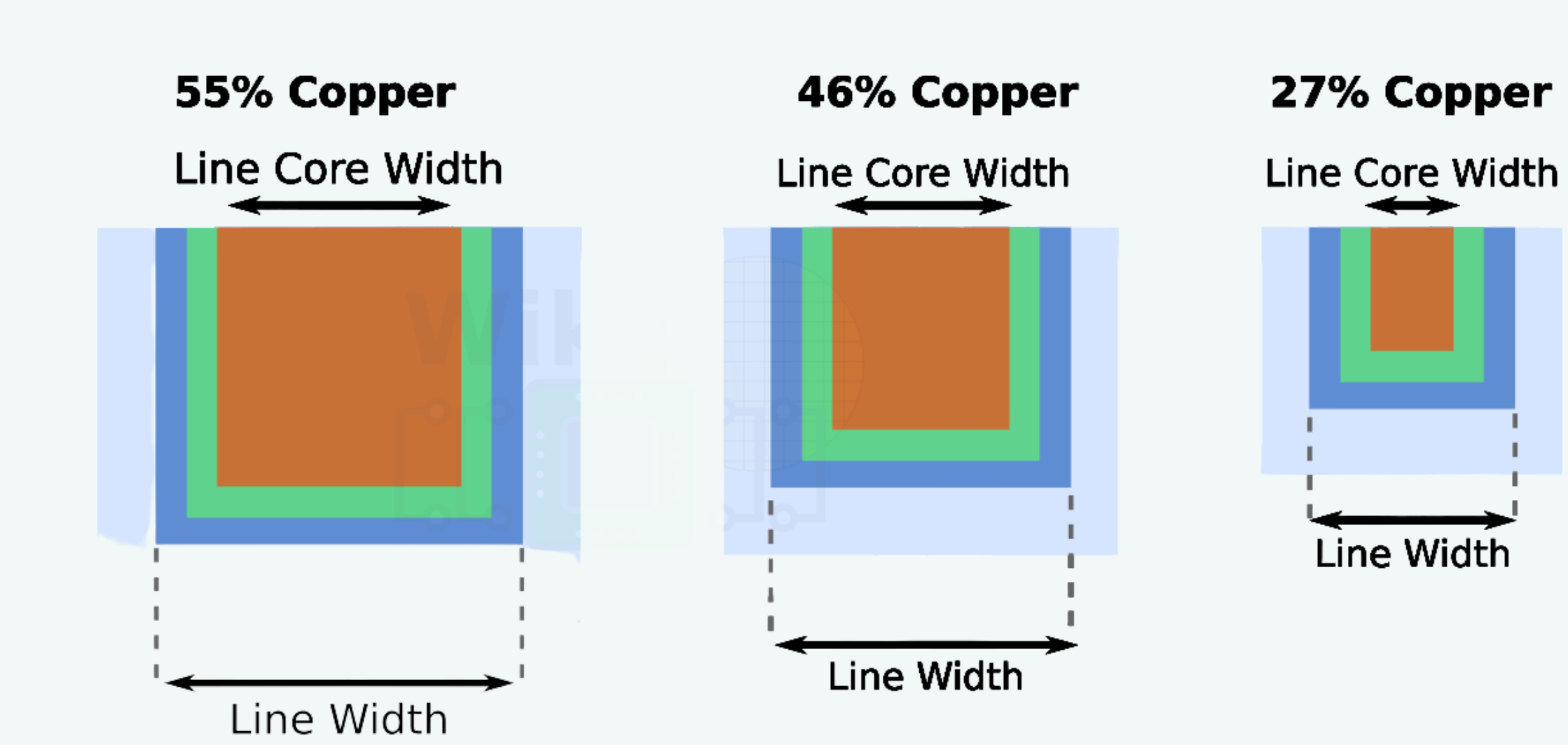




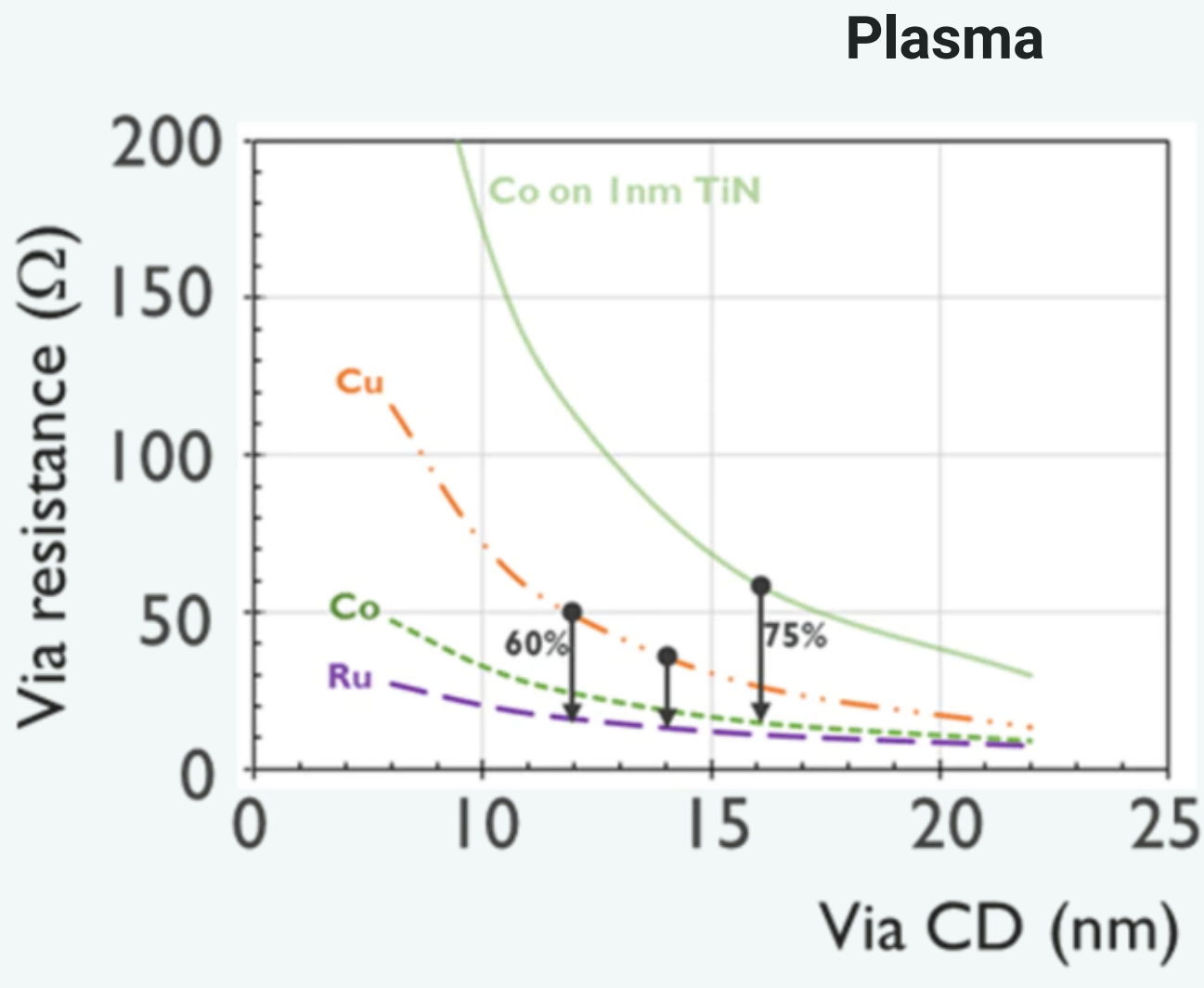
Physical properties of ruthenium films grown by atomic layer deposition

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IEDM 2017 + ISSCC 2018: Intel's 10nm, switching to cobalt interconnects



IITC 2018, imec



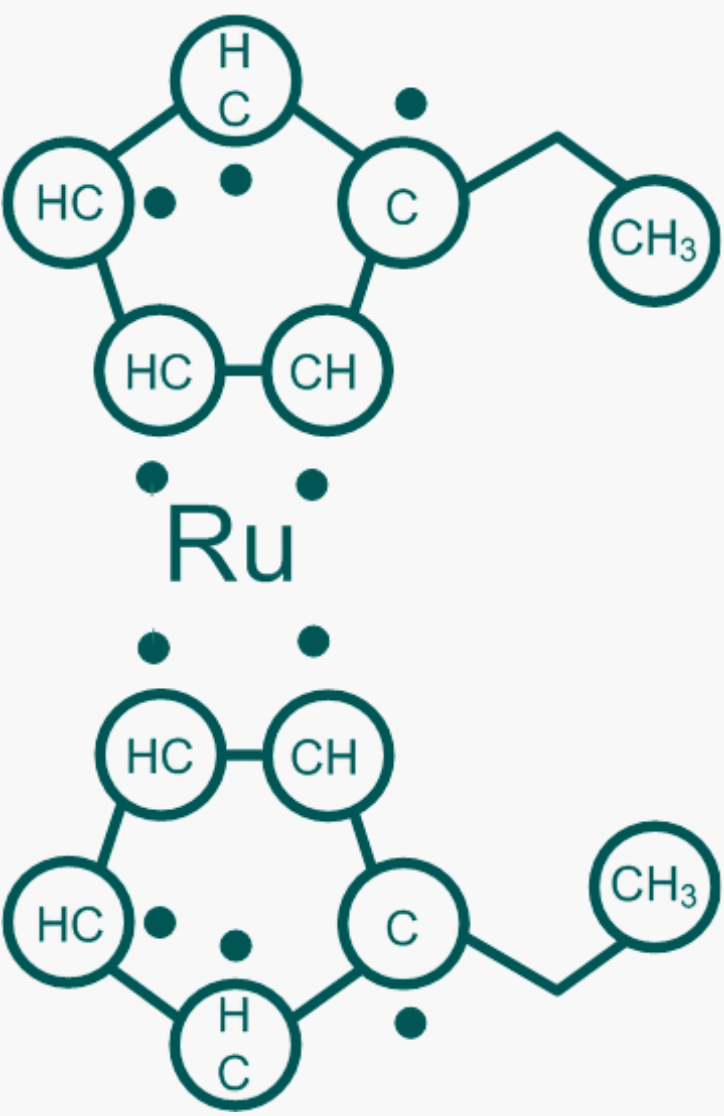
High melting point and, as a result, high resistance to electromigration



The optimal ratio of the free path length and resistivity for trenches with critical dimensions less than 15 nm



There is no need to use barrier layers

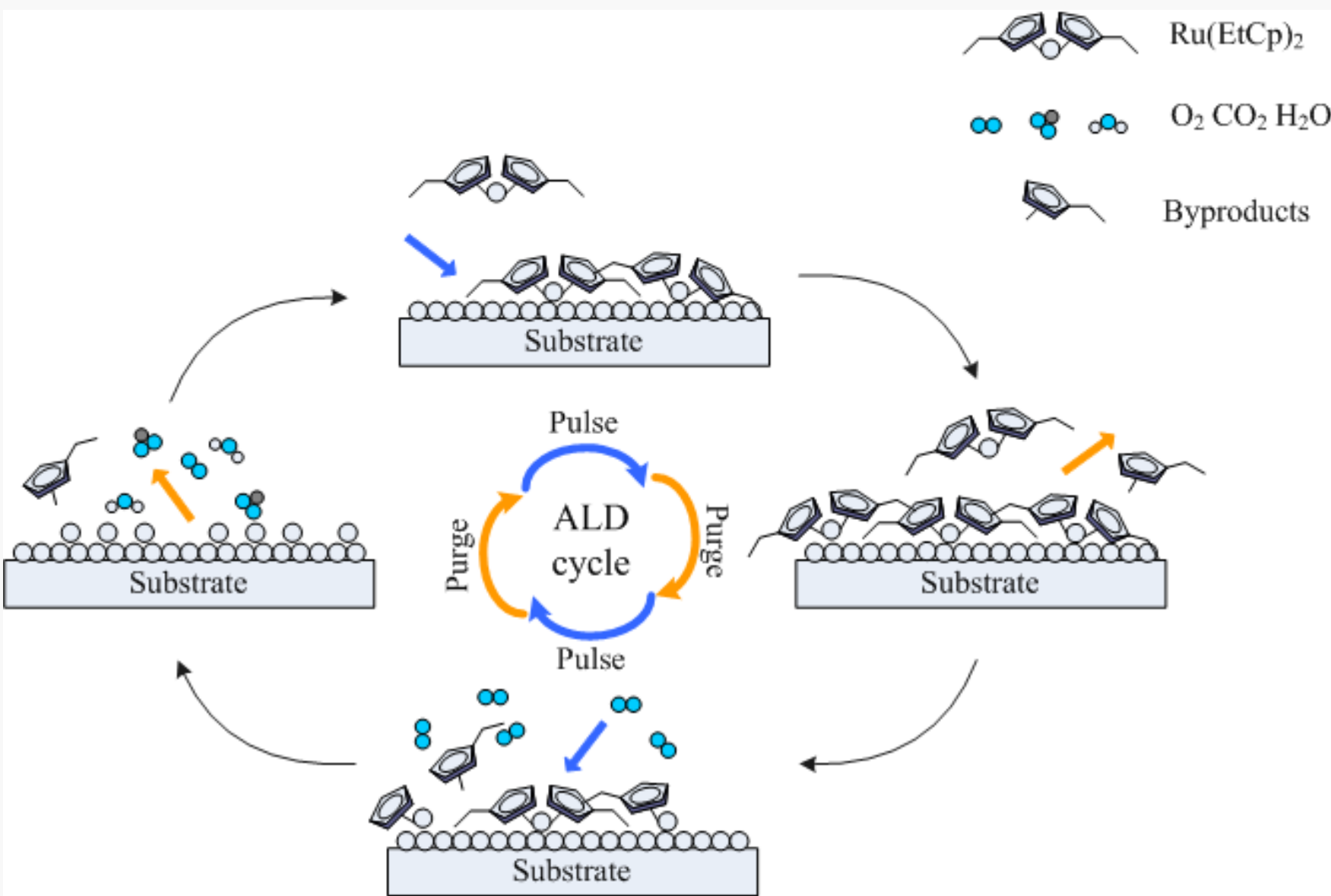


Precursor

bis(ethylcyclopentadienyl)ruthenium(II) or $\text{Ru}(\text{EtCp})_2$

form liquid
bp 100 °C/0.01 mmHg (lit.)
mp 6 °C (lit.)
density 1.3412 g/mL at 25 °C (lit.)

Step	Dose Ru	Ru Purge	Plasma Gas Stab.	Plasma	Post Plasma Purge
Flow , sccm	150 Ar	150 Ar	60 O ₂	60 O ₂	150 Ar
Pressure, mTorr	80	80	65	65	80
ICP RF power, W				75	
Time, s	2	4	2	1	4



Experimental Set Up

ALD processes were performed in a commercial FlexAl system (Oxford Instruments Plasma Technology) with a base pressure of 10⁻⁶ Torr, using a 13.56 MHz ICP remote plasma source

Stress analysis of samples was carried out using a Zygo New View 5000 interference microscope.

The light radiation of the plasma in the deposition of ruthenium is captured by a quartz optical fiber connected to the Ocean Optics HR4PRO spectrometer. This spectrometer has a wavelength detection range of 200-900 nm and a resolution of approximately 0.5 nm.



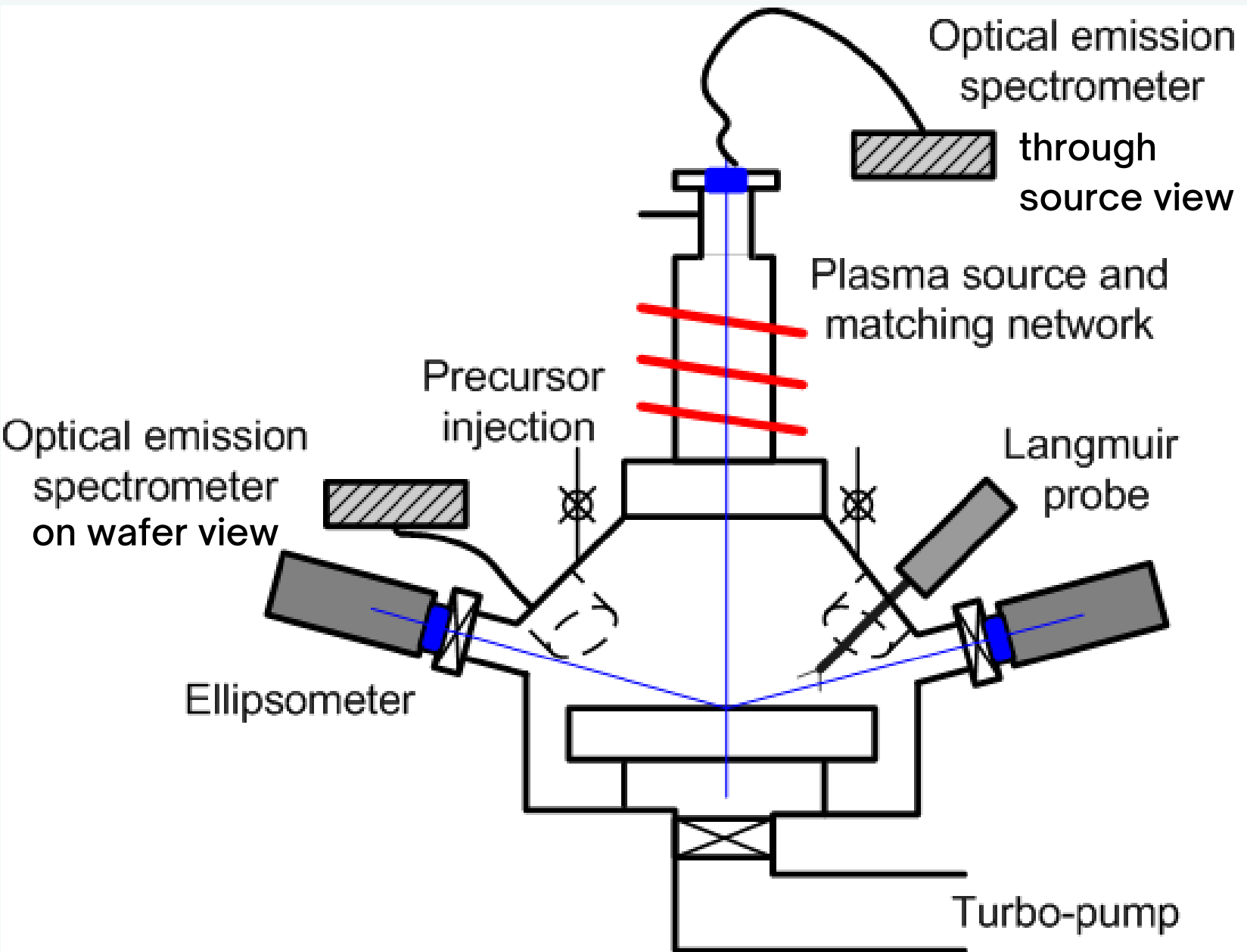
Zygo New View 5000



Ocean Optics HR4PRO



FlexAl

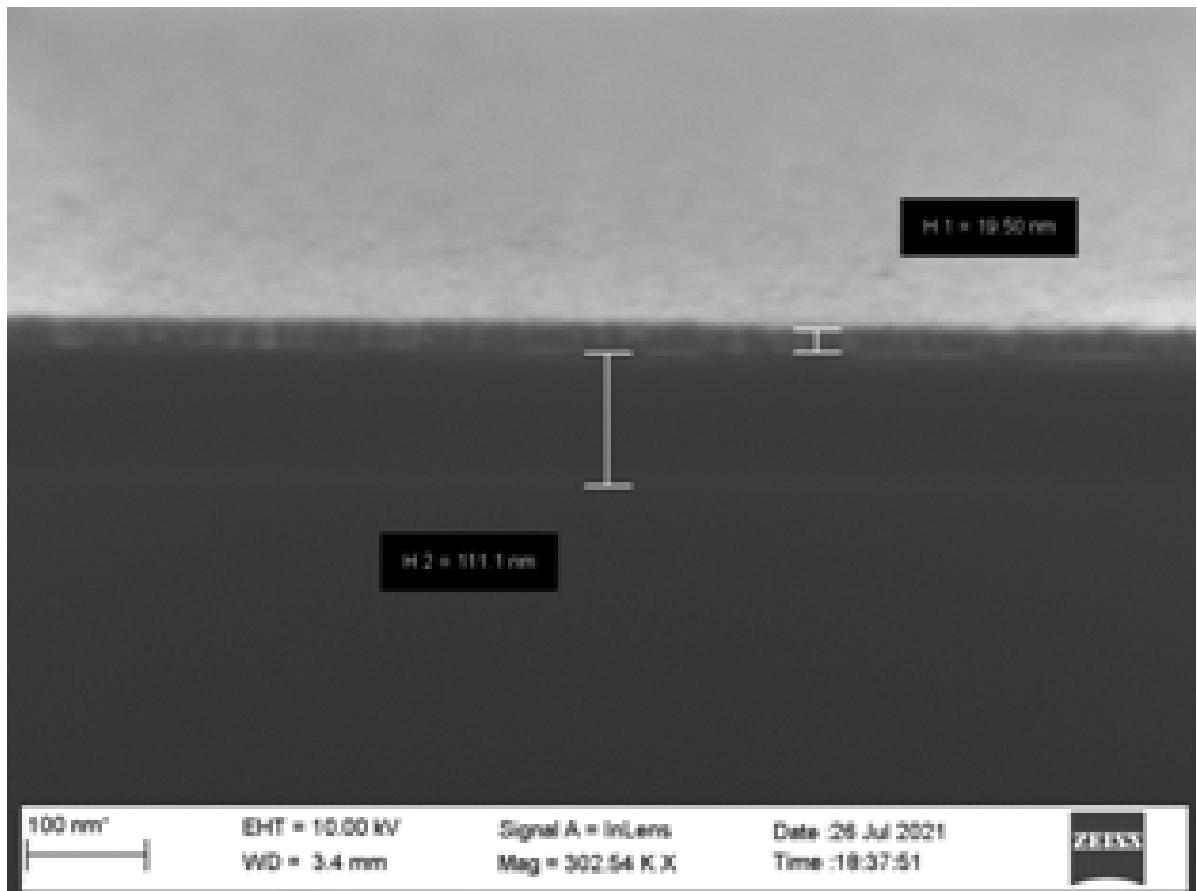


Results and Discussion

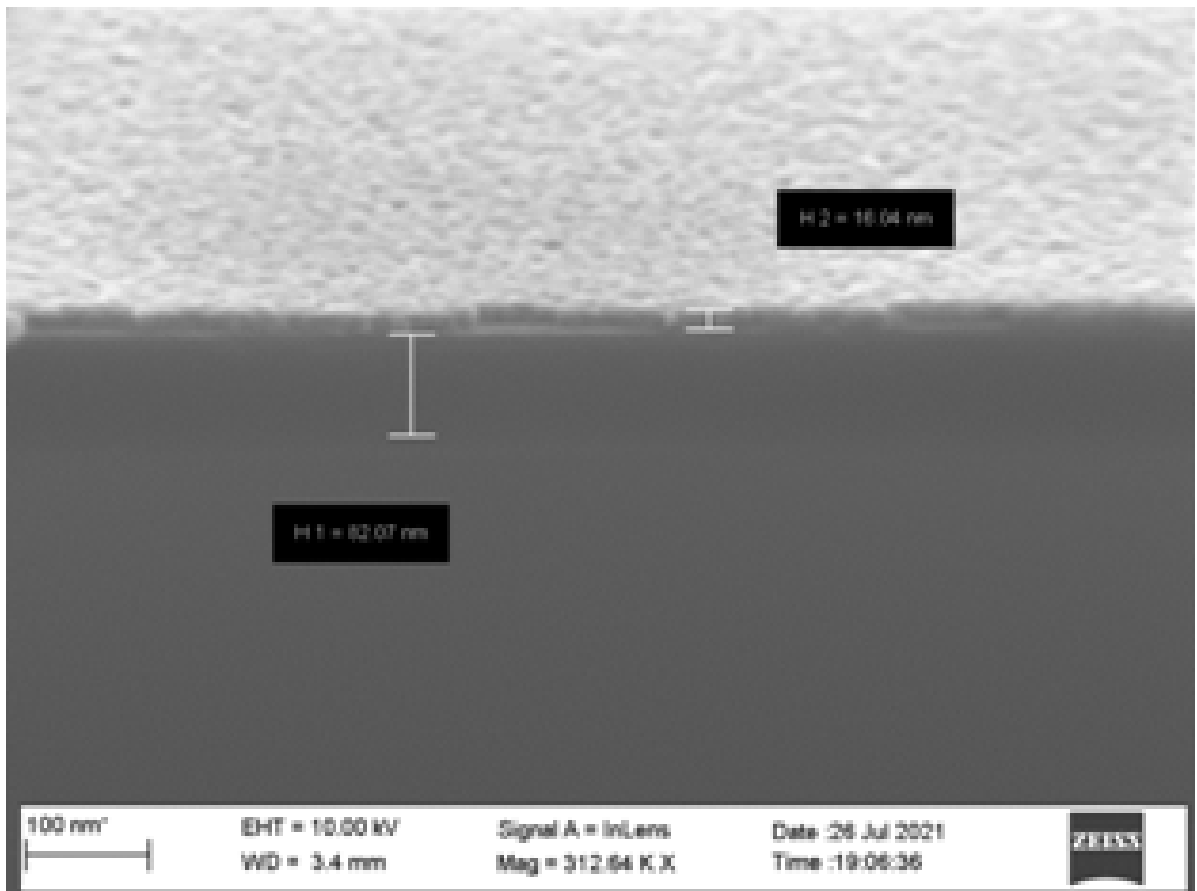
It was noticed that at 375 °C an abrupt change in surface reaction mechanisms takes place, leading to the changing in film composition and structure from polycrystalline RuO_2 at low temperatures to pure Ru film at higher temperatures.

Mechanical stress data are consistent with the roughness of the films. The mechanism of relaxation of the ruthenium film on a single-crystal silicon surface is associated with the formation of blisters. Stress values of 2.8–4.6 GPa (on Si) were measured.

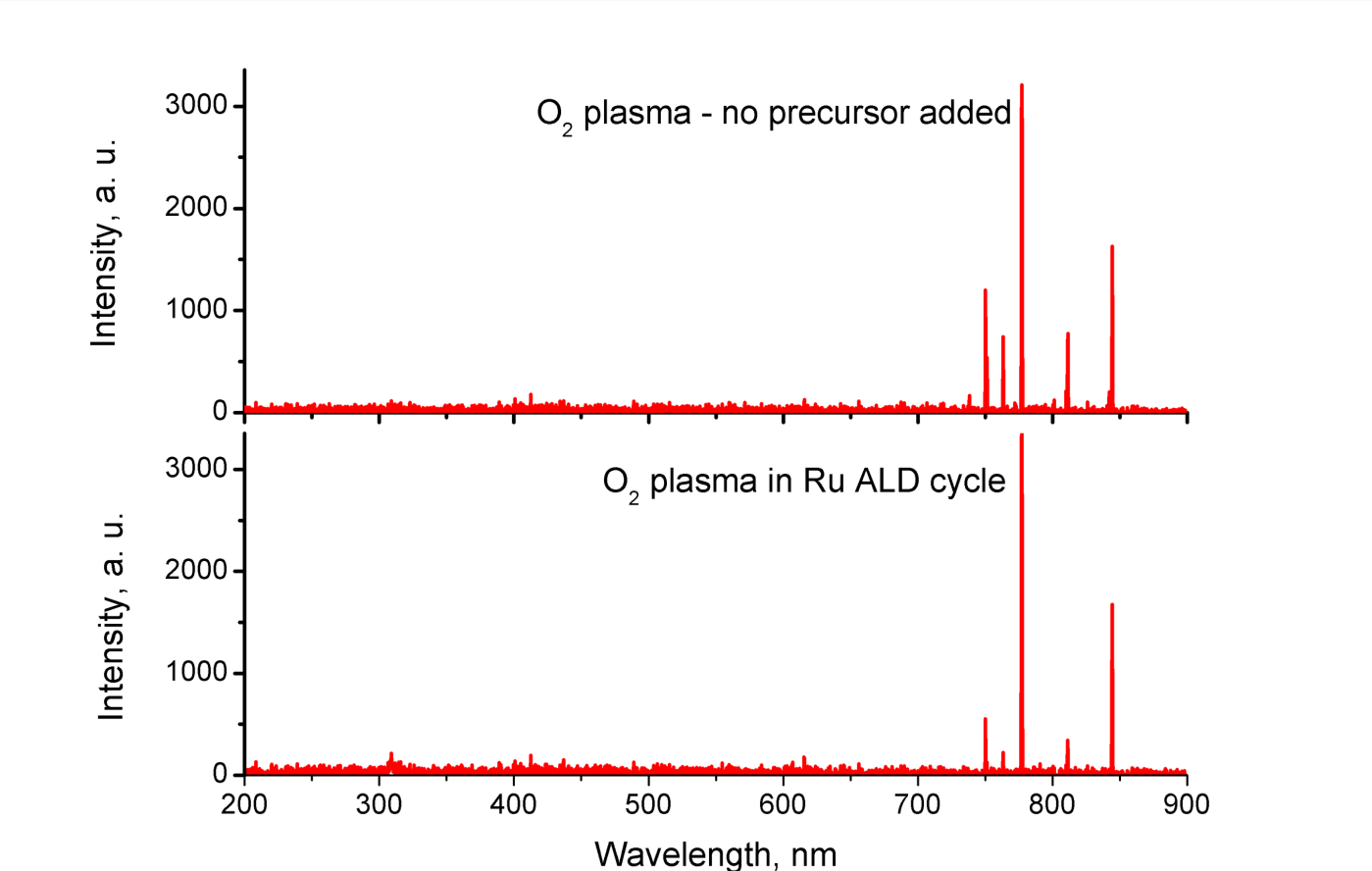
An increase in the plasma power has little effect on the conductivity of the film, but slightly increases the roughness.



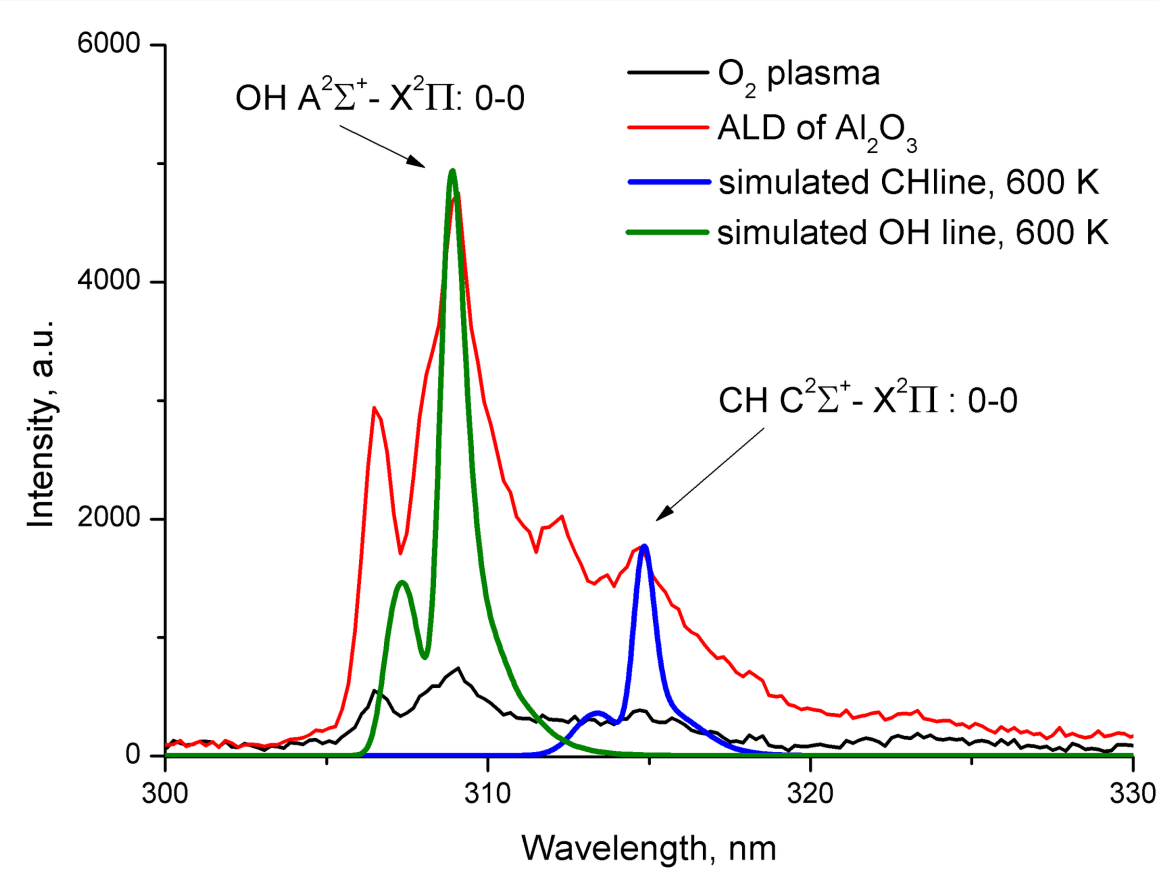
20 nm, 75 W
GPC=0,43 nm/cycle, r=0,021 mOhm*cm



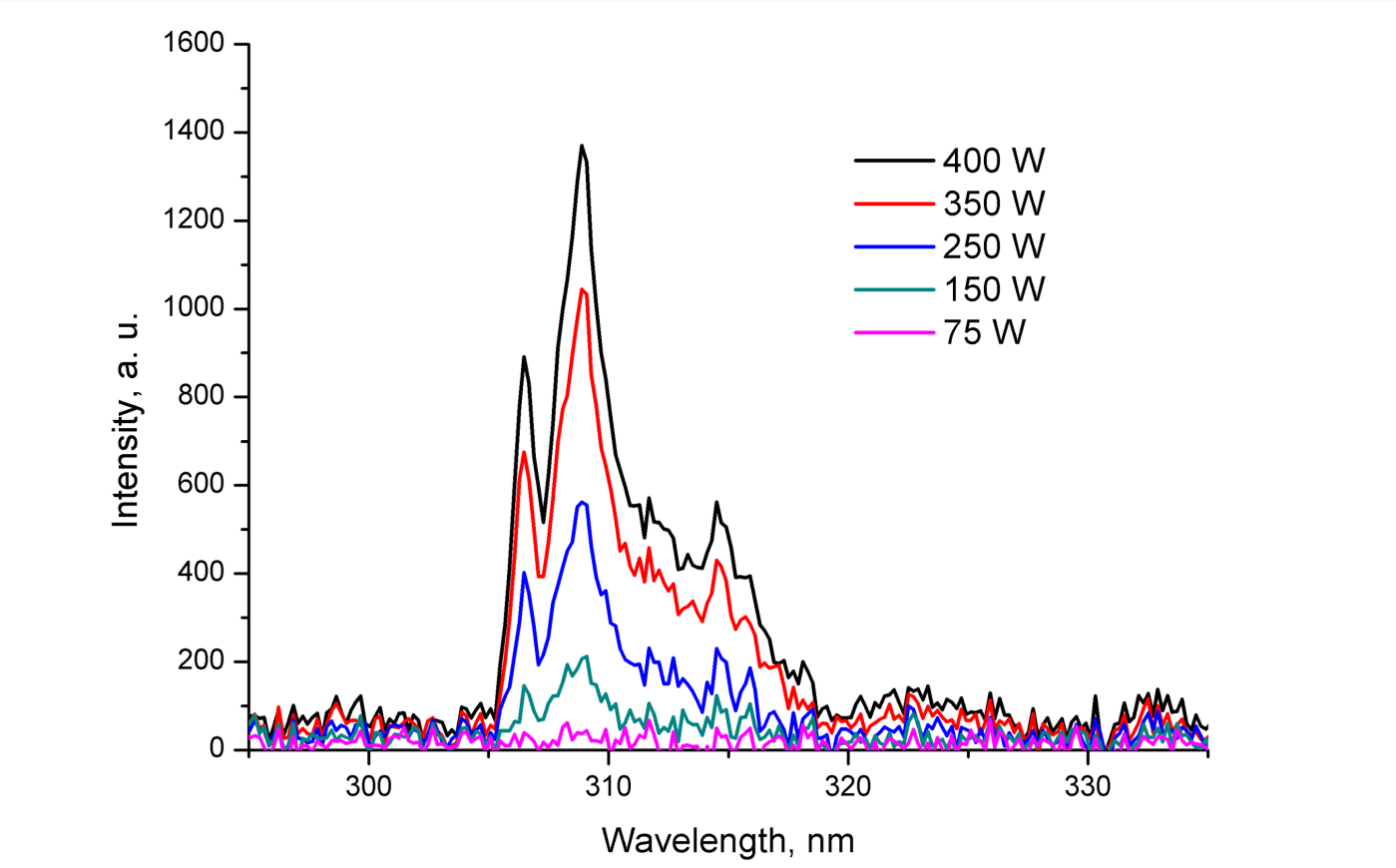
16 nm, 400 W
GPC= 0,34 nm/cycle, r=0,019 mOhm*cm



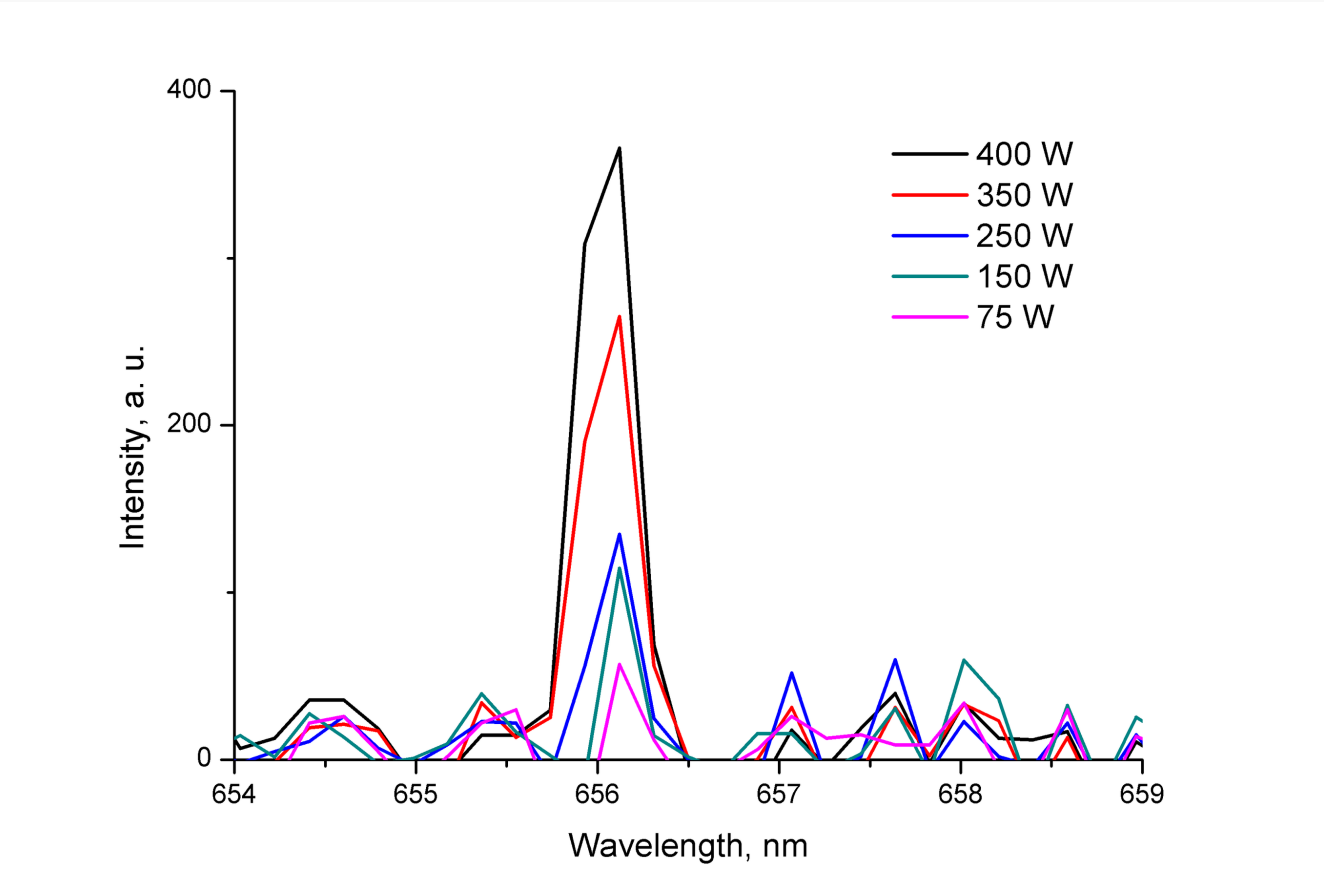
Comparison of the stationary spectrum of oxygen plasma and the spectrum in the Ru ALD cycle



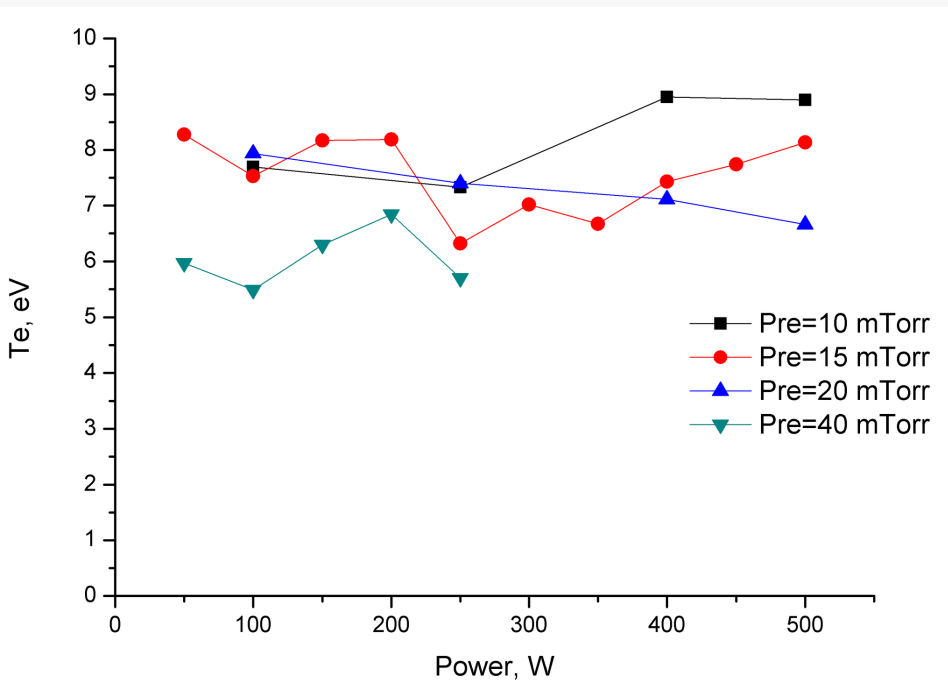
Identification of lines in the plasma spectrum in the ALD cycle of aluminium oxide



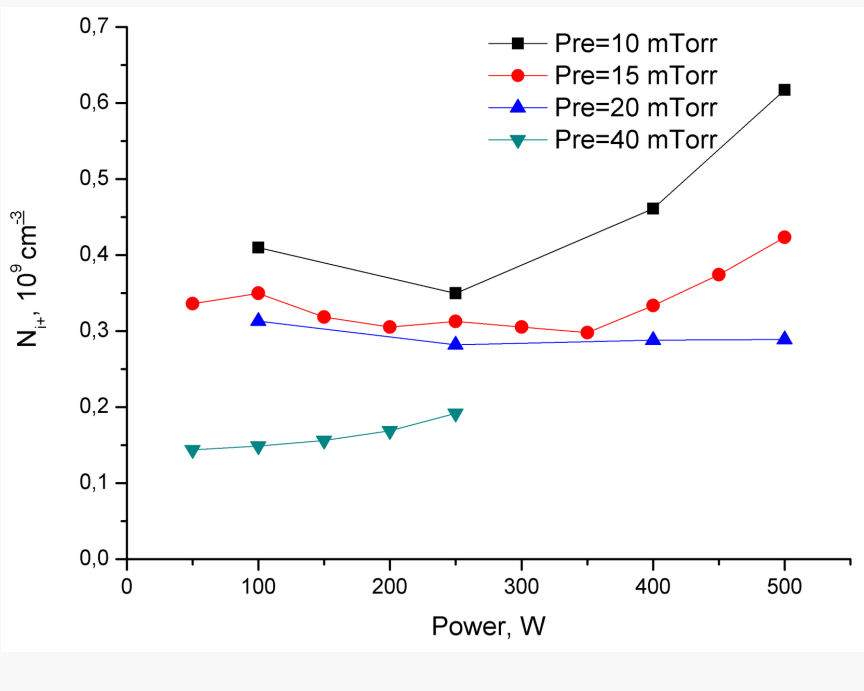
OES spectrum in the Ru ALD recipe at different plasma powers (OH band)



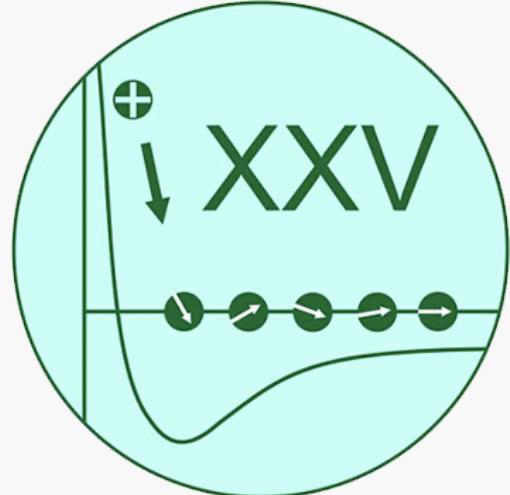
OES spectrum in the Ru ALD recipe at different plasma powers (H line)



Electron temperature in oxygen plasma



Plasma ion concentration in the ALD reactor



Acknowledgments

The investigation was partially supported by Program no. 0066-2019-0004 of the Ministry of Science and Higher Education of Russia for Valiev Institute of Physics and Technology of RAS and partially funded by RFBR, according to the research project № 18-29-27029