INDUCTION DEVICES FOR INDUCTIVELY COUPLED PLASMA TORCHES AND METHODS AND SYSTEMS INCLUDING SAME

Field

[0001] The present technology relates to plasma sources and, more particularly, to inductively coupled plasma torches and induction devices used therewith.

Background

[0002] Some inductively coupled plasma (ICP) devices use an ICP torch including an induction device to generate plasma. It is desirable to design the induction device such that robust plasma is generated that can ionize challenging samples without extinguishing.

Summary

[0003] In an aspect, the present disclosure refers to an induction device including a helical structure including a first aperture, and a non-helical structure including a second aperture. The first and second apertures define a passageway that is configured to receive a portion of a body of an inductively coupled plasma (ICP) torch, and the passageway defines a longitudinal axis.

[0004] In some examples, the helical structure includes a helical plate and the non-helical structure includes a flat plate.

[0005] In some examples, the helical plate includes a primary body including the first aperture and first and second legs extending away from the primary body. In some examples, the flat plate includes a primary body including the second aperture and first and second legs extending away from the primary body.

[0006] In some examples, the first leg of the helical plate and the flat plate are spaced apart axially a first distance, and the second leg of the helical plate and the flat plate are spaced apart axially a second distance. The second distance may be greater than the first distance. The first distance may be the smallest gap between the helical plate and the flat plate and the second distance may be the largest gap between the helical plate and the flat plate. The first distance may be 2 to 3 mm and/or the second distance may be 5 to 6 mm.

[0007] In some examples, the first leg of the helical plate is axially aligned with the second leg of the flat plate, and the second leg of the helical plate is laterally offset from the flat plate relative to the longitudinal axis.

[0008] In some examples, the second leg of the helical plate and the first leg of the flat plate are each configured to be supplied with radio-frequency electric current, and the first leg of the helical plate and the second leg of the flat plate are configured to be connected to ground.

[0009] In some examples, the induction device further includes a spacer between the first leg of the helical plate and the second leg of the flat plate. The spacer may contact each of the first leg of the helical plate and the second leg of the flat plate.

[0010] In some examples, the induction device further includes an electrode connected to each of the second leg of the helical plate, the first leg of the flat plate, and the second leg of the flat plate.

[0011] In some examples, the induction device further includes a conductive plate to which the helical plate and flat plate are coupled. The electrodes and/or the conductive plate may be configured as a heat sink to promote cooling of the helical plate and flat plate.

[0012] In some examples, the primary body of the helical plate is in the shape of a loop and makes substantially a single rotation or turn between the first leg and the second leg of the helical plate.

[0013] In some examples, the helical plate and the flat plate each have a thickness of about 2 mm.

[0014] In some examples, the helical plate has a pitch of 4 to 6 mm per rotation.

[0015] In some examples, the helical structure comprises a coil. The coil may be a single coil.

[0016] In some examples, the helical structure and/or the non-helical structure are formed of aluminum.

[0017] In some examples, the helical structure and/or the non-helical structure are formed of copper.

[0018] In an aspect, the present disclosure refers to an inductively coupled plasma (ICP) torch including: an injector configured to receive a flow of a sample fluid; a plurality of tubes disposed about the injector and configured to receive and direct a flow of one or more torch gases; and an induction device disposed about at least one of the plurality of tubes,

the induction device configured to receive a radio-frequency electric current to inductively energize at least one of the one or more torch gases to produce a plasma proximate a distal end of the ICP torch. The induction device includes a helical structure including a first aperture, and a non-helical structure including a second aperture. The first and second apertures define a passageway that is configured to receive the at least one of the plurality of tubes, and the passageway defines a longitudinal axis.

[0019] In some examples, the helical structure includes a helical plate and the non-helical structure includes a flat plate.

[0020] In some examples, the helical plate includes a primary body including the first aperture and first and second legs extending away from the primary body, and the flat plate includes a primary body including the second aperture and first and second legs extending away from the primary body.

[0021] In some examples, the first leg of the helical plate and the flat plate are spaced apart axially a first distance, the second leg of the helical plate and the flat plate are spaced apart axially a second distance, and the second distance is greater than the first distance. The first distance may be the smallest gap between the helical plate and the flat plate and the second distance may be the largest gap between the helical plate and the flat plate. The first distance may be 2 to 3 mm and/or the second distance may be 5 to 6 mm.

[0022] In some examples, the first leg of the helical plate is axially aligned with the second leg of the flat plate, and the second leg of the helical plate is laterally offset from the flat plate relative to the longitudinal axis.

[0023] In some examples, the second leg of the helical plate and the first leg of the flat plate are each configured to be supplied with radio-frequency electric current, and the first leg of the helical plate and the second leg of the flat plate are configured to be connected to ground.

[0024] In some examples, the ICP torch further includes a spacer between the first leg of the helical plate and the second leg of the flat plate. The spacer may contact each of the first leg of the helical plate and the second leg of the flat plate.

[0025] In some examples, the ICP torch further includes an electrode connected to each of the second leg of the helical plate, the first leg of the flat plate, and the second leg of the flat plate.

[0026] In some examples, the ICP torch further includes a conductive plate to which the helical plate and flat plate are coupled. The electrodes and/or the conductive plate may be configured as a heat sink to promote cooling of the helical plate and flat plate.

[0027] In some examples, the primary body of the helical plate is in the shape of a loop and makes substantially a single rotation or turn between the first leg and the second leg of the helical plate.

[0028] In some examples, the helical plate and the flat plate each have a thickness of about 2 mm.

[0029] In some examples, the helical plate has a pitch of 4 to 6 mm per rotation.

[0030] In some examples, the helical structure includes a coil. The coil may be a single coil.

[0031] In some examples, the helical structure and/or the non-helical structure are formed of aluminum.

[0032] In some examples, the helical structure and/or the non-helical structure are formed of copper.

[0033] In some examples, the plurality of tubes include: an intermediate tube disposed about the injector, wherein the injector and the intermediate tube define an auxiliary gas passage configured to receive a flow of an auxiliary gas; and a plasma tube disposed about the intermediate tube, wherein the intermediate tube and the plasma tube define a plasma gas passage configured to receive a flow of a plasma gas.

[0034] In some examples, a maximum axial gap between a distal end of the intermediate tube and the helical plate is 4.9 to 5.1 mm.

[0035] In some examples, an axial gap between a distal end of the injector and a distal end of the intermediate tube is 2 to 3 mm.

[0036] In an aspect, the present disclosure refers to an optical emission spectrometry (ICP-OES) system including an ICP torch as described herein.

[0037] In an aspect, the present disclosure refers to a method for generating a plasma. The method includes providing an inductively coupled plasma (ICP) torch including: an injector tube including an injector flow passage to receive a flow of a sample fluid; an intermediate tube disposed about the injector tube, wherein the injector and the intermediate tube define an auxiliary gas passage configured to receive a flow of an auxiliary gas; a plasma