CLAIMS

1. A wafer processing apparatus including a top electrode and a bottom electrode of a processing chamber, the wafer processing apparatus comprising:

a first radio frequency (RF) power source, a second RF power source, and a third RF power source, the first, second, and third RF power sources being coupled to the bottom electrode;

a fourth RF power source coupled to the top electrode, wherein a stray capacitance is defined between ground and the top electrode;

a first resonant circuit coupled to the top electrode and directly coupled to electrical ground, wherein the first resonant circuit comprises a single physical capacitive element and includes an inductor coupled to the top electrode and a variable capacitor as the physical capacitive element, the variable capacitor being connected directly to electrical ground and connected directly to the inductor in series, the variable capacitor being a tuning element operable to vary a frequency-dependent impedance of the first resonant circuit, wherein the frequency-dependent impedance of the first resonant circuit is defined to present a maximum value at a frequency of the first RF power source, wherein the variable capacitor is tuned to set the frequency-dependent impedance of the first resonant circuit based on the impedance of the stray capacitance coupled in parallel solely with the variable capacitor and the inductor in combination;

a second resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the second resonant circuit is defined to present a maximum value at a frequency of the second RF power source;

a third resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the third resonant circuit is

defined to present a maximum value at a frequency of the third RF power source, wherein the first, second and third RF resonant circuits are coupled in parallel; and

a filter coupled between the top electrode and the fourth RF power source, wherein a first end of the filter is coupled to the top electrode and to the first resonant circuit, to the second resonant circuit, and to the third resonant circuit, wherein a second end of the filter is coupled to the fourth RF power source, wherein the filter blocks power from the bottom electrode from reaching the fourth RF power source.

2. The apparatus as recited in claim 1 further including:

a system controller, wherein the system controller is operable to set each of the first, second, third, and fourth RF powers to be one of turned on or turned off independently during a wafer processing operation, and wherein the system controller is operable to couple or uncouple the first resonant circuit to the top electrode.

3. The apparatus as recited in claim 2, wherein the system controller is further operable to couple or uncouple the top electrode to electrical ground.

4. The apparatus as recited in claim 1, wherein the wafer processing apparatus is configured according to a configuration including:

the first RF power source settable to a frequency of 60 MHz;

the second RF power source settable to a frequency of 27 MHz;

the third RF power source settable to a frequency of 2 MHz; and

the fourth RF power source settable to a frequency of 400 KHz.

5. The apparatus as recited in claim 1, wherein the frequency-dependent impedance is calculated as

$$\frac{j\frac{1}{wC_s}(Lw-\frac{1}{wC_x})}{\frac{1}{wC_s}-(Lw-\frac{1}{wC_x})},$$

wherein L is an inductance of the inductor, C_s is the stray capacitance, and C_x is a capacitance of the variable capacitor.

6. The apparatus as recited in claim 5, further including:

a system controller defined to set a value of a capacitance of the variable capacitor to make the frequency-dependent impedance have the maximum value at the frequency of the first RF power source.

7. The apparatus as recited in claim 1,

wherein the second resonant circuit comprises a single physical second capacitive element and includes a second inductor coupled to the top electrode and a second variable capacitor as the physical capacitive element, the second variable capacitor being connected directly to electrical ground and connected directly to the second inductor in series, the second variable capacitor being a tuning element operable to vary the frequency-dependent impedance of the second resonant circuit;

wherein the third resonant circuit comprises a single physical third capacitive element and includes a third inductor coupled to the top electrode and a third variable capacitor as the physical capacitive element, the third variable capacitor being connected directly to electrical ground and connected directly to the third inductor in series, the third variable capacitor being a tuning element operable to vary the frequency-dependent impedance of the third resonant circuit, and

wherein the first end of the filter is directly connected simultaneously to the top electrode, to the inductor of the first resonant circuit at an end of the inductor opposite the variable capacitor, to the second inductor of the second resonant circuit at an end of the second inductor opposite the second variable capacitor, and to the third inductor of the third resonant circuit at an end of the third inductor opposite the third variable capacitor.

8. A wafer processing apparatus including a top electrode and a bottom electrode of a processing chamber, the wafer processing apparatus comprising:

a first radio frequency (RF) power source, a second RF power source, a third RF power source, and a fourth RF power source, the first, second, and third RF power sources being coupled to the bottom electrode, wherein a stray capacitance is defined between ground and the top electrode;

a first resonant circuit directly coupled to the top electrode and directly coupled to electrical ground, wherein the first resonant circuit comprises a single physical capacitive element and includes an inductor coupled to the top electrode and a variable capacitor as the capacitive element, the variable capacitor being connected directly to electrical ground and connected directly to the inductor in series, the variable capacitor being a tuning element operable to vary a frequency-dependent impedance of the first resonant circuit, wherein the frequency-dependent impedance of the first resonant circuit is defined to present a maximum value at a frequency of the first RF power source, wherein the variable capacitor is tuned to set the frequency-dependent impedance of the first resonant circuit based on the impedance of the stray capacitance coupled in parallel solely with the variable capacitor and the inductor in combination;

a second resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the second resonant circuit is defined to present a maximum value at a frequency of the second RF power source;

a third resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the third resonant circuit is defined to present a maximum value at a frequency of the third RF power source, wherein the first, second and third RF resonant circuits are coupled in parallel;

a filter coupled between the top electrode and the fourth RF power source, wherein a first end of the filter is coupled to the top electrode and to the first resonant circuit, to the second resonant circuit, and to the third resonant circuit, wherein a second end of the filter is coupled to the fourth RF power source, wherein the filter blocks power from the bottom electrode from reaching the fourth RF power source; and

a first switch, a second switch, and a third switch, the first switch being operable to couple the top electrode to the fourth RF power source, the second switch being operable to couple the top electrode to the first resonant circuit or the second resonant circuit or the third resonant circuit, and the third switch being operable to couple the top electrode to a first voltage.

9. The apparatus as recited in claim 8, wherein a frequency of the first RF power is 60 MHz, wherein a frequency of the second RF power is 27 MHz, wherein a frequency of the third RF power is 2 MHz, and wherein a frequency of the fourth RF power is 400 KHz.

10. The apparatus as recited in claim 8, further including:

a first power controller operable to activate the first RF power source based on a recipe for processing the wafer.

11. The apparatus as recited in claim 8, further including:

a system controller operable to set power levels for the first, second, third, and fourth RF power sources.

12. The apparatus as recited in claim 8, wherein a frequency of the fourth RF power is in a range from 0.1 to 10 MHz.

13. The apparatus as recited in claim 8, further including:

a system controller defined to set a value of a capacitance of the variable capacitor to make the frequency-dependent impedance have the maximum value at the frequency of the first RF power source, wherein the frequency-dependent impedance is calculated as

$$\frac{j\frac{1}{wC_s}(Lw-\frac{1}{wC_x})}{\frac{1}{wC_s}-(Lw-\frac{1}{wC_x})} \quad ,$$

wherein L is an inductance of the inductor, C_s is the stray capacitance, and C_x is a capacitance of the variable capacitor.

14. A wafer processing apparatus including a top electrode and a bottom electrode of a processing chamber, the wafer processing apparatus comprising:

a first radio frequency (RF) power source, a second RF power source, a third RF power source, and a fourth RF power source, the first, second, and third RF power sources being coupled to the bottom electrode, wherein a stray capacitance is defined between ground and the top electrode;

a first resonant circuit directly coupled to the top electrode and directly coupled to electrical ground, wherein the first resonant circuit comprises a single physical capacitive element and includes an inductor coupled to the top electrode and a variable capacitor as the physical capacitive element, the variable capacitor being connected directly to electrical ground and connected directly to the inductor in series, the variable capacitor being a tuning element operable to vary a frequency-dependent impedance of the first resonant circuit, wherein the frequency-dependent impedance of the first resonant circuit is defined to present a maximum value at a frequency of the first RF power source, wherein the variable capacitor is tuned to set the frequency-dependent impedance of the first resonant circuit based on the impedance of the stray capacitance coupled in parallel solely with the variable capacitor and the inductor in combination;

a second resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the second resonant circuit is defined to present a maximum value at a frequency of the second RF power source;

a third resonant circuit coupled between the top electrode and electrical ground, wherein a frequency-dependent impedance of the third resonant circuit is defined to present a maximum value at a frequency of the third RF power source, wherein the first, second and third RF resonant circuits are coupled in parallel;

a filter coupled between the top electrode and the fourth RF power source, wherein a first end of the filter is coupled to the top electrode and to the first resonant circuit, to the second resonant circuit, and to the third resonant circuit, wherein a second end of the filter is coupled to the fourth RF power source, wherein the filter blocks power from the bottom electrode from reaching the fourth RF power source; and

a first switch, a second switch, a third switch, a fourth switch, and a fifth switch, the first switch being operable to couple the top electrode to the fourth RF power source, the second switch being operable to couple the top electrode to the first resonant circuit, the third switch being operable to couple the top electrode to a first voltage, the fourth switch being operable to couple the top electrode to the second resonant circuit, and the fifth switch being operable to couple the top electrode to the third resonant circuit.

15. The apparatus as recited in claim 14, further including:

a system controller defined to set a value of a capacitance of the variable capacitor to make the frequency-dependent impedance have the maximum value at the frequency of the first RF power source, wherein the frequency-dependent impedance is calculated as

$$\frac{j\frac{1}{wC_s}(Lw-\frac{1}{wC_x})}{\frac{1}{wC_s}-(Lw-\frac{1}{wC_x})},$$

wherein L is an inductance of the inductor, C_s is the stray capacitance, and C_x is a capacitance of the variable capacitor.