Tungsten Sputtering Film using AJA#2 Sputter with Xe/Ar

Objective: To study the sputtering rate, resistivity, and stress of tungsten films using AJA#2 sputtering tool with Xe/Ar as working gases.

Experimental: Tungsten films were sputtered onto thermally-oxidized Si pieces (~500nm thick SiO2) for 4-probe resistivity measurements (after the resistivity measurements, these pieces were cleaved for SEM to get the film thickness as well as cross-section profile) and 4" Si wafers for stress measurements. Prior to each film sputtering, the chamber were W coated for 10 min. The gun angle, z-distance (the sample height), and sample rotation speed were set to 5, 2.75, and 10rpm, respectively.

Results and Discussions:

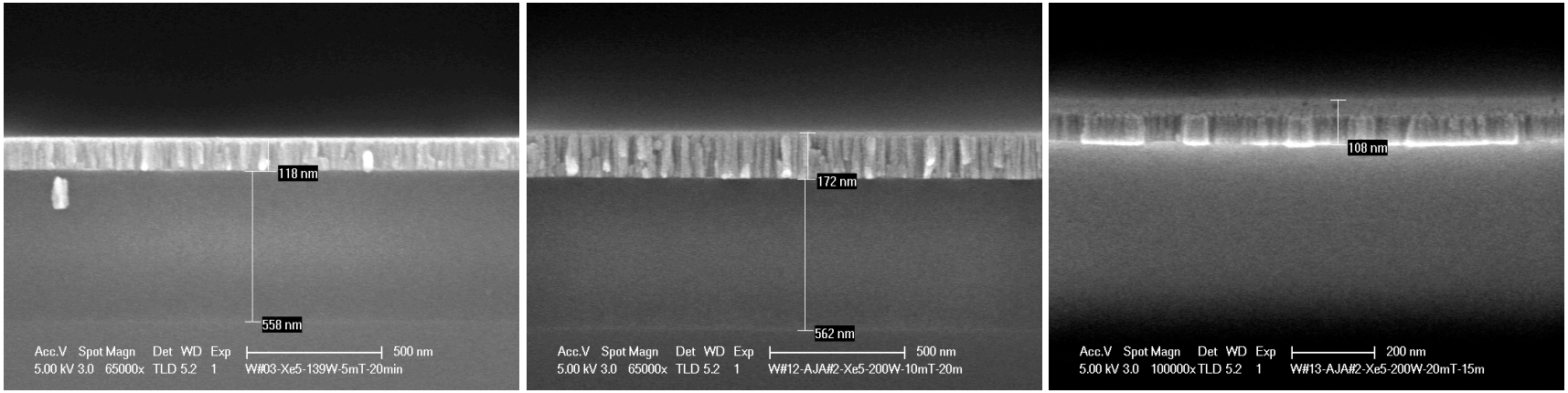
a) Sputtering W with the use of Xe.

Table 1

W Sputtering Film using AJA#2 with Xe [Power=200W (except at 5mT: power=140W), Xe Flow-rate=5sccm, Gun-angle=5, z=2.75, Rotation speed=10rpm]			
Pressure (mT)	Sputtering Rate (nm/min)	Resistivity (Ohm-cm)	Stress (MPa)
5	5.95	1.3E-03	-277.7
10	8.65	4.3E-03	-178.77
20	7.27	1.3E-02	N/A

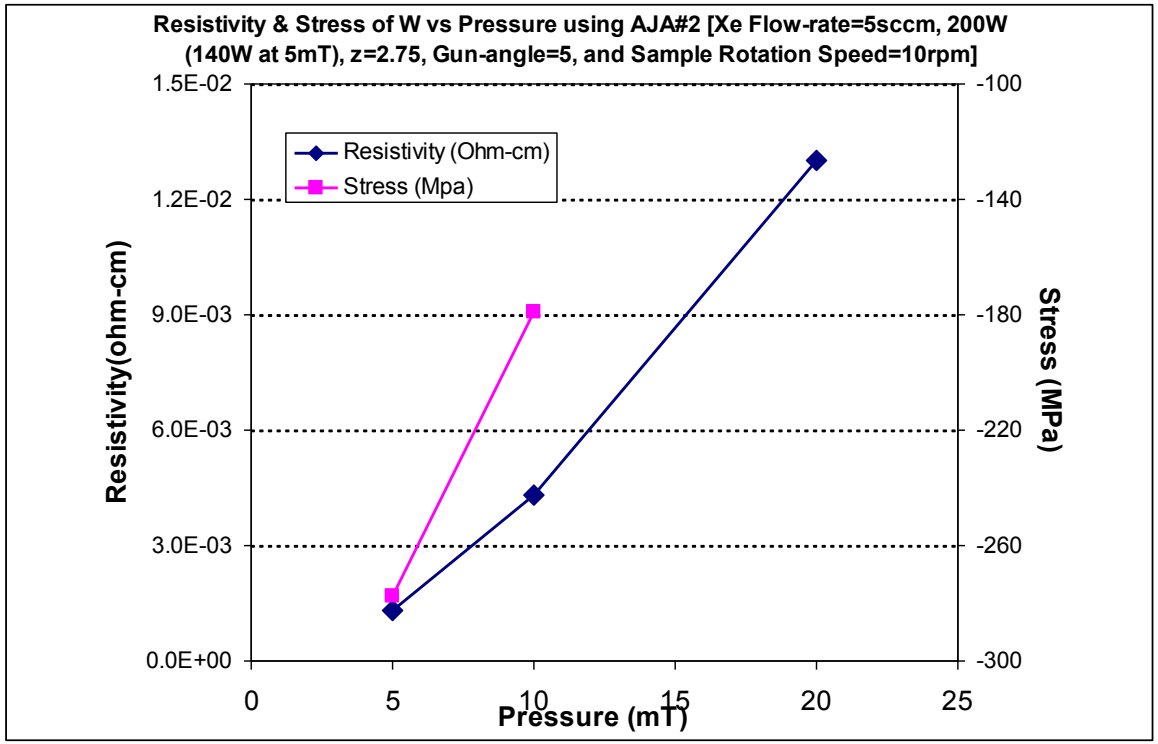
The sputtering rate of W films increases from 5.95 to 8.65 nm/min as the pressure increases from 5 to 10mT, then, drops to 7.27 nm/min as the pressure increases further to 20mT.

Figure 1 Cross-section of the W films sputtered using Xe: a)5mT; b)10mT; c)20mT.



(a) (b) (c)

Figure 2 Resistivity and stress of W film as functions of pressure with the use of AJA#2 sputter. The sputtering parameters are Xe flow-rate=5 sccm, power=200W (except at the pressure of 5mT: 140W), z=2.75, gun-angle=5, and rotation-speed=10rpm.



As one can see from Figure 2, the resistivity increases, while the absolute value of stress decreases, with the increase of pressure. Also, it is noted that the absolute values of the resistivity are very high, which are in the range of E-03 to E-02, and the stress is compressive, as indicated by a negative sign.

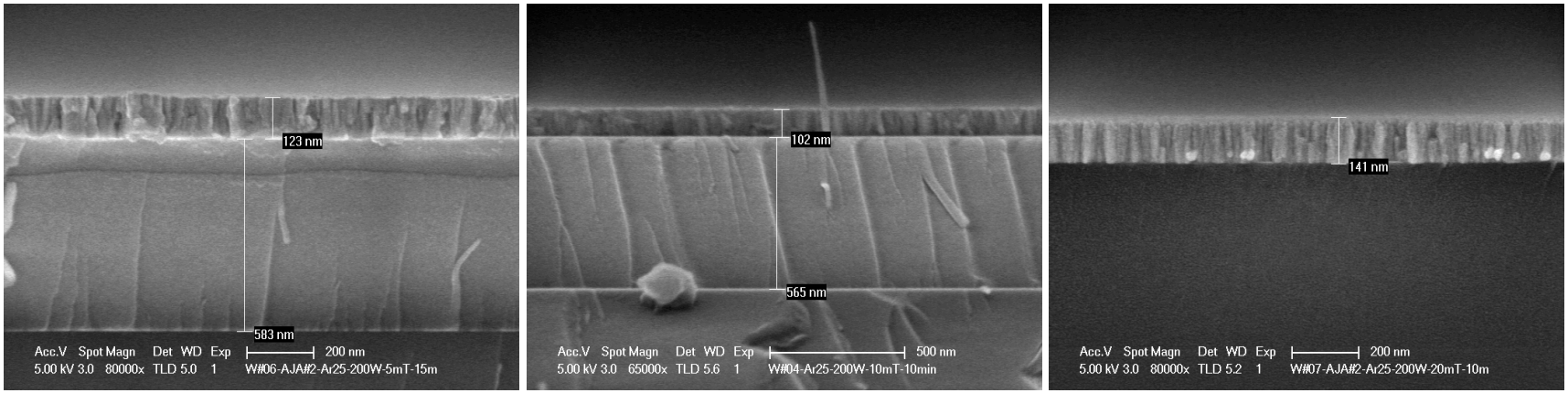
b) Sputtering W with the use of Ar.

Table 2

W Sputtering Film using AJA#2 with Ar [Power=200W, Ar Flow-rate=25sccm, Gun-angle=5, z=2.75, Rotation speed=10rpm]			
Pressure (mT)	Sputtering Rate (nm/min)	Resistivity (Ohm-cm)	Stress (MPa)
5	8.4	3.0E-05	2075.7
10	10.4	5.1E-04	186.64
20	13.6	3.2E-03	-210.89

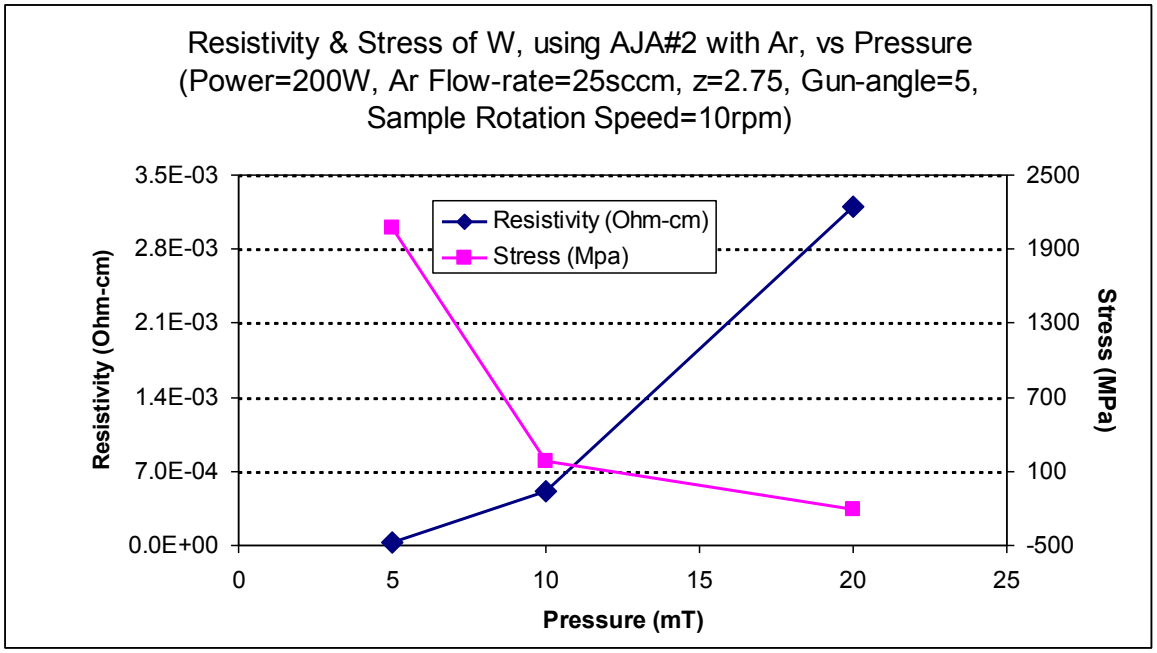
The sputtering rate of W film increases with the increases of pressure.

Figure 3 Cross-section of the W films sputtered using Ar: a)5mT; b)10mT; c)20mT.



(a) (b) (c)

Figure 4 Resistivity and stress of W as functions of pressure with the use of AJA#2 sputter. The sputtering parameters are Ar flow-rate=25 sccm, power=200W, z=2.75, gun-angle=5, and rotation-speed=10rpm.



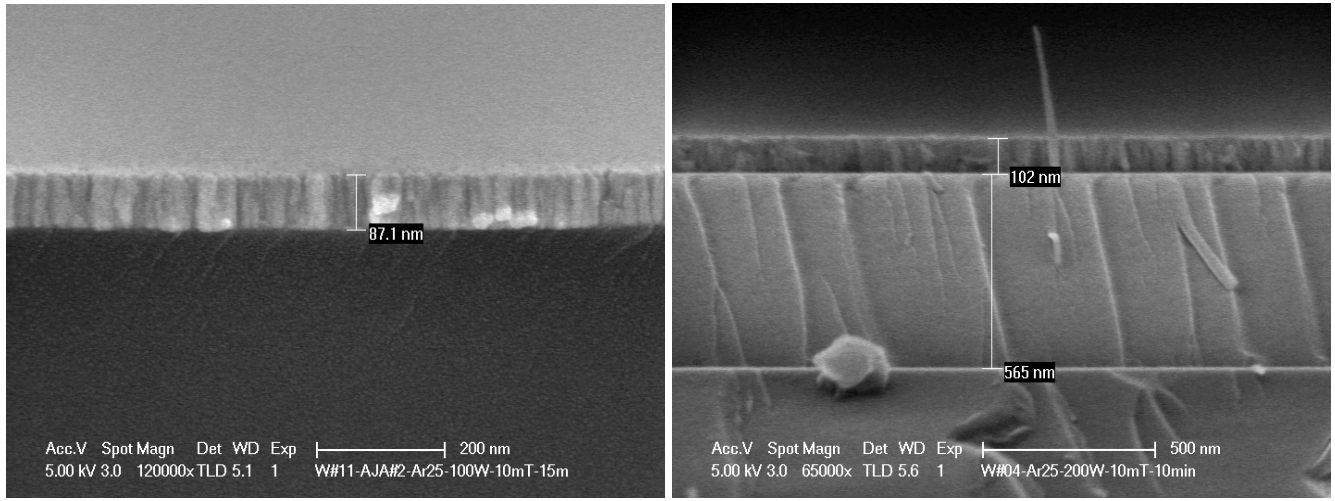
As seen from Figure 4, the resistivity increases with the increase of pressure, while the stress is tensile and decreases as the pressure rises from 5 to 10mT, then, becomes compressive as the pressure further rises to 20mT. The absolute values of the resistivity are lower in comparison with those of the W films sputtered using Xe.

Table 3

W Sputtering Film using AJA#2 with Ar [Pressure=10mT, Ar Flow-rate=25sccm, Gun-angle=5, z=2.75, Rotation speed=10rpm]		
Power (W)	Sputtering Rate (nm/min)	Resistivity (Ohm-cm)
100	5.74	9.2E-04
200	10.4	5.1E-04

As noted from Table 3, the sputtering rate of W increases, while the resistivity decreases, with the increase of the power from 100 to 200W.

Figure 5 Cross-section of the W films sputtered using Ar: a)100W; b)200W.



(a) (b)

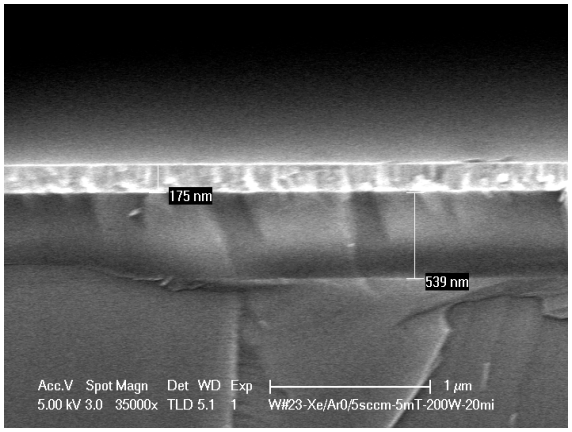
c) Sputtering W with the use of Xe/Ar.

Table 4

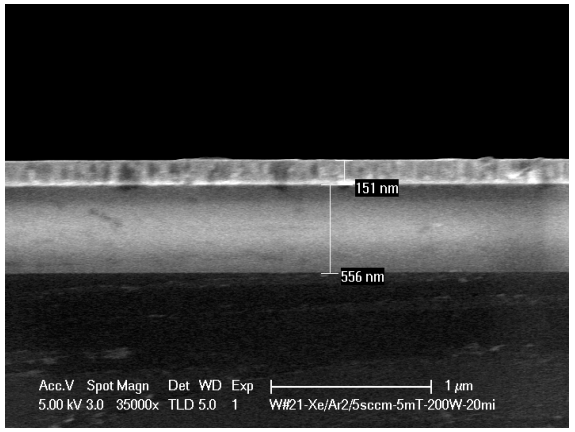
W Sputtering Film using AJA#2 with Xe and Ar [Pressure=5mT, Power=200W, Ar Flow-rate=5sccm, Gun-angle=5, z=2.75, Rotation speed=10rpm]					
Xe Flow Rate (sccm)	Sputtering Rate (nm/min)	Resistivity (Ohm-cm)	Stress (MPa)	DC Voltage (v)	DC Current (A)
0	8.6	4.8E-05	2326	390	0.511
2	7.5	3.3E-04	650	508	0.393
5	8.15	5.9E-04	222	550	0.363

It is noted that the sputtering rate of W decreases from 8.6 to 7.5 nm/min as the Xe flow-rate increases from 0 to 2sccm, and increases to 8.15 nm/min as it further increases to 5sccm.

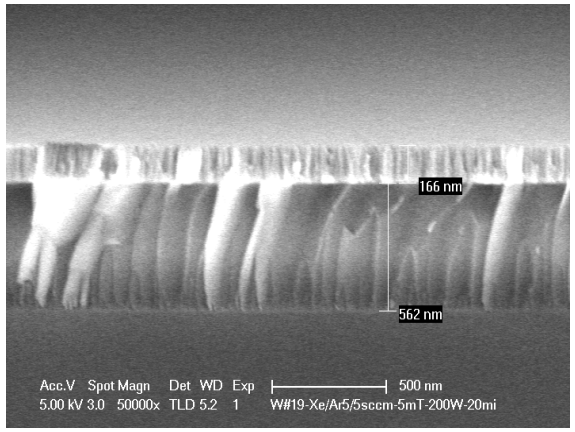
Figure 6 Cross-section of the W films sputtered using Xe/Ar(5sccm): a)Xe flow-rate=0; b)2sccm; c)5sccm.



(a)

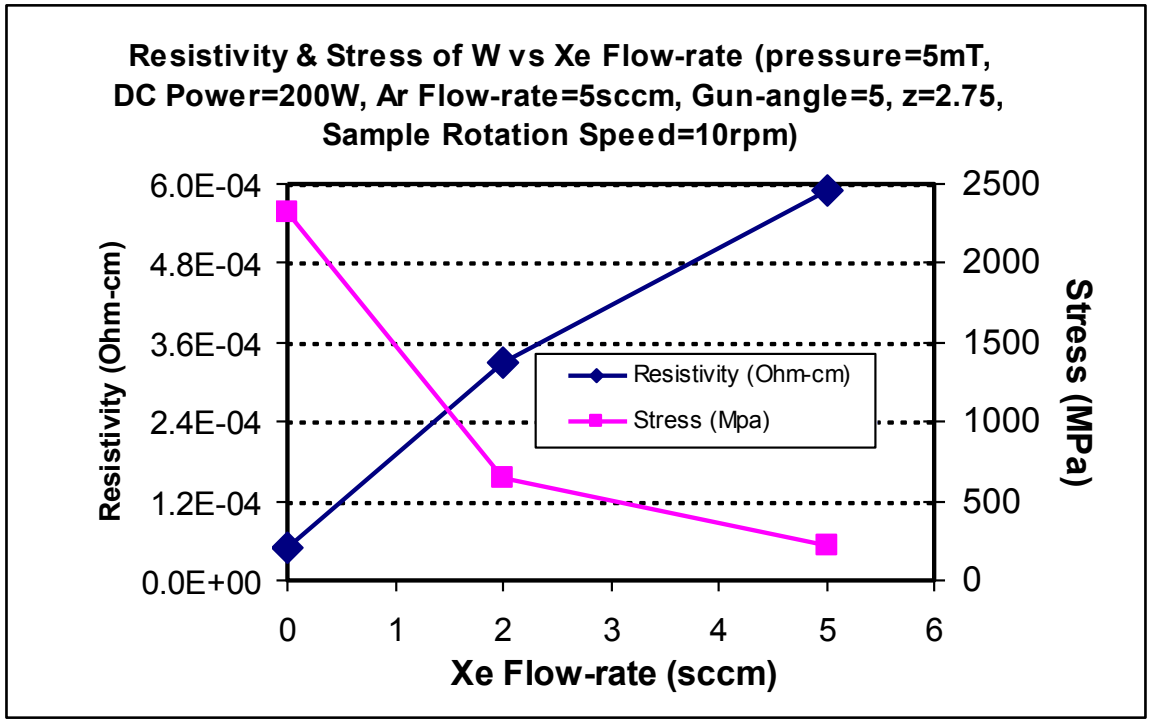


(b)



(c)

Figure 7 Resistivity and stress of W as functions of Xe flow-rate, while keeping Ar flow-rate at 5 sccm, with the use of AJA#2 sputter. The rest of the sputtering parameters are: pressure=5mT, power=200W, z=2.75, gun-angle=5, and rotation-speed=10rpm.



As seen from Figure 7, the resistivity increases, while the tensile stress decreases, with the increase of Xe flow-rate.

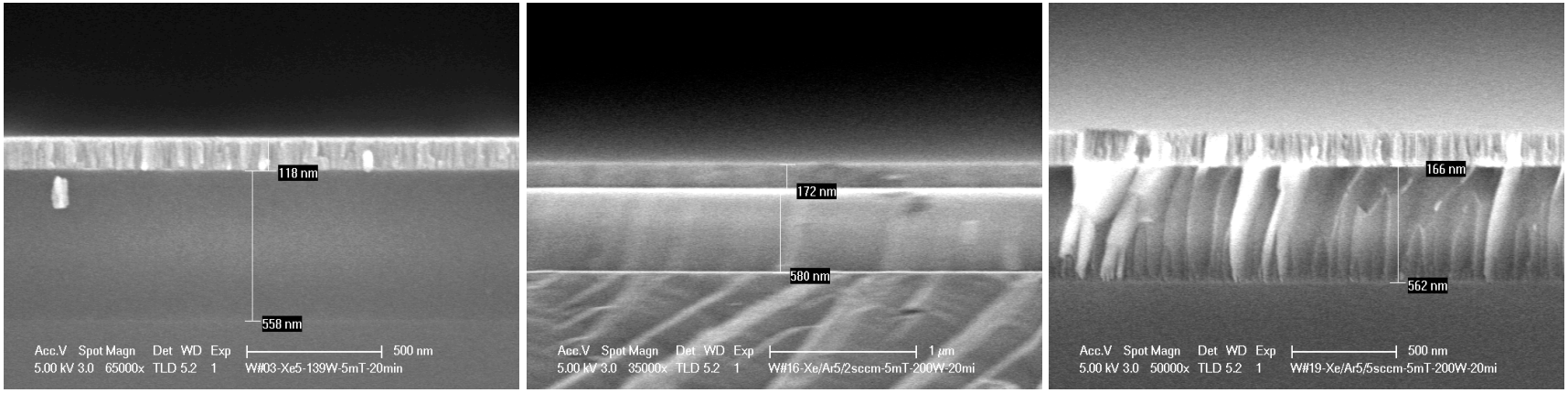
Table 5

W Sputtering Film using AJA#2 with Xe and Ar [Pressure=5mT, Power=200W, Xe Flow-rate=5sccm, Gun-angle=5, z=2.75, Rotation speed=10rpm]					
Ar Flow Rate (sccm)	Sputtering Rate (nm/min)	Resistivity (Ohm-cm)	Stress (MPa)	DC Voltage (v)	DC Current (A)
0*	5.95	1.3E-03	-277.7	629	0.22
2	8.6	7.3E-04	-224	607	0.329
5	8.15	5.9E-04	222	550	0.363

*: For Ar-flow-rate=0, power setting point=200W and actual power=139W

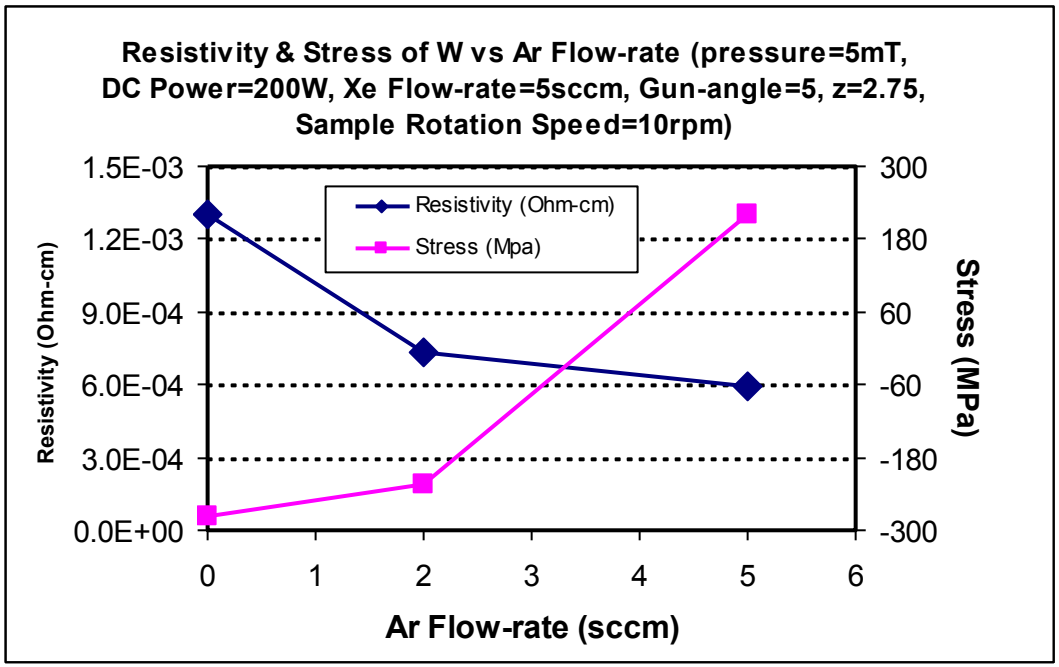
The W sputtering rate increases from 5.95 to 8.6 nm/min as the Ar-flow-rate increases from 0 to 2sccm, then, decreases to 8.15 nm/min as the flow-rate increases further to 5sccm.

Figure 8 Cross-section of the W films sputtered using Xe(5sccm)/Ar: a)Ar flow-rate=0; b)2sccm; c)5sccm.



(a) (b) (c)

Figure 9 Resistivity and stress of W as functions of Ar flow-rate, while keeping Xe flow-rate at 5 sccm, with the use of AJA#2 sputter. The rest of the sputtering parameters are: pressure=5mT, power=200W, z=2.75, gun-angle=5, and rotation-speed=10rpm.



As can be seen from Figure 9, the resistivity of W decreases with the increase of the Ar flow-rate, while the stress of the film changes from -278 to -224 MPa (both are the compressive ones) as the Ar flow-rate increase from 0 to 2sccm, and crosses zero and becomes 222 MPa (in the tensile region) as the flow-rate further increases to 5 sccm.