/Pt films (3 compositions) viewed in a scanning electron microscope (SEM)

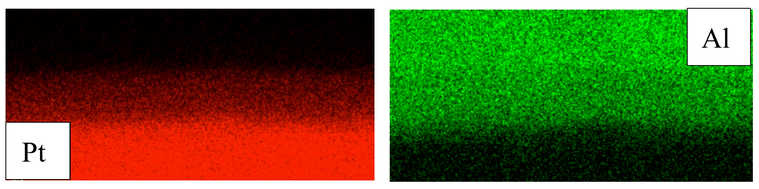


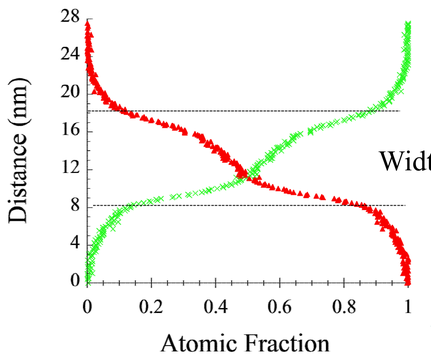
Each multilayer shown above has a bilayer thickness of 400 nm.
Images were obtained using a STEM detector in the SEM.

Evidence of intermixing along interfaces



Energy Dispersive Spectroscopy (EDS): portion of one bilayer



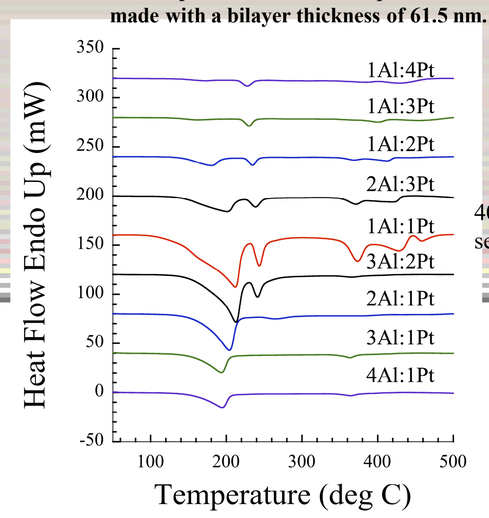


Plot of local composition obtained from EDS using a probe aberration corrected transmission electron microscope (AC-TEM)

Measured heats from calorimetry

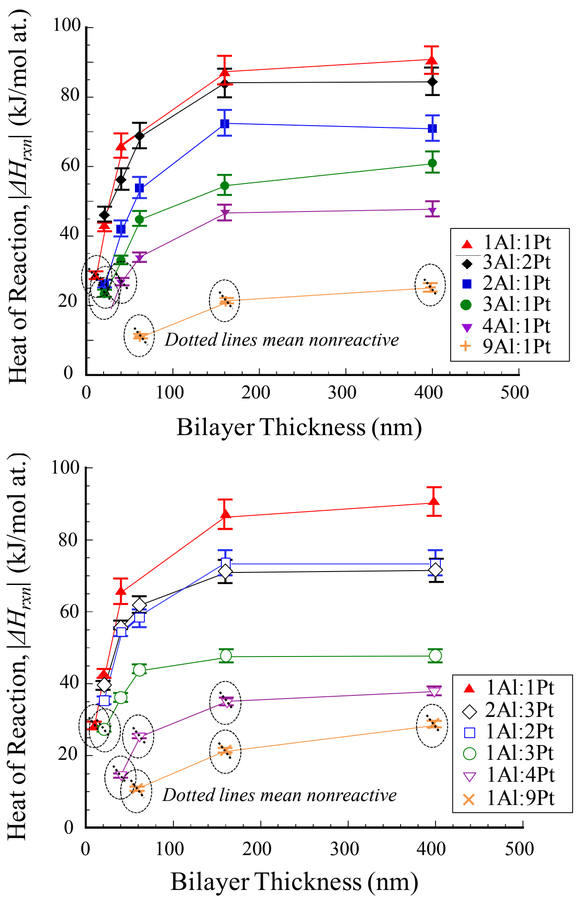
Thermograms from differential scanning calorimetry (DSC)

All samples described in this plot were made with a bilayer thickness of 61.5 nm.



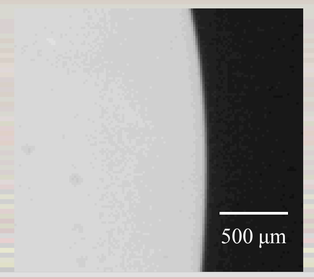
40 C/min, N_2, sealed Cu pan

Heats of reaction

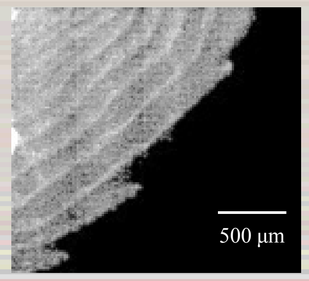


Results from high speed videography (after point ignition)

Reaction wavefront morphology

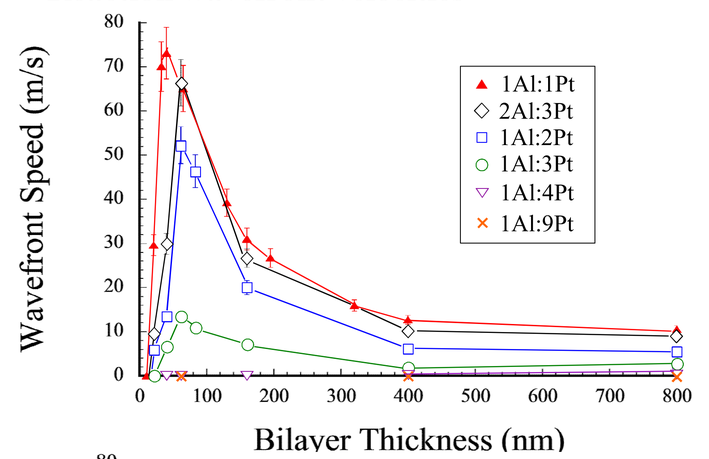


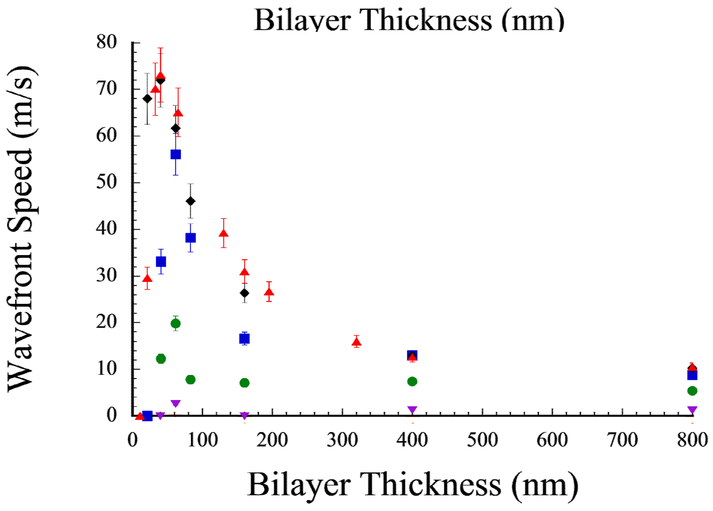
All multilayer designs (except for the one listed on right) undergo stable propagation characterized by a smooth wavefront morphology.



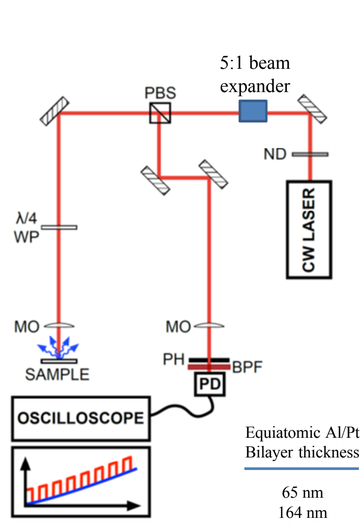
Only multilayer exhibiting a 2-D (spin) instability.
Composition is 1 Al: 4 Pt.
Bilayer thickness = 800 nm.

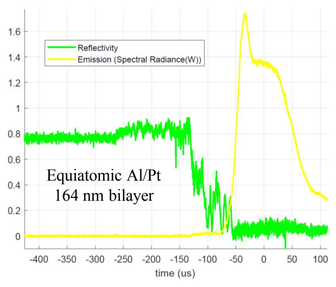
Reaction wavefront velocities

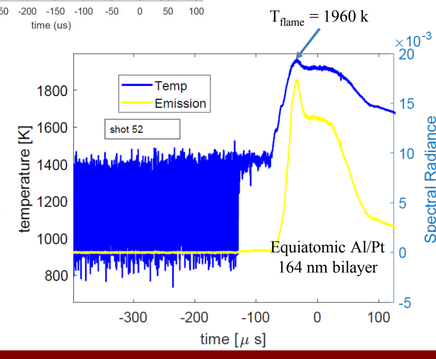




Reaction wavefront temperatures







Equiatomic Al/Pt Bilayer thickness	Average Measured T_{flame}
65 nm	1950 K
164 nm	2000 K
328 nm	2100 K
800 nm	2000 K

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