

THE FAMILY OF DIELECTRIC RESONATORS FOR PRECISE MEASUREMENTS OF ELECTROMAGNETIC PROPERTIES OF MATERIALS AT MICROWAVE FREQUENCIES

RESONATORS

QWED manufactures several types of resonators for precise measurements of electromagnetic properties of materials at microwave frequencies, based on years of research led by prof. Jerzy Krupka. Each resonator is equipped with specialised software for extracting the relevant data from measurements. The quality of the resonators has been recognised by industrial practitioners, leading researchers, and industrial standard creators. QWED is especially proud of recognition by Agilent Technologies who decided to supplement their 85071E Material Measurement Software with Option 300 serving directly QWED's Split Post Dielectric Resonators as described in technical overview available at: <http://cp.literature.agilent.com/litweb/pdf/5988-9472EN.pdf>.



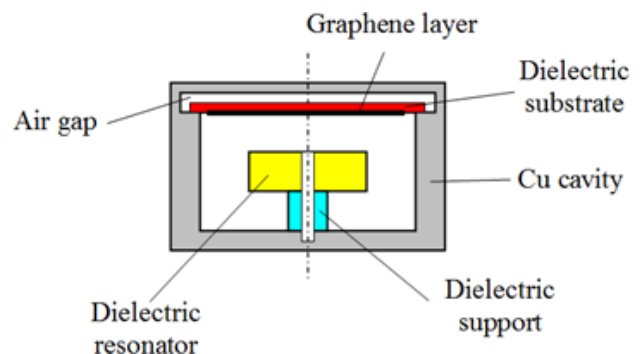
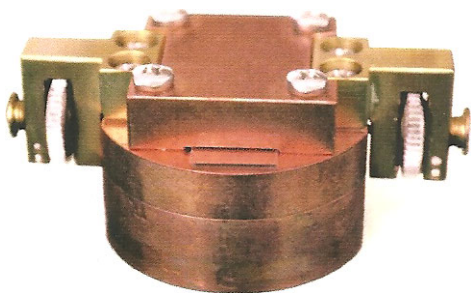
Jerzy A. Krupka is a world recognised expert in electromagnetic property measurements of materials at microwave frequencies. He received the Ph. D. and the D. Sc. in electronic engineering from the Warsaw University of Technology, where he is currently a Professor.

RESONATORS FOR GRAPHENE MEASUREMENTS

Specifically designed for the measurements of electrical properties of graphene deposited on small 10 mm x 10 mm dielectric substrates at microwave frequencies (around 13 GHz). Resonant frequency and Q - factor of the empty resonator and the resonator with the graphene layer deposited on the dielectric substrate are measured. Dedicated software application (supplied with the resonator) is used to calculate the surface resistance R of the graphene layer. The electric conductivity of the graphene layer of thickness h is calculated using the following formula:

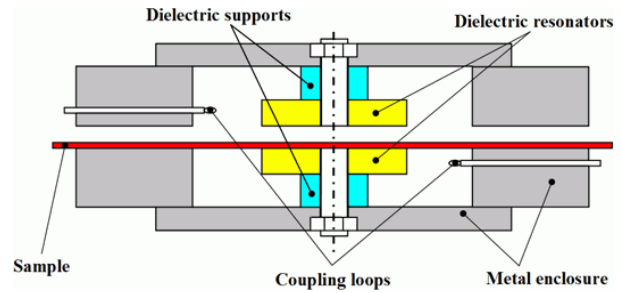
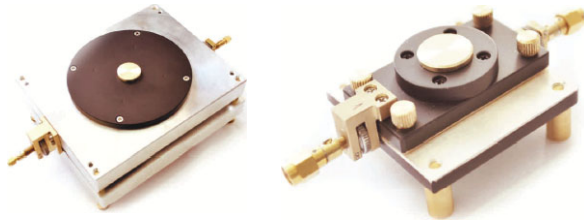
$$\sigma = 1/(R \cdot h)$$

The accuracy of calculation of the electric conductivity is proportional to the accuracy of the measurement of the thickness of the deposited graphene layer.



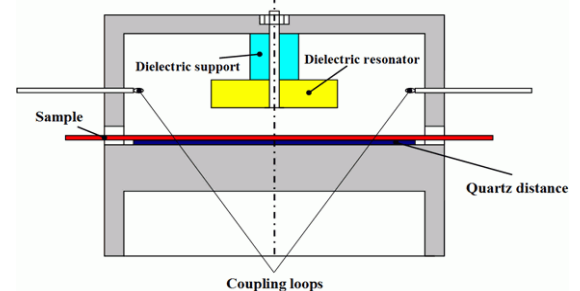
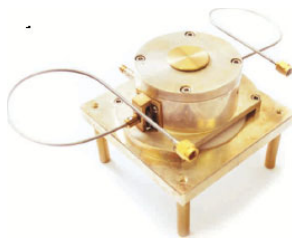
SPLIT POST DIELECTRIC RESONATORS (SPDR)

SPDRs are intended for the measurements of the complex permittivity of laminar dielectric materials including LTCC substrates, but also thin ferroelectric films deposited on low loss dielectric substrates. Additionally, SPDRs can be used for the measurements of the surface resistance and conductivity of various conducting materials such as commercial resistive layers, thin conductive polymer films or high resistivity semiconductors. Such measurements are only possible for large surface resistance samples with $R_s > 5 \text{ k}\Omega/\text{square}$. The nominal frequencies of the basic line of SPDRs are: **1.1 GHz, 1.9 GHz, 2.45 GHz, 5 GHz, 10 GHz**. Resonators for the other frequencies in the range between 1.1 and 20 GHz can be manufactured upon special request.



SINGLE POST DIELECTRIC RESONATORS (SiPDR)

SiPDRs are intended for the measurements of the surface impedance of metamaterials and resistive films as well as for the contact-less measurements of the conductivity of semiconductor wafers. Range of thin film materials that can be measured includes resistive layers, thin metal films and conductive polymer films with the surface resistance $R_s < 20 \text{ k}\Omega/\text{square}$. For semiconductor wafers the upper limit for resistivity measurements is about $1000 \text{ }\Omega\text{cm}$. Semiconductors with higher resistivity values can be conveniently measured with split post dielectric resonators.



TE₀₁₆ MODE DIELECTRIC RESONATOR

TE₀₁₆ mode dielectric resonator technique is intended for very precise complex permittivity measurements of bulk low loss disc or cylinder shape dielectric ceramics. Additionally, with this technique the thermal coefficients of permittivity and the dielectric loss tangent can be measured. With this application QWED offers dedicated software for the rigorous computations of the complex permittivity as well as cavities of different size with adjustable coupling mechanisms and low loss dielectric supports.

