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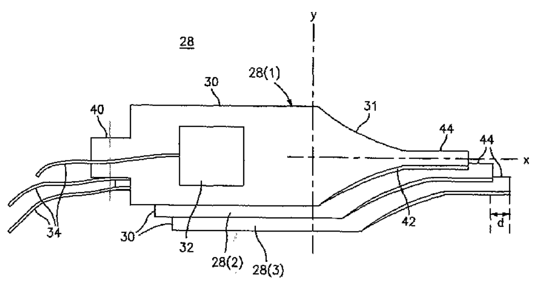
(54)【発明の名称】積層された小さい刃から形成された、長い超音波切断刃

(57)【要約】
超音波外科用器具の末端エフェクタが提供される。この超音波外科用器具は、操作可能な構造体、本体部分であって、この操作可能な構造体に作動可能に連結され、遠位端を有する本体部分、変換器、およびこの本体部分のこの遠位端上に支持されている末端エフェクタを備え、この末端エフェクタは、複数の共鳴部材要素を備え、各共鳴部材は、この共鳴部材の長さに沿って振動をもたらすために複数の変換器のうちの１つの変換器に作動可能に連結されており、そして組織の切開、切断、凝固、結紮および／または止血をもたらすように構成される作動表面を備えており、ここで、複数の共鳴部材の第１部材の振動に関連した変位曲線は、複数の共鳴部材の第２部材の振動に関連した変位曲線に対してオフセットされている。



【特許請求の範囲】
【請求項１】
超音波外科用器具の末端エフェクタであって、該超音波外科用器具は、操作可能な構造体、該操作可能な構造体に作動可能に連結され遠位端を有する本体部分、複数の変換器、および該本体部分の遠位端上に支持された該末端エフェクタを備え、該末端エフェクタは、複数の共鳴部材を備え、各共鳴部材は、該共鳴部材の長さに沿った振動をもたらすための該複数の変換器のうちの１つの変換器に作動可能に連結されており、そして組織の切開、切断、凝固、結紮および／または止血をもたらすように構成されている作動表面を備えており、ここで、該複数の共鳴部材の第１部材の該振動に関連した変位曲線は、該複数の共鳴部材の第２部材の振動に関連した変位曲線に対してオフセットされている、末端エフェクタ。
【請求項２】
前記振動が、長手軸方向である、請求項１に記載の末端エフェクタ。
【請求項３】
前記振動が、横方向である、請求項１に記載の末端エフェクタ。
【請求項４】
前記第１共鳴部材が、前記第２共鳴部材に対して長手軸方向にずらして配置される、請求項１に記載の末端エフェクタ。
【請求項５】
前記第１共鳴部材が、可撓性結合によって前記第２共鳴部材に連結される、請求項１に記載の末端エフェクタ。
【請求項６】
前記第１共鳴部材および第２共鳴部材が、積層プロセスによって一緒に積層される、請求項１に記載の末端エフェクタ。
【請求項７】
前記複数の共鳴部材が、積層体の形態である、請求項１に記載の末端エフェクタ。
【請求項８】
前記複数の共鳴部材が、一緒に積層される、請求項１に記載の末端エフェクタ。
【請求項９】
前記操作可能な構造体が、ハンドルである、請求項１に記載の末端エフェクタ。
【請求項１０】
前記操作可能な構造体が、前記器具から離れて位置するモジュール上に位置する、請求項１に記載の末端エフェクタ。
【請求項１１】
前記本体部分が、前記モジュールから前記末端エフェクタへと遠位に延びる細長可撓性部材を備える、請求項１０に記載の末端エフェクタ。
【請求項１２】
前記変換器が、ずらして配置された複数の変換器を備える、請求項１に記載の末端エフェクタ。
【請求項１３】
前記変換器は、ずらして配置された複数の変換器を備えるが、前記複数の共鳴部材の共鳴部材はずらして配置されていない、請求項１に記載の末端エフェクタ。
【請求項１４】
前記変換器が、それぞれ、前記第１共鳴部材および第２共鳴部材に作動可能に連結された第１変換器および第２変換器を備える、請求項１に記載の末端エフェクタ。
【請求項１５】
前記末端エフェクタが、前記変換器を備える、請求項１に記載の末端エフェクタ。
【請求項１６】
前記複数の共鳴部材の各々の共鳴部材が、フレームおよび共鳴構造体を備え、前記変換器が、該共鳴構造体に作動可能に連結されており、そして該共鳴構造体が前記作動表面を備

える、請求項１に記載の末端エフェクタ。
【請求項１７】
各共鳴構造体が近位端を有し、そして前記第１共鳴部材の共鳴構造体の近位端が、前記第２共鳴部材の近位端に対してずらして配置されている、請求項１６に記載の末端エフェクタ。
【請求項１８】
前記変換器が複数の変換器を備え、ここで前記第１共鳴部材が、前記複数の変換器のうちの１つの変換器をさらに備え、ここでさらに備えられる変換器が、前記第１共鳴部材の共鳴構造体と接触して配置される、請求項１６に記載の末端エフェクタ。
【請求項１９】
超音波外科用器具であって、該超音波外科用器具は、以下：
操作可能な構造体；
変換器；
該操作可能な構造体に作動可能に連結され遠位端を有する、本体部分；および
該本体部分の遠位端上に支持された末端エフェクタ
を備え、該末端エフェクタは、複数の共鳴部材を備え、各共鳴部材は、該共鳴部材の長さに沿って振動をもたらすために該変換器に作動可能に連結されており、各共鳴部材は、組織の切開、切断、凝固、結紮および／または止血をもたらすように構成された作動表面を備え、ここで、該複数の共鳴部材の第１部材の該振動に関連した変位曲線は、該複数の共鳴部材の第２部材の振動に関連した変位曲線に対してオフセットされている、超音波外科用器具。
【請求項２０】
前記振動が、長手軸方向である、請求項１９に記載の超音波外科用器具。
【請求項２１】
前記振動が、横方向である、請求項１９に記載の超音波外科用器具。
【請求項２２】
前記第１共鳴部材が、前記第２共鳴部材に対して長手軸方向にずらして配置される、請求項１９に記載の超音波外科用器具。
【請求項２３】
前記第１共鳴部材が、可撓性結合によって前記第２共鳴部材に連結される、請求項１９に記載の超音波外科用器具。
【請求項２４】
前記第１共鳴部材および第２共鳴部材が、積層プロセスによって一緒に積層される、請求項１９に記載の超音波外科用器具。
【請求項２５】
前記複数の共鳴部材が、積層体の形態である、請求項１９に記載の超音波外科用器具。
【請求項２６】
前記複数の共鳴部材が、一緒に積層される、請求項１９に記載の超音波外科用器具。
【請求項２７】
前記変換器が、複数の変換器を備える、請求項１９に記載の超音波外科用器具。
【請求項２８】
前記操作可能な構造体が、ハンドルである、請求項１９に記載の超音波外科用器具。
【請求項２９】
前記操作可能な構造体が、前記器具から離れて位置するモジュール上に位置する、請求項１９に記載の超音波外科用器具。
【請求項３０】
前記本体部分が、前記モジュールから前記末端エフェクタへと遠位に延びる細長可撓性部材を備える、請求項２９に記載の超音波外科用器具。
【請求項３１】
前記変換器が、ずらして配置された複数の変換器を備える、請求項１９に記載の超音波外

科用器具。

【請求項３２】

前記複数の変換器の変換器は、ずらして配置されるが、前記複数の共鳴部材の共鳴部材はずらして配置されていない、請求項３１に記載の超音波外科用器具。

【請求項３３】

前記変換器が、それぞれ、前記第１共鳴部材および第２共鳴部材に作動可能に連結された第１変換器および第２変換器を備える、請求項１９に記載の超音波外科用器具。

【請求項３４】

前記末端エフェクタが、前記変換器を備える、請求項１９に記載の超音波外科用器具。

【請求項３５】

前記複数の共鳴部材の各々の共鳴部材が、フレームおよび共鳴構造体を備え、前記変換器が、該共鳴構造体に作動可能に連結されており、そして該共鳴構造体が前記作動表面を備える、請求項１９に記載の超音波外科用器具。

【請求項３６】

各共鳴構造体が近位端を有し、そして前記第１共鳴部材の共鳴構造体の近位端が、前記第２共鳴部材の近位端に対してずらして配置されている、請求項３５に記載の超音波外科用器具。

【請求項３７】

前記変換器が複数の変換器を備え、ここで前記第１共鳴部材が、前記複数の変換器のうちの１つの変換器をさらに備え、ここでさらに備えられる変換器が、前記第１共鳴部材の共鳴構造体と接触して配置される、請求項３５に記載の超音波外科用器具。

【請求項３８】

前記超音波器具内に配置され、そして変換器手段と作動可能に連結した遠位端および電源と連絡した近位端を有する電導体をさらに備える、請求項１９に記載の超音波外科用器具。

【発明の詳細な説明】

【技術分野】

【０００１】

本願は、２００１年１０月１１日に出願された、米国仮出願番号６０／３２８，５９７（これは、その全体が本明細書中に参考として援用される）に対して優先権を主張する。

【０００２】

（背景）

（１．技術分野）

本開示は、一般に、超音波外科用器具に関する。より具体的には、本開示は、組織の解剖、切断、凝固（ｃｏａｇｕｌａｔｉｏｎ）、結紮および／または止血をもたらすように構成された末端エフェクタを有する、超音波外科用器具に関し、この器具は、開胸手術手順および腹腔鏡下手術手順または内視鏡下手術手順において使用され得る。

【背景技術】

【０００３】

（２．関連技術の背景）

組織における切開、切断、結紮、凝固（ｃｏａｇｕｌａｔｉｏｎ）の実施、および／または止血の実施を包含する手術手順のための超音波器具の使用、ならびにこの器具に関連する利点は、周知である。例えば、超音波発生器を、外科用メスと組み合わせて使用することは、器官組織のより迅速かつより容易な切断を容易にする。さらに、メスの刃と身体組織との間の摩擦接触によって発生する熱（メスの刃が高周波数で振動するので）は、切断の領域における血管の凝固（ｃｌｏｔｔｉｎｇ）を加速する（すなわち、凝固（ｃｏａｇｕｌａｔｉｏｎ）を加速する）。熱発生の速度は、２つの因子（すなわち、システムによって発生する振動の周波数（製造業者によって決定される）、および刃が移動する場合の振動の運動の振幅または距離（使用者によって決定される））によって、制御される。

【０００４】

超音波外科用器具に関連する利点としては、最小の横方向の熱損傷、速度、患者を通る電気回路の作製の非存在、および煙のような望ましくない副生成物の非存在が挙げられる。超音波外科用器具は、従来の開胸手術手順のために適切であり、そして特に、最小侵襲性手術（例えば、腹腔鏡下手術および内視鏡下手術）のために適切である。

【０００５】

超音波外科用器具は、代表的に、操作可能な構造体（例えば、ハンドピース）を備え、これは、振動結合器を介して、末端エフェクタ（例えば、切断／凝固刃）に接続された超音波変換器を有する。この振動結合器は、超音波振動数のたて振動を、超音波変換器から末端エフェクタへと伝える。

【０００６】

超音波の変位（すなわち、変換器から末端エフェクタへと伝達される振動の振幅）は、性質上正弦波である。刃の振動の正弦波運動は、この刃の有効長さを制限する限定因子である。この正弦波曲線に沿った、振幅が０に等しい地点で、刃のゼロ運動が存在する。刃に沿ったゼロ運動の領域を回避するために、振動の波長の１／２より短い刃が使用される。現在、ゼロ運動の領域のない刃の最大刃長さは、約０．２５０インチである。

【０００７】

あるいは、最大運動の領域、および振動する刃の長さに沿った運動のない領域を有する、より長い刃が使用される。運動のない領域は、刃の有効長さを減少させ、刃の効率を低下させ、従って望ましくないことには、手術手順を完了するために必要とされる時間を長くする。

【０００８】

さらに、刃の長さに沿った振幅の大きな変動が存在し、これは、振動の正弦波の性質に起因し、刃の一貫しない挙動、および刃の長さに沿った均一な作動結果の欠如を生じる。均一性は、均等な切断速度および凝固速度のために必要であり、外科医が均等な速度で切断手順を進行させることを可能にし、そしてこの外科医に、外科用デバイスの作動の結果を確実に予測する能力を提供する。

【発明の開示】

【発明が解決しようとする課題】

【０００９】

従って、正弦波振幅曲線に沿ったゼロ点を減少させることにより、末端エフェクタの有効長さを増大させることによって、この末端エフェクタの効率を増加させることにより、手術時間を短くする必要性が存在する。さらに、末端エフェクタの長さに沿って、均一な作動結果を得るための、末端エフェクタの挙動の一貫性を増加させることが、必要とされる。最後に、マイクロ電気機械システム（ＭＥＭＳ）技術（ここで、この器具は、大きさおよび重量が減少され、一方で末端エフェクタの有効長さおよび挙動の一貫性を増す）を使用して構成された超音波外科用器具に対する必要性が存在する。

【課題を解決するための手段】

【００１０】

（要旨）

超音波外科用器具の末端エフェクタが提供され、この超音波外科用器具は、操作可能な構造体、この操作可能な構造体に作動可能に接続され遠位端を有する本体部分、複数の変換器を有し、この末端エフェクタは、本体部分の遠位端上に支持されており、この末端エフェクタは、複数の共鳴部材を備え、この共鳴部材の各々は、この共鳴部材の長さに沿って振動をもたらすために、複数の変換器のうちの変換器の１つに作動可能に接続され、そして組織の切開、切断、凝固、結紮および／または止血をもたらすように構成された、作動表面を備え、ここで、複数の共鳴部材のうちの第１の共鳴部材の振動に関連する変位曲線は、共鳴部材のうちの第２の共鳴部材の振動に関連する変位曲線に対してオフセットしている。

【００１１】

好ましい実施形態において、複数の共鳴部材は、積層体であり、ここで、この積層体は、

第１の共鳴部材が第２の共鳴部材に対して長手軸方向にずらされて、好ましくは、可撓性結合を提供する。好ましくは、この変換器は、それぞれ第１の共鳴部材および第２の共鳴部材に作動可能に接続された、第１の変換器および第２の変換器を備える。
【００１２】
別の好ましい実施形態において、各共鳴部材は、フレームおよび共鳴構造体を備え、ここで、この変換器は、共鳴構造体に作動可能に接続され、そしてこの共鳴構造体は、作動表面を備え、ここで、第１の共鳴部材の共鳴構造体の近位端は、好ましくは、第２の共鳴部材の近位端に対してずれている。好ましくは、第１の共鳴部材は、複数の変換器の内の１つの変換器をさらに備え、そしてさらに備えられる変換器は、第１の共鳴部材の共鳴構造体と接触して配置される。
【００１３】
添付の図面は、本明細書に組み込まれ、そして本明細書の一部を構成し、本発明の実施形態を図示し、そして上に与えられる本発明の一般的な説明、および以下に与えられる実施形態の説明と一緒になって、本発明の原理を説明する役に立つ。
【００１４】
（詳細な説明）
末端エフェクタにおいて手術手順を実施するための超音波外科用器具が提供され、ここで、この末端エフェクタは、ずれた要素のアレイを備え、ここで、このずれは、各要素の変位に関連する変位曲線が、要素のアレイの効果的な作動、および要素のアレイの作動の一貫性を集合的に最大にするために、互いに対してオフセットされるように、構成される。
【００１５】
本開示の超音波外科用器具の好ましい実施形態が、ここで図面を参照して詳細に説明される。この図において、同じ参照番号は、いくつかの図の各々において、同一の要素または対応する要素を表す。図１Ａおよび１Ｂは、例示的な超音波外科用システム（一般に、１０として示される）の、それぞれ第１および第２の実施形態の概略図を示す。システム１０は、超音波器具１２、制御モジュール１４、および超音波器具１２を制御モジュール１４に相互接続する導電性ケーブル１６を備える。超音波器具１２は、開胸手術手順、内視鏡下手術手順または腹腔鏡下手術手順のために構成され得、そして細長本体２０、末端エフェクタ２２、および操作可能な構造体１８を備え、この操作可能な構造体１８は、本体および／または末端エフェクタ２２を操作するために、本体２０および／または末端エフェクタ２２に作動可能に接続される。図１Ａに示される操作可能な構造体１８は、ピストルグリップ構成を有するハンドルアセンブリ１８ａであるが、他のハンドル構成が企図される（例えば、インラインハンドル、ペンシルグリップ、標準的なはさみグリップ、新たな人間工学的に設計されたグリップなど）。回転ノブ１３が、公知の様式で細長本体２０の回転を容易にするために、提供され得る。
【００１６】
図１Ｂに示される操作可能な構造体１８は、ケーブル１６を介して受信された制御信号に従って、本体および／または末端エフェクタ２２を操作する、ロボットシステム１８ｂである。好ましくは、ロボットシステム１８ｂは、制御モジュールおよび操作モジュール（図示せず）を備え、ここで、この制御モジュールは、制御信号を受信し、そしてこの制御信号に従って、所望の操作を実施するように、操作モジュールを制御する。制御モジュールおよび操作モジュールの少なくとも１つは、超音波器具１２の残りの部分から離れた位置に位置し得る。
【００１７】
別の実施形態（図示せず）において、本体２０は、超音波器具１２および操作可能な構造体１８から省略され、そして末端エフェクタ２２は、操作可能な構造体１８に設置される。異なる実施形態（図示せず）において、本体２０は、操作可能な構造体１８を収容する。なお別の実施形態において、操作可能な構造体の少なくとも一部は、超音波器具１２から離れた位置に位置するモジュールの内部または表面に位置する。なお異なる実施形態（図示せず）において、本体２０は、離れて位置するモジュールから末端エフェクタ２２へ

と遠位に延びる、細長可撓性部材を備える。

【００１８】

末端エフェクタ２２は、複数のずれた共鳴部材２８（ｘ）（好ましくは、アレイ２８に形成され、ここでｘ＝（１～ｎ）であり、そしてｎは、共鳴部材２８（ｘ）の数である）を備え、そして好ましくは、移動可能な、例えば、旋回可能なクランプ部材２４をさらに備える。好ましくは、複数の共鳴部材２８（ｘ）は、公知のプロセスによって作製された積層体である。例えば、各共鳴部材２８（ｘ）は、隣接する共鳴部材２８（ｘ）への積層プロセスによって、積層され得る。積層体または積層は、好ましくは、可撓性結合であり、隣接する共鳴部材２８（ｘ）に対する１つの共鳴部材２８（ｘ）の運動を可能にする。積層体は、好ましくは、複数の層を有する。

【００１９】

図示されるように、制御モジュール１４は、電気コンセント（図示せず）との係合のための、電力コード１５を備え得る。あるいは、制御モジュール１４は、バッテリーパックまたはａ／ｃ発生器から電力を受容するように適合され得る。発生器または他の電源が、制御モジュール１４に組み込まれ得ることもまた、企図される。

【００２０】

制御モジュール１４は、電気信号発生器（図示せず）および好ましくは、電気制御回路を備えて、１つ以上の超音波周波数で、器具１２に配置される変換器（図示せず）を駆動する。患者、外科医またはシステムハードウェアへの損傷を防止するために、保護回路が、好ましくは提供される。制御モジュール１４はまた、使用者に情報を提供するため、および使用者からの情報を受けるために、ディスプレイ回路およびハードウェア（図示せず）を備える。この情報は、器具の末端エフェクタに配置されたセンサ（図示せず）から得られ得る。このセンサは、手術されている組織の温度、密度、または超音波インピーダンスもしくは電気インピーダンスをモニタリングするために、提供され得る。

【００２１】

より効果的な結紮、切断、切開、凝固などを提供するために提供される任意のセンサと相互作用するために、フィードバック回路が提供され得る。例えば、フィードバック回路は、組織の温度、密度または超音波インピーダンスもしくは電気インピーダンスが、予め決定された最大値を超えたことをセンサが示す場合に、システムの作動を停止させ得る。超音波インピーダンスは、温度の上昇に起因して、組織が硬化するにつれて増加する。同様に、電気インピーダンスは、加熱に起因して、組織水レベルが低下する場合に低下する。フィードバック回路は、外科医によって選択的に作動および停止され、そして／または制御もしくはモニタリングされて、この器具の作動のさらなる融通性を外科医に提供し得る。さらに、制御モジュール１４は、器具１２またはそのハードウェアを試験および／または手直しする際に補助する、診断回路を備え得る。

【００２２】

超音波器具１２の作動は、コンピュータの使用によって自動的に制御され得ることが企図される。本開示のシステムの１つの好ましい代替の実施形態において、コンピュータ２１は、超音波器具の末端エフェクタに配置されるセンサからデータを受信する。上で議論されたように、センサは、手術中の組織の異なる特徴（とりわけ、温度および／または超音波インピーダンスもしくは電気インピーダンスが挙げられる）をモニタリングするために、提供され得る。コンピュータ２１は、好ましくは、センサから受信されたアナログ信号を処理して、このアナログ信号をデジタル信号に変換するための回路を備える。この回路は、アナログ信号を増幅およびフィルタリングするための手段を備え得る。その後、デジタル信号が評価され得、そして超音波器具の作動がモニタリングされて、組織の内部または表面における所望の効果を達成し得、そして周囲の組織に対する損傷を防止し得る。コンピュータ２１は、制御モジュール１４に組み込まれ得るか、または制御モジュール１４に連結されて、器具１２の作動の所望の改変または適切な改変をもたらし得る。

【００２３】

図２は、３つの例示的な共鳴部材２８（１～３）を示す。器具１２は、異なる数の共鳴部

材２８（ｘ）を有するアレイ２８で構成され得る。共鳴部材２８（１～３）は、並列で配置され得、その結果、これらは、互いに対して横方向に接近する。共鳴部材２８（ｘ）は、互いに結合または付着され、そして１つのユニットとして、超音波器具１２の細長本体２０内に設置されるか、あるいは、共鳴部材２８（ｘ）は、互いから離され、そして超音波器具１２の本体２０内に個々に設置される。

【００２４】

共鳴部材２８（ｘ）の近位端は、隣接する共鳴部材２８（ｘ）に対してずらされ、そして好ましくは、このずれの距離ｄは、隣接する共鳴部材２８（ｘ）の各対について均一であり、ここで、距離ｄは、図４に関して以下に記載されるように、アレイ２８における共鳴部材２８（ｘ）の数、および共鳴部材２８（ｘ）の変位曲線の波長によって決定される。変換器３２（１つが示される）は、各それぞれの超音波部材要素２８（ｘ）上に同様に配置され得る。あるいは、各共鳴部材２８（ｘ）上での変換器３２の配置は、距離ｄだけずらされ得る。共鳴部材２８（ｘ）の長さは、均一であっても変動可能であってもよい。従って、共鳴部材２８（ｘ）の遠位端は、互いと同一平面上であり得るか、またはずらされ得る。共鳴部材２８（ｘ）はそれぞれ、種々の形状を有し得ることが企図される。

【００２５】

共鳴部材２８（ｘ）は、好ましくは、積層体を形成する。この積層体は、任意の公知のプロセス（例えば、積層、何らかの型の結合、押出し成型、射出成形、成形またはこれらの組み合わせ）によって形成される。好ましくは、共鳴部材２８（ｘ）は、可撓性材料によって互いに結合され、これは、別の共鳴部材２８（ｘ）に対する１つの共鳴部材２８（ｘ）の移動を可能にし、この相対的な移動は、代表的に、ミクロンのオーダーである。隣接する共鳴部材２８（ｘ）を結合するための結合材料の位置決めは、設計の考慮に関して変化し得、従って、隣接する共鳴部材２８（ｘ）の、接着材料が塗布された対面する表面積の割合は、変化し得る。

【００２６】

器具１２の共鳴部材２８（１～３）は、好ましくは、マイクロ電気機械システム（ＭＥＭＳ）技術を使用して構成される。共鳴部材２８（１～３）は、各々、本体部分３０および共鳴構造体３１を備える。示されるＭＥＭＳ構造において、変換器３２は、各共鳴部材２８（１～３）に支持されるか、共鳴部材２８（１～３）の間に位置するか、または共鳴部材２８（１～３）の本体部分３０の表面もしくは内部に結合される。各それぞれの共鳴部材２８（ｘ）に関連する変換器３２は、変換器のアレイであり得る。

【００２７】

変換器３２は、共鳴部材２８（１）の表面、内部、または隣接位置に配置されて、任意の軸（例えば、ｘ軸、ｙ軸、ｚ軸、またはｘ軸とｙ軸とｚ軸との間の任意の軸）に沿った振動を生じ得る。共鳴部材２８（１）は、組織の切開、切断、凝固、結紮、および／または止血の実施をもたらすように構成された、作動表面（一般に４２で示される）を備える。あるいは、共鳴部材２８（１）は、異なる作業（例えば、切断および凝固）を実施するための複数の作動表面を備え得る。システム１０（器具１２を備える）は、種々の外科的アプローチ（一般的な手順、婦人科学的手術手順、泌尿器科学的手術手順、胸部の手術手順、心臓の手術手順、および神経学的手術手順が挙げられる）において使用され得る。器具１２は、内視鏡下手術手順と開胸手術手順との両方を実施するように構成され得、そして公知の様式で、指スイッチまたはフットペダルを介して始動され得る。始動デバイスは、器具１２の始動をもたらすために、無線伝達回路を備え得る。

【００２８】

各変換器３２は、制御モジュール１４における電気信号発生器（図示せず）から電気信号を受信して、各変換器３２を（例えば、圧電素子または電気ひずみ素子を介して）電気的に励起させる。各変換器３２は、この電気信号を機械的エネルギーに変換し、変換器３２および共鳴部材２８（１）の超音波振動数の振動運動を生じる。超音波部材２８（１）は、高周波数範囲と低周波数範囲との両方で振動し得る。低周波数範囲（約２０～１００ｋＨｚ）において、この器具は、組織において空洞現象を発生させ、組織の切断をもたらす

。高周波数範囲（１ＭＨｚより高い）において、この器具は、組織の加熱および凝固のために使用され得る。高周波数および低周波数での始動は、両方の周波数を発生させ得る電力増幅器によって同時に起こり得る。振動運動は、好ましくは、主として長手軸方向である。振動運動は、例えば、Ｂａｌａｍｕｔｈ振動でのような横向きの運動であることが、企図される。

【００２９】

図３は、振動する共鳴部材２８（１）に沿った変位曲線のプロットを示す。ｙ軸は、振動の変位／振幅であり、そしてｘ軸は、共鳴部材２８（１）の長さである。このプロットは、振動の振幅に関して性質が正弦波であり、そして共鳴部材２８（１）の運動の量は、共鳴部材２８（１）の長さに沿って変化する。この曲線の振幅は、振動する共鳴部材２８（１）の変位の量に対応する。共鳴部材２８（１）の点Ａ、ＢおよびＣは、最大の運動の点（腹としてもまた公知）であり、そして共鳴部材２８（１）の点Ｄ、ＥおよびＦは、実質的に運動がない点であり、ここで、この曲線の振幅は０である（節としてもまた公知）。

【００３０】

好ましくは、変換器３２は、圧電変換器である。あるいは、圧電以外の他の変換機構が使用され得、熱応力、電気ひずみ、磁気ひずみ、または光学駆動機構が挙げられる。変換器３２は、電気コネクタ（好ましくは、ケーブル３４）によって、電気信号発生器および制御モジュール１４に接続される。ケーブル３４は、ケーブル１６と組み合わせられ得る。ケーブル３４は、変換器３２から器具１２の本体２０（図１）を通って近位に延び、そして電気信号発生器への接続のために、この器具のハンドルアセンブリ１８の開口部（図示せず）を通って器具１２から出得る。図３に示されるように、１つのケーブルは、各変換器３２のために提供され、第１の端部は、電気信号発生器に接続され、そして第２の端部は、それぞれの変換器３２と接続される。別の実施形態において、１つのケーブル３４が提供され、これは、第１の端部において電気信号発生器に接続され、そして第２の端部において、複数のケーブル分枝３４ａに分枝し、各ケーブル分枝３４ａが、変換器のアレイの１つの変換器３２に接続される。

【００３１】

図４は、振動する共鳴部材２８（１～３）にそれぞれ沿った、変位曲線４０（１～３）のプロットを示し、ここで、曲線４０（１～３）の相対的オフセットは、共鳴部材２８（１～３）を長手軸方向に沿って互いにずらすことによって、生じる。曲線４０（１～３）は、各曲線の極大点Ａ、Ｂ、Ｃが、それぞれ他の曲線の極大点Ａ、Ｂ、Ｃからオフセットし、そして極小点Ｄ、Ｅ、Ｆについても同様にオフセットするように、互いからオフセットする。

【００３２】

アレイ２８の長さに沿って、組み合わせられた（すなわち合計された）変位曲線４０（１～３）は、組み合わせられた振幅が０であるいずれの節をも有さず、従って、振動アレイ２８の正味の変位は常に０でない。従って、アレイ２８の全長に沿って、正味の振動運動は存在せず、このことは、１つのみの振動要素を有する従来の超音波部材に対してアレイ２８の有効長さを長くする。アレイ２８の長さは、ゼロ運動の領域が全くなしで、アレイ２８の全長に沿って正味の振動運動が存在するように、無限に伸長され得る。

【００３３】

さらに、アレイ２８の長さに沿って、組み合わせられた変位曲線４０（１～３）は、単一の組み合わせられた変位曲線よりずっと低い振幅変化を有し、従って、振動アレイに沿った正味の運度は、１つのみの振動要素を有する超音波部材に対して比較的一定である。

【００３４】

波長λを有する、ｎ個の共鳴部材の変位曲線間のオフセットは、好ましくは、λ／ｎである。従って、図２における距離ｄは、λ／３である。同様に、ｎ個の共鳴部材２８（ｘ）を有するアレイについては、オフセットの距離ｄは、好ましくは、λ／ｎである。別の実施形態において、距離ｄは、λ／ｎ以外であるように選択され得、そしてｎ個の振動共鳴部材２８（ｘ）の変位曲線のオフセットは、λ／ｎとは異なり得る。

【００３５】
別の実施形態において、異なる共鳴部材２８（ｘ）についての変位曲線は、異なる波長および／または異なる振幅を有する。１より多い周波数で振動を引き起こされる超音波部材２８（ｘ）は、１つより多くの変位曲線を有し得、これらの変位曲線は、異なる波長を有する。例えば、変換器のアレイの異なる変換器３２は、異なる周波数を有する振動を発生させ得る（例えば、変換器への入力を変化させること、または異なって構成された変換器を有することによる）。あるいは、周波数、波形または振幅を変化させるため、変換器３２によって発生された振動の１つより多い周波数またはその組み合わせを重ねるために、回路が提供され得る。従って、共鳴部材２８（ｘ）の振動は、正弦波以外であり得る。
【００３６】
共鳴部材２８（ｘ）を長手軸方向にずらす代わりに、共鳴部材２８（ｘ）の変位曲線を互いに対してオフセットさせるための他の手段が提供され得ることが、企図される。例えば、変換器３２または変換器内に入力または出力を提供するラインの少なくとも１つに、遅延回路が提供され得る。別の実施形態において、変換器の作動を制御するための制御ユニット、および／または変位曲線のオフセットをもたらすための遅延回路が提供される。
【００３７】
従来の器具において、変換器は、従来、ハンドピースの近位端に取り付けられ、そして細長振動結合器を介して、器具の末端エフェクタに接続されている。本発明の変換器のアレイは、従来の器具の変換器と同様に配置され得ること、および振動結合器は、このアレイの各変換器を、器具１２の遠位端に設置されたそれぞれの共鳴部材２８（ｘ）に接続するために提供されることが、企図される。
【００３８】
変換器３２が、器具の遠位先端に隣接する共鳴部材２８（ｘ）の表面、間、または内部に位置する、ＭＥＭＳ構成について、以下の利点が実現され得る：ａ）チタンから形成される細長振動結合器の必要性が除かれ、器具の費用を減少させる；ｂ）器具の本体部分の長さが、器具の性能の変化を実質的に伴わずに変化（例えば、短縮または伸長）され得（例えば、器具の振動結合器が導電体によって交換されているので）、この器具は、本体の長さの変化後に、相当の費用で戻される必要がない；ｃ）超音波エネルギーが、より効率的に患者に伝達され得、従って、エネルギー電力の要件を低下させる；ｄ）この器具の使い捨ての部分が容易に変更され得、そして制限された再使用ハンドルを備える器具の先端、器具全体、またはこれらの間の任意の程度の使い捨て可能性のみを備え得る；ｅ）ハンドルアセンブリが変換器を支持しないので、このハンドルアセンブリは、排除され得るか、またはより人間工学的に構成され得る；そしてｆ）器具の近位端において大きい変換器を使用する代わりに、器具の遠位端の表面、内部または隣接位置において小さい変換器を使用することは、実質的に、その器具の重量を減少させ、そして繊細な手術手順の間に特に、管理することを容易にする。
【００３９】
共鳴部材２８（ｘ）の各々の共鳴構造体３１は、好ましくは、ケイ素または金属の共鳴構造体、あるいはケイ素／金属複合材料から形成される。あるいは、チタンまたは他の金属のような材料が、このケイ素に何らかの様式で結合または接合されて、破損耐性を改善し得る。超音波使用に適したケイ素以外の材料が、共鳴構造体３１を形成するために使用され得ることが、企図される。
【００４０】
共鳴構造体３１は、エッチングプロセス（例えば、等方性エッチング、深反応性イオンエッチングなど）を使用して形成され得る。適切なエッチングプロセスは、１９９４年１０月３１日に出願された米国特許第５，７２８，０８９号（これもまた、その全体が本明細書中に参考として援用される）に開示されている。あるいは、他の公知の手段（種々の異なる機械的プロセスが挙げられる）を使用して、超音波部材を形成し得る。
【００４１】
共鳴構造体３１は、作動表面４４を有する線状刃として示される（図２）。図５Ａ～Ｋは

、共鳴部材２８（ｘ）の共鳴構造体３１の代替の構成を示し、とりわけ、Ｊ字型フック（図５Ａ）、Ｌ字型フック（図５Ｂ）、種々の異なる断面形状（図５Ｄ～５Ｇ）を有するシャー（図５Ｃ）、へら型（図５Ｈ）、弓型（図５Ｉおよび５Ｊ）、ならびに矩形（図５Ｋ）が挙げられる。末端エフェクタはまた、湾曲した刃（例えば、１９９７年8月１４日に出願された米国特許第６，０２４，７５０号に開示される刃）および／または角度のついた刃（例えば、１９９６年１０月４日に出願された米国特許第６，０３６，６６７号に開示される）を有するように構成され得る（これらの両方が、その全体が本明細書中に参考として援用される）。

【００４２】

共鳴部材２８（ｘ）の各々または一体的なユニットとしてのアレイ２８は、任意の公知の様式で、器具１２の遠位端に取り付けられ得る。例えば、共鳴部材２８（ｘ）の各々またはアレイ２８は、器具１２の本体２０の遠位端内に支持される基板またはシャフトまたは取り付け部材（図示せず）に、例えば、スナップフィット接続、止めねじまたはクランピングもしくはスエージ加工によって、固定され得る。共鳴部材２８（ｘ）の各々または一体的なアレイ２８の近位端の表面に形成されるかまたはその表面もしくは内部に配置される、ねじ切りされたシャンク４０または他の取り付け構造体が、器具１２の遠位端への共鳴部材２８（ｘ）またはアレイ２８の取り付けのために提供され得る。

【００４３】

図６は、ＭＥＭＳ構成で構成され、そして超音波外科用システム１０の本開示の超音波外科用器具において使用するために適切な、共鳴部材２８（１）の１つの好ましい実施形態を図示する。好ましくは、共鳴部材２８（２～ｎ）（図示せず）は、類似の実施形態を有する。共鳴部材２８（１）は、好ましくは、圧電積層構造体であり、これは、フレーム１０２、共鳴構造体３１、および変換器３２を有する、本体３０を備える。変換器３２は、好ましくは、ケイ素プレート１１０で隔てられた、一対のＰＺＴ結晶１０８を備える。あるいは、ＰＺＴ結晶以外の結晶が、電力を有効な機械的振動に変換するために使用され得ることが、企図される。適切な結合剤またはプロセス（例えば、はんだ結合、拡散結合、接着剤など）が、結晶１０８をプレート１１０に固定するために使用される。

【００４４】

共鳴構造体３１は、好ましくは、その遠位端に、第１の共鳴部材１０４ａおよび第２の共鳴部材１０４ｂを備える。共鳴部材１０４ａおよび１０４ｂの近位端は、一緒になって、変換器３２を受容するための空洞を規定する。あるいは、共鳴構造体３１は、一片の材料からモノリシックに形成され得る。ＰＺＴ結晶１０８と、共鳴部材１０４ａおよび１０４ｂとの嵌合表面は、適切な可撓性結合剤または結合プロセス（例えば、ガラス結合、接着剤など）を使用して、一緒に固定される。

【００４５】

フレーム１０２は、本体１１２を備え、この本体は、好ましくは、剛性材料（金属、セラミックなどが挙げられる）から形成され、そして共鳴構造体３１および変換器３２のアセンブリを受容するような寸法および構成にされた、空洞１１４を備える。結合層１１８（好ましくは、導電性金属から形成される）は、共鳴部材１０４ａおよび１０４ｂの近位部分と、フレーム１０２との間に配置され、変換器３２（これは、移動可能である）を、フレーム１０２（これは、静止している）に結合する。フレーム１０２の近位端は、貫通孔１２０を備え、この貫通孔は、導電体１２２（例えば、ワイヤまたは同軸ケーブル）の通過を可能にする寸法にされて、変換器３２に電力を供給する。この導電体は、好ましくは、高電圧高周波数のテフロン（登録商標）絶縁ケーブルであるが、他の導体の使用が企図される。導体１２２の遠位端は、可撓性導電性ワイヤ１２４によってプレート１１０に接続され、このワイヤは、フレーム１０２と変換器３２との間の相対的な移動を制限しない。

【００４６】

上で議論されたように、共鳴構造体３１の形状は、図６に示されるものと異なり得る。より具体的には、共鳴構造体３１の遠位作動表面１２６は、図５Ａ～５Ｋに示される構成の

いずれか、または本明細書中には示されない任意の他の構成（これは、特定の手術手順を実施するために有利であり得る）を呈し得る。さらに、クランプが、組織の把持を容易にするために提供され得る。

【００４７】

好ましい実施形態において、共鳴部材２８（ｘ）のアレイ２８の第１の共鳴部材２８（１）の共鳴部材１０４ａおよび１０４ｂの近位端は、それぞれの共鳴部材の変位曲線におけるオフセットを生じるために、第２の共鳴部材の近位端に対してずらされる。

【００４８】

種々の改変が、本明細書中に開示される実施形態になされ得ることが、理解される。例えば、末端エフェクタの超音波部材の構成は、本明細書中に示されるとおりである必要はなく、むしろ、特定の外科適用に適切な任意のものであり得る。さらに、変換器は、この器具の遠位の末端エフェクタの超音波部材の近位に取り付けられ得、そして超音波部材に直接設置される必要はない。従って、上記記載は、限定として解釈されるべきではなく、単に、好ましい実施形態の例示として解釈されるべきである。当業者は、本明細書に添付される特許請求の範囲の範囲および精神の範囲内で、他の改変を予測する。

【図面の簡単な説明】

【００４９】

【図１Ａ】図１Ａは、組織における切断、切開、結紮、凝固および／または止血の実施のための外科用器具を備える、本開示の超音波外科用システムの１つの実施形態の概略図である。

【図１Ｂ】図１Ｂは、本開示の超音波外科用システムの別の実施形態の概略図である。

【図２】図２は、本開示の超音波外科用器具の複数の共鳴部材の、１つの好ましい実施形態の概略上面図または概略側面図である。

【図３】図３は、本開示の超音波外科用器具の超音波部材の振動共鳴部材の変位曲線のプロットである。

【図４】図４は、本開示の超音波外科用器具の超音波部材の複数の振動共鳴部材の変位曲線のプロットである。

【図５Ａ】図５Ａは、本開示の超音波外科用器具の共鳴部材の１つの好ましい代替の実施形態の側面図である。

【図５Ｂ】図５Ｂは、本開示の超音波外科用器具の共鳴部材の別の好ましい代替の実施形態の側面図である。

【図５Ｃ】図５Ｃは、本開示の超音波外科用器具の共鳴部材の別の好ましい代替の実施形態の側面図である。

【図５Ｄ】図５Ｄは、図５Ｃの分割線Ｘ－Ｘに沿った断面図である。

【図５Ｅ】図５Ｅは、図５Ｃの分割線Ｘ－Ｘに沿って見た場合の、図Ｄに示される超音波部材の代替の実施形態の断面図である。

【図５Ｆ】図５Ｆは、図５Ｃの分割線Ｘ－Ｘに沿って見た場合の、図Ｄに示される超音波部材の代替の実施形態の断面図である。

【図５Ｇ】図５Ｇは、図５Ｃの分割線Ｘ－Ｘに沿って見た場合の、図Ｄに示される超音波部材の代替の実施形態の断面図である。

【図５Ｈ】図５Ｈは、本開示の超音波部材の別の代替の実施形態の上面図である。

【図５Ｉ】図５Ｉは、本開示の超音波部材の別の実施形態の側面斜視図である。

【図５Ｊ】図５Ｊは、本開示の超音波部材の別の実施形態の側面斜視図である。

【図５Ｋ】図５Ｋは、本開示の超音波部材の別の実施形態の側面図である。

【図６】図６は、本開示の超音波外科用器具の超音波部材の好ましい実施形態の、上面または側面の概略図である。

【図３】

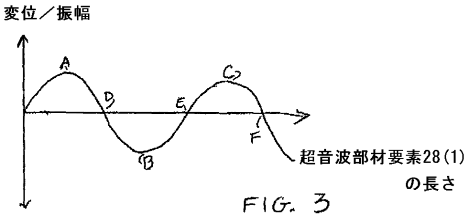


FIG. 3

【図４】

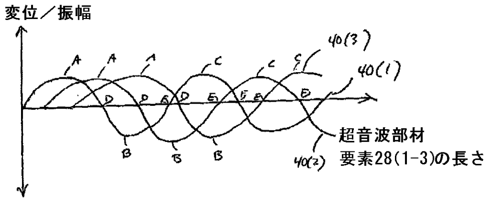


FIG. 4

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LONG ULTRASONIC CUTTING BLADE FORMED OF LAMINATED SMALLER BLADES

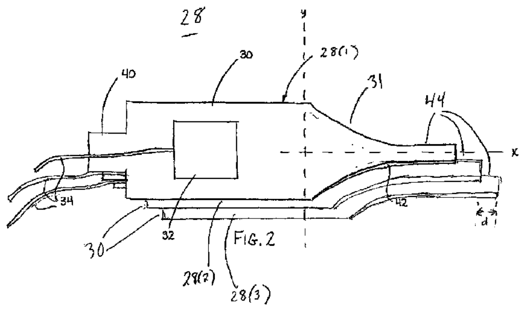

FIG. 2

(57) Abstract: An end effector of an ultrasonic surgical instrument is provided, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a transducer, and the end effector being supported on the distal end of the body portion, the end effector including a plurality of resonant member elements, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member, and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

WO 03/030754 A1

LONG ULTRASONIC CUTTING BLADE FORMED OF LAMINATED SMALLER BLADES

This application claims priority to U.S. Provisional Application Serial No. 60/328,597, filed October 11, 2001, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates generally to ultrasonic surgical instruments. More specifically, the present disclosure relates to ultrasonic surgical instruments having an end effector configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, which instrument can be used in open as well as laparoscopic or endoscopic surgical procedures.

2. Background of Related Art

The use of ultrasonic instruments for surgical procedures including dissecting, cutting, ligating, effecting coagulation in, and/or effecting hemostasis in tissue and the benefits associated therewith are well known. For example, the use of an ultrasonic generator in conjunction with a surgical scalpel facilitates faster and easier cutting of organic tissue. Furthermore, heat generated by frictional contact between the scalpel blade and the body tissue, as the scalpel blade is vibrated at a high frequency, accelerates blood vessel clotting in the area of the cut, i.e., accelerates coagulation. The speed of heat generation is controlled by two factors, namely the frequency of the oscillations generated by the system, (determined by the manufacturer), and the amplitude or distance of movement of the oscillations as the blade is moved (determined by the user).

Advantages associated with ultrasonic surgical instruments include minimal lateral thermal damage, speed, absence of creation of an electrical circuit through the patient, and absence of unwanted byproducts such as smoke. Ultrasonic surgical instruments are suitable for traditional open surgical procedures and are particularly suitable for minimally invasive surgery such as laproscopic and endoscopic surgery.

An ultrasonic surgical instrument typically includes a manipulatable structure, such as a hand piece, having an ultrasonic transducer connected to an end-effector, such as a cutting/coagulating blade, via a vibration coupler that conducts ultrasonic frequency longitudinal vibrations from the ultrasonic transducer to the end-effector.

The ultrasonic displacements, i.e., amplitude of the vibrations transmitted from the transducer to the end-effector are sinusoidal by nature. The sinusoidal motion of the vibrations of the blade is a limiting factor that constrains the effective length of the blade. At the points along the sinusoidal curve where the amplitude is equal to zero, there is zero motion of the blade. To avoid areas of zero motion along the blade, a blade shorter than ½ wavelength of the oscillations is used. Currently the maximum blade length of a blade without zero motion areas is approximately .250".

Alternatively, a longer blade is used having areas of maximum motion, as well as areas of no motion along the length of the vibrating blade. The areas of no motion decrease the effective length of the blade, decreasing efficiency of the blade, and thus undesirably increasing the time needed to complete the surgical procedure.

Furthermore, there are large variations in amplitude along the length of the blade due to the sinusoidal nature of the oscillations, resulting in inconsistent behavior of the blade, and a lack of uniform operative results along the length of the blade. Uniformity is desirable for an even rate of cutting and coagulation, allowing the surgeon to proceed with the cutting procedure at an even rate and providing the surgeon with the ability to reliably predict results of operation of the surgical device.

Accordingly, the need exists for a decrease in operative time by increasing efficiency of the end-effector by increasing the effective length of the end-effector by reducing zero points along the sinusoidal amplitude curve. Furthermore, there is a need for increased consistency of behavior of the end-effector for obtaining uniform operative results along the length of the end-effector. Finally, the need exists for an ultrasonic surgical instrument configured using Micro Electrical Mechanical Systems (MEMS) technology in which the instrument is reduced in size and weight while increasing the effective length and behavior consistency of the end effector.

SUMMARY

An end effector of an ultrasonic surgical instrument is provided, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a plurality of transducers, and the end effector being supported on the distal end of the body portion, the end effector including a plurality of resonant members, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member, and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

In a preferred embodiment, the plurality of resonant members is a laminate, where the laminate preferably provides a flexible bond, with the first resonant member staggered longitudinally relative to the second resonant member. Preferably, the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

In another preferred embodiment, each resonant member includes a frame and a resonant structure, wherein the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface, wherein the proximal end of the resonant structure of the first resonant member is preferably staggered relative to the proximal end of the second resonant member. Preferably, the first resonant member further includes a transducer of the plurality of transducers, and the further included transducer is positioned in contact with the resonant structure of the first resonant member.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1A is a schematic representation of one embodiment of the presently disclosed ultrasonic surgical system including a surgical instrument for cutting, dissecting, ligating, coagulating and/or effecting hemostasis in tissue;

FIG. 1B is a schematic representation of another embodiment of the presently disclosed ultrasonic surgical system;

FIG. 2 is a schematic top or side representation of one preferred embodiment of a plurality of resonant members of the presently disclosed ultrasonic surgical instrument;

FIG. 3 is a plot of a displacement curve of a vibrating resonant member of the ultrasonic member of the presently disclosed ultrasonic surgical instrument;

FIG. 4 is a plot of a displacement curve of multiple vibrating resonant members of the ultrasonic member of the presently disclosed ultrasonic surgical instrument;

FIG. 5A is a side view of one preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5B is a side view of another preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5C is a side view of another preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5D is a cross-sectional view taken along section lines X-X in FIG. 5C;

FIG. 5E is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5F is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5G is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5H is a top view of another alternate embodiment of the presently disclosed ultrasonic member;

FIG. 5I is a side perspective view of another embodiment of the presently disclosed ultrasonic member;

FIG. 5J is a side perspective view of another embodiment of the presently disclosed ultrasonic member;

FIG. 5K is a side view of another embodiment of the presently disclosed ultrasonic member; and

FIG. 6 is a top or side schematic representation of a preferred embodiment of the ultrasonic member of the presently disclosed ultrasonic surgical instrument.

DETAILED DESCRIPTION

An ultrasonic surgical instrument for effecting a surgical procedure at an end effector is provided, in which the end effector includes an array of staggered elements, where the staggering is configured so that displacement curves associated with displacement of each element are offset with respect to one another for collectively maximizing effective operation and consistency of operation of the array of elements.

Preferred embodiments of the presently disclosed ultrasonic surgical instrument will now be described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. FIGS. 1A and 1B illustrate schematic views of first and second embodiments, respectively, of exemplary ultrasonic surgical system shown generally as 10. System 10 includes an ultrasonic instrument 12, a control module 14 and conductive cable 16 interconnecting ultrasonic instrument 12 to control module 14. Ultrasonic instrument 12 may be configured for open, endoscopic or laparoscopic surgical procedures and includes an elongated body 20, an end effector 22, and a manipulatable structure 18 operatively connected to the body 20 and/or the end effector 22 for manipulating the body and/or the end effector 22. The manipulatable structure 18 shown in FIG. 1A is a handle assembly 18a having a pistol grip configuration, although other handle configurations are envisioned, e.g., in-line handle, pencil grips, standard scissor grips, new ergonomically designed grips, etc. Rotation knob 13 may be provided to facilitate rotation of elongated body 20 in a known manner.

Manipulatable structure 18 shown in FIG. 1B is a robotic system 18b that manipulates the body and/or the end effector 22 in accordance with control signals received via cable 16. Preferably, the robotic system 18b includes a control module and a manipulation module (not shown), where the control module receives the control signals and controls the manipulation module to effect the desired manipulations in accordance with the control signals. At least one of the control module and the manipulation module may be located remotely from the rest of the ultrasonic instrument 12.

In another embodiment (not shown) the body 20 is omitted from the ultrasonic instrument 12 and from the manipulatable structure 18, and the end effector 22 is mounted to the manipulatable structure 18. In a different embodiment (not shown) the body 20 houses the manipulatable structure 18. In still another embodiment, at least a portion of the manipulatable structure is located in or on a module remotely located from the ultrasonic instrument 12. In yet a different embodiment (not shown) the body 20 includes an elongated flexible member extending distally from the remotely located module to the end effector 22.

End effector 22 includes a plurality of staggered resonant members 28(x), preferably formed in an array 28, where x = (1 to n), and n is the number of resonant members 28(x), and preferably further includes a movable, e.g., pivotable clamp member 24. Preferably, the plurality of resonant members 28(x) a laminate made by a known process. For example, each resonant member 28(x) can be laminated by a lamination process to an adjacent resonant member 28(x). The laminate or lamination is preferably a flexible bonding allowing for motion of one resonant member 28(x) relative to an adjacent resonant member 28(x). The laminate preferably has multiple layers.

As illustrated, control module 14 may include a power cord 15 for engagement with an electrical outlet (not shown). Alternately, control module 14 may be adapted to receive power from a battery pack or from an a/c generator. It is also envisioned that a generator or other power source may be incorporated into control module 14.

Control module 14 includes an electronic signal generator (not shown) and preferably electronic control circuitry to drive a transducer (not shown) positioned on instrument 12 at one or more ultrasonic frequencies. Protective circuitry is preferably provided to prevent injury to a patient, a surgeon or system hardware. Control module 14 also includes display circuitry and hardware (not shown) to provide information to and accept information from a user. This information may be obtained from sensors (not shown) positioned on the instrument end effector. The sensors may be provided to monitor the temperature, density, or ultrasonic or electric impedance, of the tissue being operated on.

Feedback circuitry may be provided to interact with any sensors provided to provide more effective ligation, cutting, dissection, coagulation, etc. For example, the feedback circuitry may terminate operation of the system if a sensor indicates that tissue temperature, density, or ultrasonic or electrical impedance has exceeded a predetermined maximum. The ultrasonic impedance increases as tissue hardens due to rising temperatures. Similarly, electrical impedance is reduced when tissue water level is decreased due to overheating. The feedback circuitry may be selectively activated and deactivated and/or controlled or monitored by a surgeon to provide a surgeon more flexibility in operating the instrument. Further, control module 14 may include diagnostic circuitry to aid in testing and/or debugging instrument 12 or its hardware.

It is contemplated that operation of ultrasonic instrument 12 may be automatically controlled through the use of a computer. In one preferred alternative embodiment of the presently disclosed system, a computer 21 receives data from sensors positioned on the end effector of the ultrasonic instrument. As discussed above, sensors may be provided to monitor different characteristics of the tissue being operated upon including, inter alia, temperature and/or ultrasonic or electrical impedance. Computer 21 preferably includes circuitry to process an analogue signal received from the sensor(s) and to convert the analogue signal to a digital signal. This circuitry may include means to amplify and filter the analogue signal. Thereafter, the digital signal can be evaluated and operation of the ultrasonic instrument can be modified to achieve the desired effect in or on the tissue and prevent damage to surrounding tissue. Computer 21 may be incorporated into control module 14 or linked to control module 14 to effect the desired or appropriate modification of the operation of the instrument 12.

FIG. 2 shows three exemplary resonant members 28(1-3). Instrument 12 may be configured with an array 28 having a different number of resonant members 28(x). The resonant members 28(1-3) can be positioned side by side so that they are transversely close to one another. The resonant members 28(x) are bonded or attached to one another and mounted as one unit within elongated body 20 of the ultrasonic instrument 12, or alternatively, the resonant members 28(x) are detached from one another and mounted individually within the body 20 of the ultrasonic instrument 12.

Proximal ends of the resonant members 28(x) are staggered relative to adjacent resonant members 28(x), and preferably the staggering distance d is uniform for each pair of adjacent resonant members 28(x), where the distance d is determined by the number of resonant members 28(x) in the array 28, and the wavelength of displacement curves of the resonant members 28(x), as described below with respect to FIG. 4. Transducers 32 (one is shown) can be identically located on each respective ultrasonic member element 28(x). Alternatively, the positioning of the transducer 32 on each resonant member 28(x) may be staggered by a distance d. The lengths of the resonant members 28(x) may be uniform or may be variable. Thus, the distal ends of the resonant members 28(x) may be even with one another, or may be staggered. It is contemplated that the resonant members 28(x), respectively, may have a variety of shapes.

The resonant members 28(x) preferably form a laminate. The laminate is formed by any known process, such as a lamination, some type of bonding, extrusion, injection, molding or combination thereof. Preferably the resonant members 28(x) are bonded to one another by a flexible material that allows movement of one resonant member 28(x) relative to another resonant member 28(x), the relative movement typically being on the order of microns. The positioning of the bonding material for bonding adjacent resonant members 28(x) may vary with respect to design considerations, and thus the percentage of facing surface areas of adjacent resonant members 28(x) having bonding material applied thereto may vary.

Resonant members 28(1-3) of instrument 12 are preferably configured using Micro Electrical Mechanical Systems (MEMS) technology. Resonant members 28(1-3) each include a body portion 30 and a resonant structure 31. In the MEMs configuration shown, a transducer 32, is supported on, located between, or bonded to or within the body portion 30 of each resonant member 28(1-3). The transducer 32 associated with each respective resonant member 28(x) can be an array of transducers.

Transducer 32 can be positioned on, within or adjacent resonant member 28(1) to effect vibration along any axis, e.g., the x-axis, the y-axis, the z-axis or any axis in between the x, y and z axes. Resonant member 28(1) includes an operating surface generally designated 42 configured to effect dissection, cutting, coagulation, ligation and/or to effect hemostasis of tissue. Alternately, resonant member 28(1) may include multiple operating surfaces to perform different tasks, e.g., cutting and coagulation. System 10, including instrument 12, can be used in a variety of surgical applications including general procedures, gynecologic, urologic, thoracic, cardiac and neurological surgical procedures. Instrument 12 may be configured to perform both endoscopic and open surgical procedures and may be actuated via a finger switch or a foot pedal in a known manner. The actuation device may include wireless transmission circuitry to effect actuation of instrument 12.

Each transducer 32 receives an electrical signal from the electronic signal generator (not shown) in control module 14, causing each transducer 32 (such as via piezoelectric or magnetostrictive elements) to be electrically excited. Each transducer 32 converts the electrical signal into mechanical energy resulting in vibratory motion of an ultrasonic frequency of transducer 32 and resonant member 28(1). Ultrasonic member 28(1) may be vibrate in both high and low frequency ranges. In the low frequency range, approximately 20-100 KHz, the instrument will cause cavitation in tissue to effect cutting of the tissue. In the high frequency range, greater than 1MHz, the instrument may be used for heating and coagulation of tissue. The high and low frequency actuation may occur simultaneously by an electronic power amplifier, capable of generating both frequencies. The vibratory motion is preferably primarily in a longitudinal direction. It is contemplated that the vibratory motion is a transverse motion, such as in Balamuth vibrations.

FIG. 3 shows a plot of a displacement curve along a vibrating resonant member 28(1). The y-axis is the displacement/amplitude of the vibrations, and the x-axis is the length of the resonant member 28(1). The plot is sinusoidal by nature with respect to amplitude of the vibrations, and the amount of motion of the resonant member 28(1) varies along the length of the resonant member 28(1). The amplitude of the curve corresponds to the amount of displacement of the vibrating resonant member 28(1). Points A, B and C of the resonant member 28(1) are points of maximum motion (also known as anti-nodes), and points D, E and F of the resonant member 28(1) are points of substantially no motion where the amplitude of the curve is zero (also known as nodes).

Preferably transducers 32 are piezoelectric transducers. Alternately, other transduction mechanisms, other than piezoelectric, may be used including thermal stress, electrostriction, magnetostriction or optical drive mechanisms. Transducers 32 are connected to the electronic signal generator and control module 14 by an electrical connector, preferably cables 34. Cables 34 may be merged with cable 16. Cables 34 may extend proximally from transducers 32 through the body 20 of instrument 12 (FIG. 1) and exit instrument 12 through an opening (not shown) in the handle assembly 18 of the instrument for connecting to the electronic signal generator. As shown in FIG. 3, one cable is provided for each transducer 32, with a first end connected to the electronic signal generator, and a second end connected to a respective transducer 32. In another embodiment one cable 34 is provided, which is connected to the electronic signal generator at a first end and at a second end branches into a plurality of cable branches 34a, with each cable branch 34a connected to one transducer 32 of the array of transducers.

FIG. 4 shows a plot of displacement curves 40(1-3) along vibrating resonant members 28(1-3), respectively, where the relative offset of the curves 40(1-3) is caused by staggering of the resonant members 28(1-3) with respect to each other along the longitudinal axis. The curves 40(1-3) are offset from one another such that maximum points A, B, C of each curve are offset from maximum points A, B, C of the other curves, respectively, and likewise for the minimum points D, E, F.

Along the length of the array 28, the combined (i.e. summed) displacement curves 40(1-3) do not have any nodes where the combined amplitude = 0, and therefore the net displacement of the vibrating array 28 is always nonzero. Thus, the along the entire length of the array 28 there is net vibrational motion, which increases the effective length of the array 28 relative to a conventional ultrasonic member having only one vibrating element. The length of the array 28 may be extended indefinitely such that there is net vibrational motion along the entire length of the array 28 without any regions of zero motion.

Furthermore, along the length of the array 28, the combined displacement curves 40(1-3) have much less variation in amplitude than a single combined displacement curve, and therefore the net motion along the vibrating array is relatively consistent with respect to an ultrasonic member having only one vibrating element.

The offset between displacement curves having wavelength λ of n resonant members is preferably λ/n. Thus, the distance d in FIG. 2 is $\lambda/3$. Likewise, for an array having n resonant members 28(x), the distance offset d is preferably λ/n. In another embodiment, the distance d may be selected to be other than λ/n, and the offset of the displacement curves of the n vibrating resonant members 28(x) may be different from λ/n.

In another embodiment, the displacement curves for different resonant members 28(x) have different wavelengths and/or different amplitudes. An ultrasonic member 28(x) caused to vibrate at more than one frequency may have more than one displacement curve, the displacement curves having different wavelengths. For example, the different transducers 32 of the array of transducers may generate vibrations having different frequencies, such as by altering the input to the transducer, or having differently configured transducers. Alternatively, circuitry may be provided for altering the frequency, waveshape or amplitude, superimposing more than one frequency or a combination thereof of the vibrations generated by the transducers 32. Accordingly, the vibration of the resonant members 28(x) may be other than sinusoidal.

It is contemplated that other means may be provided for offsetting the displacement curves of resonant members 28(x) relative to one another, instead of staggering the resonant members 28(x) longitudinally. For example, delay circuitry may be provided to at least one of the lines providing input or output to the transducers 32 or within the transducer. In another embodiment a control unit is provided for controlling operation of the transducer and/or delay circuitry for effecting offsets of the displacement curves.

In conventional instruments the transducer is traditionally attached to the proximal end of the hand piece and connected to the end effector of the instrument via an elongated vibration coupler. It is contemplated that the array of transducers of the present invention may be positioned similarly to the transducer of the conventional instruments, and that a vibration coupler be provided to connect each transducer of the array to a respective resonant member 28(x) mounted at the distal end of the instrument 12.

For MEMs configurations in which the transducers 32 are positioned on, between, or in the resonant members 28(x) adjacent the distal tip of the instrument, the following benefits can be realized: a) the need for an elongated vibration coupler formed of titanium is obviated substantially reducing the cost of the instrument; b) the length of the body portion of the instrument can be changed, e.g., shortened or lengthened, with virtually no consequential change in instrument performance, e.g., since the instrument vibration coupler has been replaced by an electrical conductor, the instrument need not be retuned, at considerable expense, after changes in body length; c) ultrasonic energy can be transferred to a patient more efficiently, thus lowering energy power requirements; d) the portion of the instrument that is disposable can be easily varied and may comprise only the instrument tip with a limited reuse handle, the entire instrument or any degree of disposability therebetween; e) because the handle assembly does not support the transducer, the handle assembly can be eliminated or more ergonomically configured; and f) the use of a small transducer on, in or adjacent the distal end of the instrument in place of a large transducer on the proximal end of the instrument substantially reduces the weight of the instrument and makes it easy to manage especially during delicate surgical procedures.

The resonant structure 31 of each of the resonant members 28(x) is preferably formed of a silicon or metal resonant structure or a silicon/metal composite. Alternately, materials such as titanium or other metals may be bonded or joined in some manner to the silicon to improve fracture resistance. It is envisioned that materials other than silicon which are suitable for ultrasonic use may be used to form resonant structure 31.

The resonant structure 31 may be formed using an etching process, e.g., isotropic etching, deep reactive ion etching, etc. Suitable etching processes are disclosed in U.S. Patent No. 5,728,089 filed October 31, 1994, which is also incorporated herein in its entirety by reference. Alternately, other known means may be used to form the ultrasonic member including a variety of different mechanical processes.

The resonant structure 31 is shown as a linear blade having an operative surface 44 (FIG. 2). FIGS. 5A-K show alternate configurations of the resonant structure 31 of resonant members 28(x), including, inter alia, J-hook (FIG. 5A), L-hook (FIG. 5B), shears (FIG. 5C) having a variety of different cross-sectional shapes (FIGS. 5D-5G), spatula (FIG. 5H), arcuate (FIGS. 5I and 5J) and rectangular (FIG. 5K). The end effector may also be configured to have a curved blade such as the blade disclosed in U.S. Patent No. 6,024,750, filed on August 14, 1997 and/or an angled blade, such as disclosed in U.S. Patent No. 6,036,667, filed on October 4, 1996, both of which are incorporated herein in their entirety by reference.

Each of resonant members 28(x), or array 28 as an integral unit, may be attached to a distal portion of instrument 12 in any known manner. For example, each of resonant members 28(x) or the integral array 28 may be secured to a substrate or shaft or a mounting member (not shown) supported within a distal end of body 20 of instrument 12 such as by a snap-fit connection, a set screw or crimping or swaging. A threaded shank 40 or other attachment structure formed on or disposed on or in a proximal end of each of resonant members 28(x) or integral array 28 may be provided for attachment of the resonant members 28(x) or array 28 to the distal end of instrument 12.

FIG. 6 illustrates one preferred embodiment of resonant member 28(1) configured in the MEMs configuration and suitable for use in the presently disclosed ultrasonic surgical instrument of ultrasonic surgical system 10. Preferably resonant members 28(2-n) (not shown) have similar embodiments. Resonant member 28(1) is preferably a piezoelectric laminate structure which includes a body 30 having frame 102, a resonant structure 31, and a transducer 32. Transducer 32 preferably includes a pair of PZT crystals 108 separated by silicon plate 110. Alternately, it is envisioned that crystals other than PZT crystals may be used to convert electrical power to effect mechanical vibration. An appropriate bonding agent or process, e.g., solder bonding, diffusion bonding, adhesives, etc., is used to fasten crystals 108 to plate 110.

Resonant structure 31 preferably includes at its distal end first and second resonant members 104a and 104b. The proximal end of resonant members 104a and 104b together define a cavity for receiving transducer 32. Alternately, resonant structure 31 may be monolithically formed from a single piece of material. The mating surfaces of PZT crystals 108 and resonant members 104a and 104b are fastened together using an appropriate flexible bonding agent or bonding process, e.g., glass binding, adhesives, etc.

Frame 102 includes a body 112 which is preferably formed from a rigid material including metals, ceramics, etc. and includes a cavity 114 dimensioned and configured to receive the resonant structure 31 and transducer 32 assembly. A bonding layer or layers 118, preferably formed of a conductive material, is positioned between the proximal portion of resonant members 104a and 104b and frame 102 to bond transducer 32, which is movable, to frame 102, which is stationary. The proximal end of frame 102 includes a throughbore 120 which is dimensioned to permit passage of an electrical conductor 122, e.g., a wire or coaxial cable, to provide power to transducer 32. The electrical conductor is preferably a high-voltage high-frequency Teflon insulator cable, although the use of other conductors is envisioned. The distal end of conductor 122 is connected to plate 110 by a flexible conductive wire 124 which does not restrict relative movement between frame 102 and transducer 32.

As discussed above, the shape of resonant structure 31 may be different than that shown in FIG. 6. More specifically, distal operating surface 126 of resonant structure 31 may assume any of the configurations shown in FIGS. 5A-5K or any other configuration not shown herein which may be advantageous for performing a particular surgical procedure. Moreover, a clamp may be provided to facilitate gripping of tissue.

In the preferred embodiment, proximal ends of resonant members 104a and 104b of a first resonant member 28(1) of an array 28 of resonant members 28(x) are staggered relative to the proximal ends of a second resonant member for effecting an offset in displacement curves of the respective resonant members.

It will be understood that various modifications may be made to the embodiments disclosed herein. For example, the configuration of the ultrasonic member of the end effector need not be as shown herein but rather may be any that is suitable for the particular surgical application. Further, the transducer may be mounted proximally of the ultrasonic member of the end effector in the distal end of the instrument and need not be mounted directly to the ultrasonic member. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

WHAT IS CLAIMED IS

1. An end effector of an ultrasonic surgical instrument, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a plurality of transducers, and the end effector being supported on the distal end of the body portion, the end effector comprising:

a plurality of resonant members, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member , and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis,

wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

2. The end effector according to Claim 1, wherein the vibrations are longitudinal.

3. The end effector according to Claim 1, wherein the vibrations are transverse.

4. The end effector according to Claim 1, wherein the first resonant member is staggered longitudinally relative to the second resonant member.

5. The end effector according to Claim 1, wherein the first resonant member is bonded to the second resonant member by a flexible bond.

6. The end effector according to Claim 1, wherein the first and second resonant members are laminated together by a lamination process.

7. The end effector according to Claim 1, wherein the plurality of resonant members are in the form of a laminate.

8. The end effector according to Claim 1, wherein the plurality of resonant members are laminated together.

9. The end effector according to Claim 1, wherein the manipulatable structure is a handle.

10. The end effector according to Claim 1, wherein the manipulatable structure is located on a module remotely located from the instrument.

11. The end effector according to Claim 10, wherein the body portion includes an elongated flexible member extending distally from the module to the end effector.

12. The end effector according to Claim 1, wherein the transducer includes a plurality of staggered transducers.

13. The end effector according to Claim 1, wherein the transducer includes a plurality of staggered transducers, but resonant members of the plurality of resonant members are not staggered.

14. The end effector according to Claim 1, wherein the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

15. The end effector according to Claim 1, wherein the end effector includes the transducer.

16. The end effector according to Claim 1, wherein each resonant member of the plurality of resonant members includes a frame and a resonant structure, the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface.

17. The end effector according to Claim 16, wherein each resonant structure has a proximal end, and the proximal end of the resonant structure of the first resonant member is staggered relative to the proximal end of the second resonant member.

18. The end effector according to Claim 16, wherein the transducer includes a plurality of transducers, and wherein the first resonant member further includes a transducer of the plurality of transducers, wherein the further included transducer is positioned in contact with the resonant structure of the first resonant member.

19. An ultrasonic surgical instrument comprising:

a manipulatable structure;

a transducer;

a body portion operatively connected to the manipulatable structure and having a distal end; and

an end effector supported on the distal end of the body portion, the end effector including:

a plurality of resonant members, each resonant member being operatively connected to the transducer for effecting vibrations along the length of the resonant member, each resonant member including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis,

wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

20. The ultrasonic surgical instrument according to Claim 19, wherein the vibrations are longitudinal.

21. The ultrasonic surgical instrument according to Claim 19, wherein the vibrations are transverse.

22. The ultrasonic surgical instrument according to Claim 19, wherein the first resonant member is staggered longitudinally relative to the second resonant member.

23. The ultrasonic surgical instrument according to Claim 19, wherein the first resonant member is bonded to the second resonant member by a flexible bond.

24. The ultrasonic surgical instrument according to Claim 19, wherein the first and second resonant members are laminated together by a lamination process.

25. The ultrasonic surgical instrument according to Claim 19, wherein the plurality of resonant members are in the form of a laminate.

26. The ultrasonic surgical instrument according to Claim 19, wherein the plurality of resonant members are laminated together.

27. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes a plurality of transducers.

28. The ultrasonic surgical instrument according to Claim 19, wherein the manipulatable structure is a handle.

29. The ultrasonic surgical instrument according to Claim 19, wherein the manipulatable structure is located on a module remotely located from the instrument.

30. The ultrasonic surgical instrument according to Claim 29, wherein the body portion includes an elongated flexible member extending distally from the module to the end effector.

31. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes a plurality of staggered transducers.

32. The ultrasonic surgical instrument according to Claim 31, wherein transducers of the plurality of transducers are staggered, but resonant members of the plurality of resonant members are not staggered.

33. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

34. The ultrasonic surgical instrument according to Claim 19, wherein the end effector includes the transducer.

35. The ultrasonic surgical instrument according to Claim 19, wherein each resonant member of the plurality of resonant members includes a frame and a resonant structure, the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface.

36. The ultrasonic surgical instrument according to Claim 35, wherein each resonant structure has a proximal end, and the proximal end of the resonant structure of the first resonant member is staggered relative to the proximal end of the second resonant member.

37. The ultrasonic surgical instrument according to Claim 35, wherein the transducer includes a plurality of transducers, and wherein the first resonant member further includes a transducer of the plurality of transducers, wherein the further included transducer is positioned in contact with the resonant structure of the first resonant member.

38. The ultrasonic surgical instrument according to Claim 19, further including an electrical conductor positioned within the ultrasonic instrument, and having a distal end operatively associated with the transducer means and a proximal end communicating with a power source.

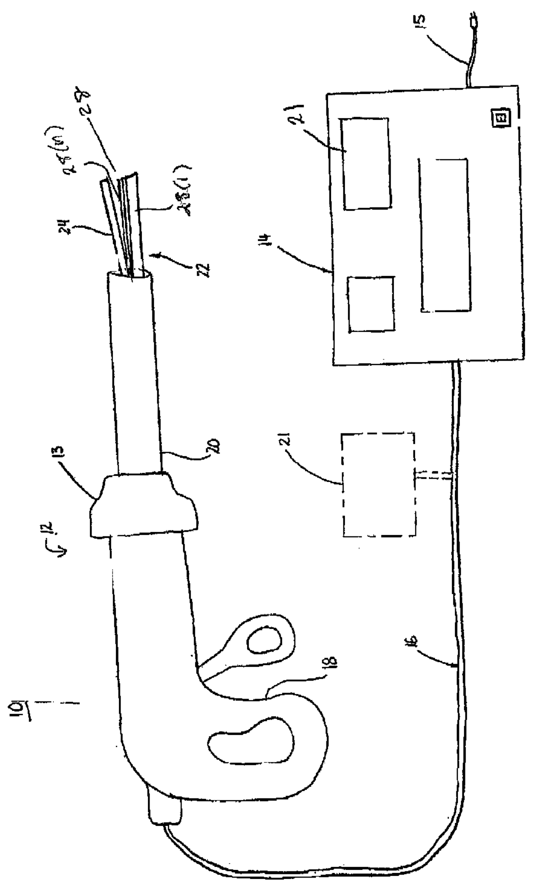

FIG. 1A

WO 03/030754 PCT/US02/32685

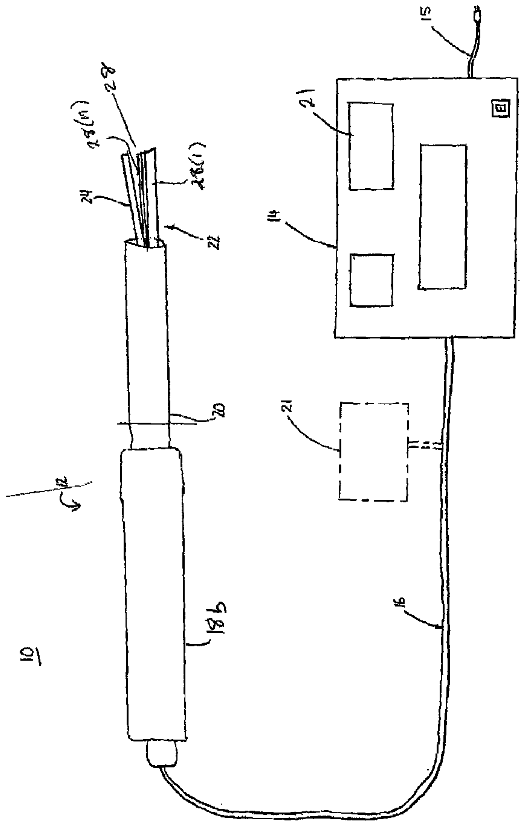

FIG. 1B

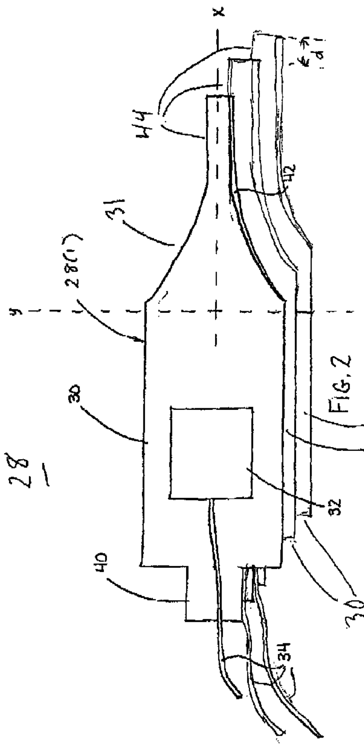

FIG. 2

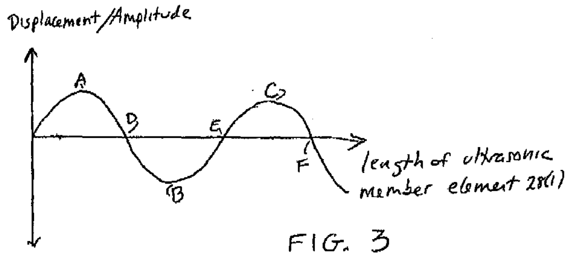
Displacement/Amplitude
A
D
E
C
F
B
length of ultrasonic member element 28(1)

FIG. 3

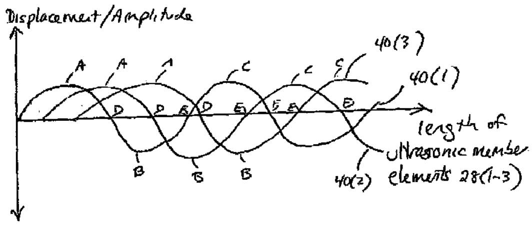
Displacement/Amplitude
40(3)
40(1)
40(2)
length of ultrasonic member elements 28(1-3)

FIG. 4

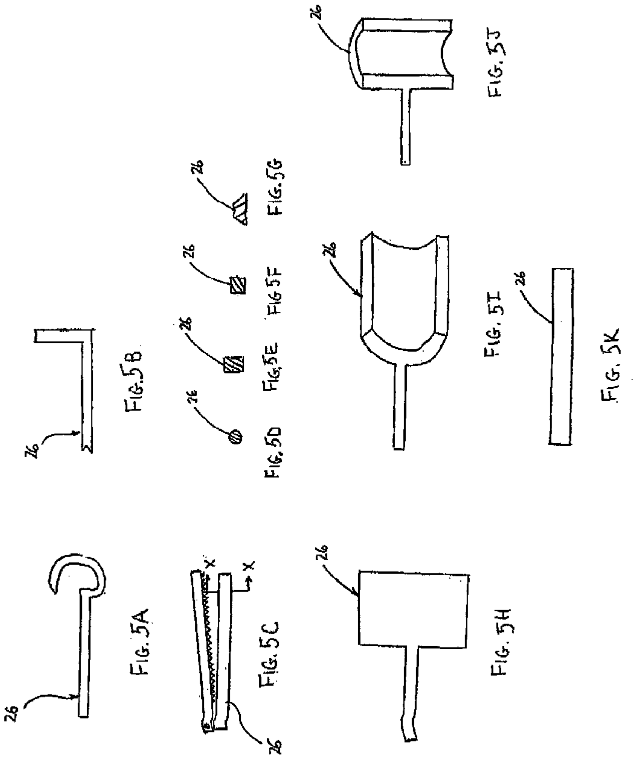

FIG. 5A FIG. 5B FIG. 5C FIG. 5D FIG. 5E FIG. 5F FIG. 5G FIG. 5H FIG. 5I FIG. 5J FIG. 5K

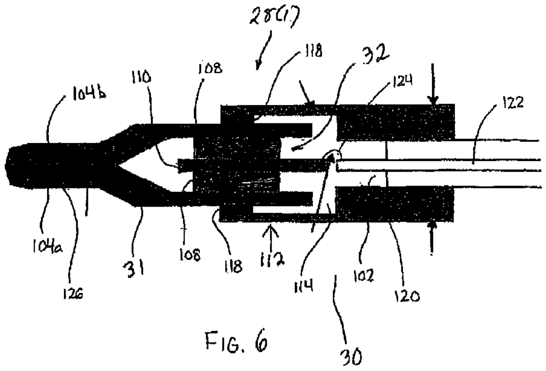
28(1)
118
32
124
122
110
108
104b
104a
126
31
108
118
112
114
102
120
30

FIG. 6

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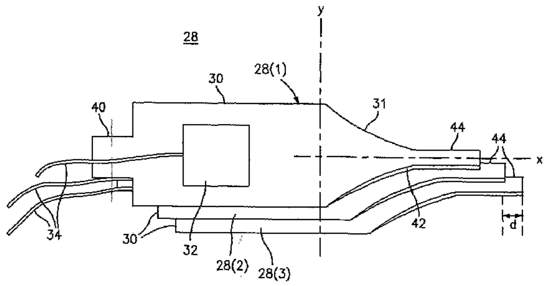

(57) Abstract: An end effector of an ultrasonic surgical instrument is provided, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a transducer, and the end effector being supported on the distal end of the body portion, the end effector including a plurality of resonant member elements, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member, and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

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PATENT APPLICATION

Attorney Docket: 203-3016 (2747PRO)

LONG ULTRASONIC CUTTING BLADE FORMED OF LAMINATED SMALLER BLADES

This application claims priority to U.S. Provisional Application Serial No. 60/328,597, filed October 11, 2001, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates generally to ultrasonic surgical instruments. More specifically, the present disclosure relates to ultrasonic surgical instruments having an end effector configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, which instrument can be used in open as well as laparoscopic or endoscopic surgical procedures.

2. Background of Related Art

The use of ultrasonic instruments for surgical procedures including dissecting, cutting, ligating, effecting coagulation in, and/or effecting hemostasis in tissue and the benefits associated therewith are well known. For example, the use of an ultrasonic generator in conjunction with a surgical scalpel facilitates faster and easier cutting of organic tissue. Furthermore, heat generated by frictional contact between the scalpel blade and the body tissue, as the scalpel blade is vibrated at a high frequency, accelerates blood vessel clotting in the area of the cut, i.e., accelerates coagulation. The speed of heat generation is controlled by two factors, namely the frequency of the oscillations generated by the system, (determined by the manufacturer), and the amplitude or distance of movement of the oscillations as the blade is moved (determined by the user).

Advantages associated with ultrasonic surgical instruments include minimal lateral thermal damage, speed, absence of creation of an electrical circuit through the patient, and absence of unwanted byproducts such as smoke. Ultrasonic surgical instruments are suitable for traditional open surgical procedures and are particularly suitable for minimally invasive surgery such as laproscopic and endoscopic surgery.

An ultrasonic surgical instrument typically includes a manipulatable structure, such as a hand piece, having an ultrasonic transducer connected to an end-effector, such as a cutting/coagulating blade, via a vibration coupler that conducts ultrasonic frequency longitudinal vibrations from the ultrasonic transducer to the end-effector.

The ultrasonic displacements, i.e., amplitude of the vibrations transmitted from the transducer to the end-effector are sinusoidal by nature. The sinusoidal motion of the vibrations of the blade is a limiting factor that constrains the effective length of the blade. At the points along the sinusoidal curve where the amplitude is equal to zero, there is zero motion of the blade. To avoid areas of zero motion along the blade, a blade shorter than ½ wavelength of the oscillations is used. Currently the maximum blade length of a blade without zero motion areas is approximately .250".

Alternatively, a longer blade is used having areas of maximum motion, as well as areas of no motion along the length of the vibrating blade. The areas of no motion decrease the effective length of the blade, decreasing efficiency of the blade, and thus undesirably increasing the time needed to complete the surgical procedure.

Furthermore, there are large variations in amplitude along the length of the blade due to the sinusoidal nature of the oscillations, resulting in inconsistent behavior of the blade, and a lack of uniform operative results along the length of the blade. Uniformity is desirable for an even rate of cutting and coagulation, allowing the surgeon to proceed with the cutting procedure at an even rate and providing the surgeon with the ability to reliably predict results of operation of the surgical device.

Accordingly, the need exists for a decrease in operative time by increasing efficiency of the end-effector by increasing the effective length of the end-effector by reducing zero points along the sinusoidal amplitude curve. Furthermore, there is a need for increased consistency of behavior of the end-effector for obtaining uniform operative results along the length of the end-effector. Finally, the need exists for an ultrasonic surgical instrument configured using Micro Electrical Mechanical Systems (MEMS) technology in which the instrument is reduced in size and weight while increasing the effective length and behavior consistency of the end effector.

SUMMARY

An end effector of an ultrasonic surgical instrument is provided, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a plurality of transducers, and the end effector being supported on the distal end of the body portion, the end effector including a plurality of resonant members, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member, and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis, wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

In a preferred embodiment, the plurality of resonant members is a laminate, where the laminate preferably provides a flexible bond, with the first resonant member staggered longitudinally relative to the second resonant member. Preferably, the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

In another preferred embodiment, each resonant member includes a frame and a resonant structure, wherein the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface, wherein the proximal end of the resonant structure of the first resonant member is preferably staggered relative to the proximal end of the second resonant member. Preferably, the first resonant member further includes a transducer of the plurality of transducers, and the further included transducer is positioned in contact with the resonant structure of the first resonant member.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1A is a schematic representation of one embodiment of the presently disclosed ultrasonic surgical system including a surgical instrument for cutting, dissecting, ligating, coagulating and/or effecting hemostasis in tissue;

FIG. 1B is a schematic representation of another embodiment of the presently disclosed ultrasonic surgical system;

FIG. 2 is a schematic top or side representation of one preferred embodiment of a plurality of resonant members of the presently disclosed ultrasonic surgical instrument;

FIG. 3 is a plot of a displacement curve of a vibrating resonant member of the ultrasonic member of the presently disclosed ultrasonic surgical instrument;

FIG. 4 is a plot of a displacement curve of multiple vibrating resonant members of the ultrasonic member of the presently disclosed ultrasonic surgical instrument;

FIG. 5A is a side view of one preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5B is a side view of another preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5C is a side view of another preferred alternate embodiment of the resonant member of the presently disclosed ultrasonic surgical instrument;

FIG. 5D is a cross-sectional view taken along section lines X-X in FIG. 5C;

FIG. 5E is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5F is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5G is a cross-sectional view of an alternate embodiment of the ultrasonic member shown in FIG. D as would be seen along section line X-X of FIG. 5C;

FIG. 5H is a top view of another alternate embodiment of the presently disclosed ultrasonic member;

FIG. 5I is a side perspective view of another embodiment of the presently disclosed ultrasonic member;

FIG. 5J is a side perspective view of another embodiment of the presently disclosed ultrasonic member;

FIG. 5K is a side view of another embodiment of the presently disclosed ultrasonic member; and

FIG. 6 is a top or side schematic representation of a preferred embodiment of the ultrasonic member of the presently disclosed ultrasonic surgical instrument.

DETAILED DESCRIPTION

An ultrasonic surgical instrument for effecting a surgical procedure at an end effector is provided, in which the end effector includes an array of staggered elements, where the staggering is configured so that displacement curves associated with displacement of each element are offset with respect to one another for collectively maximizing effective operation and consistency of operation of the array of elements.

Preferred embodiments of the presently disclosed ultrasonic surgical instrument will now be described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. FIGS. 1A and 1B illustrate schematic views of first and second embodiments, respectively, of exemplary ultrasonic surgical system shown generally as 10. System 10 includes an ultrasonic instrument 12, a control module 14 and conductive cable 16 interconnecting ultrasonic instrument 12 to control module 14. Ultrasonic instrument 12 may be configured for open, endoscopic or laparoscopic surgical procedures and includes an elongated body 20, an end effector 22, and a manipulatable structure 18 operatively connected to the body 20 and/or the end effector 22 for manipulating the body and/or the end effector 22. The manipulatable structure 18 shown in FIG. 1A is a handle assembly 18a having a pistol grip configuration, although other handle configurations are envisioned, e.g., in-line handle, pencil grips, standard scissor grips, new ergonomically designed grips, etc. Rotation knob 13 may be provided to facilitate rotation of elongated body 20 in a known manner.

Manipulatable structure 18 shown in FIG. 1B is a robotic system 18b that manipulates the body and/or the end effector 22 in accordance with control signals received via cable 16. Preferably, the robotic system 18b includes a control module and a manipulation module (not shown), where the control module receives the control signals and controls the manipulation module to effect the desired manipulations in accordance with the control signals. At least one of the control module and the manipulation module may be located remotely from the rest of the ultrasonic instrument 12.

In another embodiment (not shown) the body 20 is omitted from the ultrasonic instrument 12 and from the manipulatable structure 18, and the end effector 22 is mounted to the manipulatable structure 18. In a different embodiment (not shown) the body 20 houses the manipulatable structure 18. In still another embodiment, at least a portion of the manipulatable structure is located in or on a module remotely located from the ultrasonic instrument 12. In yet a different embodiment (not shown) the body 20 includes an elongated flexible member extending distally from the remotely located module to the end effector 22.

End effector 22 includes a plurality of staggered resonant members 28(x), preferably formed in an array 28, where x = (1 to n), and n is the number of resonant members 28(x), and preferably further includes a movable, e.g., pivotable clamp member 24. Preferably, the plurality of resonant members 28(x) a laminate made by a known process. For example, each resonant member 28(x) can be laminated by a lamination process to an adjacent resonant member 28(x). The laminate or lamination is preferably a flexible bonding allowing for motion of one resonant member 28(x) relative to an adjacent resonant member 28(x). The laminate preferably has multiple layers.

As illustrated, control module 14 may include a power cord 15 for engagement with an electrical outlet (not shown). Alternately, control module 14 may be adapted to receive power from a battery pack or from an a/c generator. It is also envisioned that a generator or other power source may be incorporated into control module 14.

Control module 14 includes an electronic signal generator (not shown) and preferably electronic control circuitry to drive a transducer (not shown) positioned on instrument 12 at one or more ultrasonic frequencies. Protective circuitry is preferably provided to prevent injury to a patient, a surgeon or system hardware. Control module 14 also includes display circuitry and hardware (not shown) to provide information to and accept information from a user. This information may be obtained from sensors (not shown) positioned on the instrument end effector. The sensors may be provided to monitor the temperature, density, or ultrasonic or electric impedance, of the tissue being operated on.

Feedback circuitry may be provided to interact with any sensors provided to provide more effective ligation, cutting, dissection, coagulation, etc. For example, the feedback circuitry may terminate operation of the system if a sensor indicates that tissue temperature, density, or ultrasonic or electrical impedance has exceeded a predetermined maximum. The ultrasonic impedance increases as tissue hardens due to rising temperatures. Similarly, electrical impedance is reduced when tissue water level is decreased due to overheating. The feedback circuitry may be selectively activated and deactivated and/or controlled or monitored by a surgeon to provide a surgeon more flexibility in operating the instrument. Further, control module 14 may include diagnostic circuitry to aid in testing and/or debugging instrument 12 or its hardware.

It is contemplated that operation of ultrasonic instrument 12 may be automatically controlled through the use of a computer. In one preferred alternative embodiment of the presently disclosed system, a computer 21 receives data from sensors positioned on the end effector of the ultrasonic instrument. As discussed above, sensors may be provided to monitor different characteristics of the tissue being operated upon including, inter alia, temperature and/or ultrasonic or electrical impedance. Computer 21 preferably includes circuitry to process an analogue signal received from the sensor(s) and to convert the analogue signal to a digital signal. This circuitry may include means to amplify and filter the analogue signal. Thereafter, the digital signal can be evaluated and operation of the ultrasonic instrument can be modified to achieve the desired effect in or on the tissue and prevent damage to surrounding tissue. Computer 21 may be incorporated into control module 14 or linked to control module 14 to effect the desired or appropriate modification of the operation of the instrument 12.

FIG. 2 shows three exemplary resonant members 28(1-3). Instrument 12 may be configured with an array 28 having a different number of resonant members 28(x). The resonant members 28(1-3) can be positioned side by side so that they are transversely close to one another. The resonant members 28(x) are bonded or attached to one another and mounted as one unit within elongated body 20 of the ultrasonic instrument 12, or alternatively, the resonant members 28(x) are detached from one another and mounted individually within the body 20 of the ultrasonic instrument 12.

Proximal ends of the resonant members 28(x) are staggered relative to adjacent resonant members 28(x), and preferably the staggering distance d is uniform for each pair of adjacent resonant members 28(x), where the distance d is determined by the number of resonant members 28(x) in the array 28, and the wavelength of displacement curves of the resonant members 28(x), as described below with respect to FIG. 4. Transducers 32 (one is shown) can be identically located on each respective ultrasonic member element 28(x). Alternatively, the positioning of the transducer 32 on each resonant member 28(x) may be staggered by a distance d. The lengths of the resonant members 28(x) may be uniform or may be variable. Thus, the distal ends of the resonant members 28(x) may be even with one another, or may be staggered. It is contemplated that the resonant members 28(x), respectively, may have a variety of shapes.

The resonant members 28(x) preferably form a laminate. The laminate is formed by any known process, such as a lamination, some type of bonding, extrusion, injection, molding or combination thereof. Preferably the resonant members 28(x) are bonded to one another by a flexible material that allows movement of one resonant member 28(x) relative to another resonant member 28(x), the relative movement typically being on the order of microns. The positioning of the bonding material for bonding adjacent resonant members 28(x) may vary with respect to design considerations, and thus the percentage of facing surface areas of adjacent resonant members 28(x) having bonding material applied thereto may vary.

Resonant members 28(1-3) of instrument 12 are preferably configured using Micro Electrical Mechanical Systems (MEMS) technology. Resonant members 28(1-3) each include a body portion 30 and a resonant structure 31. In the MEMs configuration shown, a transducer 32, is supported on, located between, or bonded to or within the body portion 30 of each resonant member 28(1-3). The transducer 32 associated with each respective resonant member 28(x) can be an array of transducers.

Transducer 32 can be positioned on, within or adjacent resonant member 28(1) to effect vibration along any axis, e.g., the x-axis, the y-axis, the z-axis or any axis in between the x, y and z axes. Resonant member 28(1) includes an operating surface generally designated 42 configured to effect dissection, cutting, coagulation, ligation and/or to effect hemostasis of tissue. Alternately, resonant member 28(1) may include multiple operating surfaces to perform different tasks, e.g., cutting and coagulation. System 10, including instrument 12, can be used in a variety of surgical applications including general procedures, gynecologic, urologic, thoracic, cardiac and neurological surgical procedures. Instrument 12 may be configured to perform both endoscopic and open surgical procedures and may be actuated via a finger switch or a foot pedal in a known manner. The actuation device may include wireless transmission circuitry to effect actuation of instrument 12.

Each transducer 32 receives an electrical signal from the electronic signal generator (not shown) in control module 14, causing each transducer 32 (such as via piezoelectric or magnetostrictive elements) to be electrically excited. Each transducer 32 converts the electrical signal into mechanical energy resulting in vibratory motion of an ultrasonic frequency of transducer 32 and resonant member 28(1). Ultrasonic member 28(1) may be vibrate in both high and low frequency ranges. In the low frequency range, approximately 20-100 KHz, the instrument will cause cavitation in tissue to effect cutting of the tissue. In the high frequency range, greater than 1MHz, the instrument may be used for heating and coagulation of tissue. The high and low frequency actuation may occur simultaneously by an electronic power amplifier, capable of generating both frequencies. The vibratory motion is preferably primarily in a longitudinal direction. It is contemplated that the vibratory motion is a transverse motion, such as in Balamuth vibrations.

FIG. 3 shows a plot of a displacement curve along a vibrating resonant member 28(1). The y-axis is the displacement/amplitude of the vibrations, and the x-axis is the length of the resonant member 28(1). The plot is sinusoidal by nature with respect to amplitude of the vibrations, and the amount of motion of the resonant member 28(1) varies along the length of the resonant member 28(1). The amplitude of the curve corresponds to the amount of displacement of the vibrating resonant member 28(1). Points A, B and C of the resonant member 28(1) are points of maximum motion (also known as anti-nodes), and points D, E and F of the resonant member 28(1) are points of substantially no motion where the amplitude of the curve is zero (also known as nodes).

Preferably transducers 32 are piezoelectric transducers. Alternately, other transduction mechanisms, other than piezoelectric, may be used including thermal stress, electrostriction, magnetostriction or optical drive mechanisms. Transducers 32 are connected to the electronic signal generator and control module 14 by an electrical connector, preferably cables 34. Cables 34 may be merged with cable 16. Cables 34 may extend proximally from transducers 32 through the body 20 of instrument 12 (FIG. 1) and exit instrument 12 through an opening (not shown) in the handle assembly 18 of the instrument for connecting to the electronic signal generator. As shown in FIG. 3, one cable is provided for each transducer 32, with a first end connected to the electronic signal generator, and a second end connected to a respective transducer 32. In another embodiment one cable 34 is provided, which is connected to the electronic signal generator at a first end and at a second end branches into a plurality of cable branches 34a, with each cable branch 34a connected to one transducer 32 of the array of transducers.

FIG. 4 shows a plot of displacement curves 40(1-3) along vibrating resonant members 28(1-3), respectively, where the relative offset of the curves 40(1-3) is caused by staggering of the resonant members 28(1-3) with respect to each other along the longitudinal axis. The curves 40(1-3) are offset from one another such that maximum points A, B, C of each curve are offset from maximum points A, B, C of the other curves, respectively, and likewise for the minimum points D, E, F.

Along the length of the array 28, the combined (i.e. summed) displacement curves 40(1-3) do not have any nodes where the combined amplitude = 0, and therefore the net displacement of the vibrating array 28 is always nonzero. Thus, the along the entire length of the array 28 there is net vibrational motion, which increases the effective length of the array 28 relative to a conventional ultrasonic member having only one vibrating element. The length of the array 28 may be extended indefinitely such that there is net vibrational motion along the entire length of the array 28 without any regions of zero motion.

Furthermore, along the length of the array 28, the combined displacement curves 40(1-3) have much less variation in amplitude than a single combined displacement curve, and therefore the net motion along the vibrating array is relatively consistent with respect to an ultrasonic member having only one vibrating element.

The offset between displacement curves having wavelength λ of n resonant members is preferably λ/n. Thus, the distance d in FIG. 2 is $\lambda/3$. Likewise, for an array having n resonant members 28(x), the distance offset d is preferably λ/n. In another embodiment, the distance d may be selected to be other than λ/n, and the offset of the displacement curves of the n vibrating resonant members 28(x) may be different from λ/n.

In another embodiment, the displacement curves for different resonant members 28(x) have different wavelengths and/or different amplitudes. An ultrasonic member 28(x) caused to vibrate at more than one frequency may have more than one displacement curve, the displacement curves having different wavelengths. For example, the different transducers 32 of the array of transducers may generate vibrations having different frequencies, such as by altering the input to the transducer, or having differently configured transducers. Alternatively, circuitry may be provided for altering the frequency, waveshape or amplitude, superimposing more than one frequency or a combination thereof of the vibrations generated by the transducers 32. Accordingly, the vibration of the resonant members 28(x) may be other than sinusoidal.

It is contemplated that other means may be provided for offsetting the displacement curves of resonant members 28(x) relative to one another, instead of staggering the resonant members 28(x) longitudinally. For example, delay circuitry may be provided to at least one of the lines providing input or output to the transducers 32 or within the transducer. In another embodiment a control unit is provided for controlling operation of the transducer and/or delay circuitry for effecting offsets of the displacement curves.

In conventional instruments the transducer is traditionally attached to the proximal end of the hand piece and connected to the end effector of the instrument via an elongated vibration coupler. It is contemplated that the array of transducers of the present invention may be positioned similarly to the transducer of the conventional instruments, and that a vibration coupler be provided to connect each transducer of the array to a respective resonant member 28(x) mounted at the distal end of the instrument 12.

For MEMs configurations in which the transducers 32 are positioned on, between, or in the resonant members 28(x) adjacent the distal tip of the instrument, the following benefits can be realized: a) the need for an elongated vibration coupler formed of titanium is obviated substantially reducing the cost of the instrument; b) the length of the body portion of the instrument can be changed, e.g., shortened or lengthened, with virtually no consequential change in instrument performance, e.g., since the instrument vibration coupler has been replaced by an electrical conductor, the instrument need not be retuned, at considerable expense, after changes in body length; c) ultrasonic energy can be transferred to a patient more efficiently, thus lowering energy power requirements; d) the portion of the instrument that is disposable can be easily varied and may comprise only the instrument tip with a limited reuse handle, the entire instrument or any degree of disposability therebetween; e) because the handle assembly does not support the transducer, the handle assembly can be eliminated or more ergonomically configured; and f) the use of a small transducer on, in or adjacent the distal end of the instrument in place of a large transducer on the proximal end of the instrument substantially reduces the weight of the instrument and makes it easy to manage especially during delicate surgical procedures.

The resonant structure 31 of each of the resonant members 28(x) is preferably formed of a silicon or metal resonant structure or a silicon/metal composite. Alternately, materials such as titanium or other metals may be bonded or joined in some manner to the silicon to improve fracture resistance. It is envisioned that materials other than silicon which are suitable for ultrasonic use may be used to form resonant structure 31.

The resonant structure 31 may be formed using an etching process, e.g., isotropic etching, deep reactive ion etching, etc. Suitable etching processes are disclosed in U.S. Patent No. 5,728,089 filed October 31, 1994, which is also incorporated herein in its entirety by reference. Alternately, other known means may be used to form the ultrasonic member including a variety of different mechanical processes.

The resonant structure 31 is shown as a linear blade having an operative surface 44 (FIG. 2). FIGS. 5A-K show alternate configurations of the resonant structure 31 of resonant members 28(x), including, inter alia, J-hook (FIG. 5A), L-hook (FIG. 5B), shears (FIG. 5C) having a variety of different cross-sectional shapes (FIGS. 5D-5G), spatula (FIG. 5H), arcuate (FIGS. 5I and 5J) and rectangular (FIG. 5K). The end effector may also be configured to have a curved blade such as the blade disclosed in U.S. Patent No. 6,024,750, filed on August 14, 1997 and/or an angled blade, such as disclosed in U.S. Patent No. 6,036,667, filed on October 4, 1996, both of which are incorporated herein in their entirety by reference.

Each of resonant members 28(x), or array 28 as an integral unit, may be attached to a distal portion of instrument 12 in any known manner. For example, each of resonant members 28(x) or the integral array 28 may be secured to a substrate or shaft or a mounting member (not shown) supported within a distal end of body 20 of instrument 12 such as by a snap-fit connection, a set screw or crimping or swaging. A threaded shank 40 or other attachment structure formed on or disposed on or in a proximal end of each of resonant members 28(x) or integral array 28 may be provided for attachment of the resonant members 28(x) or array 28 to the distal end of instrument 12.

FIG. 6 illustrates one preferred embodiment of resonant member 28(1) configured in the MEMs configuration and suitable for use in the presently disclosed ultrasonic surgical instrument of ultrasonic surgical system 10. Preferably resonant members 28(2-n) (not shown) have similar embodiments. Resonant member 28(1) is preferably a piezoelectric laminate structure which includes a body 30 having frame 102, a resonant structure 31, and a transducer 32. Transducer 32 preferably includes a pair of PZT crystals 108 separated by silicon plate 110. Alternately, it is envisioned that crystals other than PZT crystals may be used to convert electrical power to effect mechanical vibration. An appropriate bonding agent or process, e.g., solder bonding, diffusion bonding, adhesives, etc., is used to fasten crystals 108 to plate 110.

Resonant structure 31 preferably includes at its distal end first and second resonant members 104a and 104b. The proximal end of resonant members 104a and 104b together define a cavity for receiving transducer 32. Alternately, resonant structure 31 may be monolithically formed from a single piece of material. The mating surfaces of PZT crystals 108 and resonant members 104a and 104b are fastened together using an appropriate flexible bonding agent or bonding process, e.g., glass binding, adhesives, etc.

Frame 102 includes a body 112 which is preferably formed from a rigid material including metals, ceramics, etc. and includes a cavity 114 dimensioned and configured to receive the resonant structure 31 and transducer 32 assembly. A bonding layer or layers 118, preferably formed of a conductive material, is positioned between the proximal portion of resonant members 104a and 104b and frame 102 to bond transducer 32, which is movable, to frame 102, which is stationary. The proximal end of frame 102 includes a throughbore 120 which is dimensioned to permit passage of an electrical conductor 122, e.g., a wire or coaxial cable, to provide power to transducer 32. The electrical conductor is preferably a high-voltage high-frequency Teflon insulator cable, although the use of other conductors is envisioned. The distal end of conductor 122 is connected to plate 110 by a flexible conductive wire 124 which does not restrict relative movement between frame 102 and transducer 32.

As discussed above, the shape of resonant structure 31 may be different than that shown in FIG. 6. More specifically, distal operating surface 126 of resonant structure 31 may assume any of the configurations shown in FIGS. 5A-5K or any other configuration not shown herein which may be advantageous for performing a particular surgical procedure. Moreover, a clamp may be provided to facilitate gripping of tissue.

In the preferred embodiment, proximal ends of resonant members 104a and 104b of a first resonant member 28(1) of an array 28 of resonant members 28(x) are staggered relative to the proximal ends of a second resonant member for effecting an offset in displacement curves of the respective resonant members.

It will be understood that various modifications may be made to the embodiments disclosed herein. For example, the configuration of the ultrasonic member of the end effector need not be as shown herein but rather may be any that is suitable for the particular surgical application. Further, the transducer may be mounted proximally of the ultrasonic member of the end effector in the distal end of the instrument and need not be mounted directly to the ultrasonic member. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

WHAT IS CLAIMED IS

1. An end effector of an ultrasonic surgical instrument, the ultrasonic surgical instrument having a manipulatable structure, a body portion operatively connected to the manipulatable structure and having a distal end, a plurality of transducers, and the end effector being supported on the distal end of the body portion, the end effector comprising:

a plurality of resonant members, each resonant member operatively connected to a transducer of the plurality of transducers for effecting vibrations along the length of the resonant member , and including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis,

wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

2. The end effector according to Claim 1, wherein the vibrations are longitudinal.

3. The end effector according to Claim 1, wherein the vibrations are transverse.

4. The end effector according to Claim 1, wherein the first resonant member is staggered longitudinally relative to the second resonant member.

5. The end effector according to Claim 1, wherein the first resonant member is bonded to the second resonant member by a flexible bond.

6. The end effector according to Claim 1, wherein the first and second resonant members are laminated together by a lamination process.

7. The end effector according to Claim 1, wherein the plurality of resonant members are in the form of a laminate.

8. The end effector according to Claim 1, wherein the plurality of resonant members are laminated together.

9. The end effector according to Claim 1, wherein the manipulatable structure is a handle.

10. The end effector according to Claim 1, wherein the manipulatable structure is located on a module remotely located from the instrument.

11. The end effector according to Claim 10, wherein the body portion includes an elongated flexible member extending distally from the module to the end effector.

12. The end effector according to Claim 1, wherein the transducer includes a plurality of staggered transducers.

13. The end effector according to Claim 1, wherein the transducer includes a plurality of staggered transducers, but resonant members of the plurality of resonant members are not staggered.

14. The end effector according to Claim 1, wherein the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

15. The end effector according to Claim 1, wherein the end effector includes the transducer.

16. The end effector according to Claim 1, wherein each resonant member of the plurality of resonant members includes a frame and a resonant structure, the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface.

17. The end effector according to Claim 16, wherein each resonant structure has a proximal end, and the proximal end of the resonant structure of the first resonant member is staggered relative to the proximal end of the second resonant member.

18. The end effector according to Claim 16, wherein the transducer includes a plurality of transducers, and wherein the first resonant member further includes a transducer of the plurality of transducers, wherein the further included transducer is positioned in contact with the resonant structure of the first resonant member.

19. An ultrasonic surgical instrument comprising:

a manipulatable structure;

a transducer;

a body portion operatively connected to the manipulatable structure and having a distal end; and

an end effector supported on the distal end of the body portion, the end effector including:

a plurality of resonant members, each resonant member being operatively connected to the transducer for effecting vibrations along the length of the resonant member, each resonant member including an operating surface configured to effect tissue dissection, cutting, coagulation, ligation and/or hemostasis,

wherein a displacement curve associated with the vibrations of a first one of the plurality of resonant members is offset relative to the displacement curve associated with the vibrations of a second one of the plurality of resonant members.

20. The ultrasonic surgical instrument according to Claim 19, wherein the vibrations are longitudinal.

21. The ultrasonic surgical instrument according to Claim 19, wherein the vibrations are transverse.

22. The ultrasonic surgical instrument according to Claim 19, wherein the first resonant member is staggered longitudinally relative to the second resonant member.

23. The ultrasonic surgical instrument according to Claim 19, wherein the first resonant member is bonded to the second resonant member by a flexible bond.

24. The ultrasonic surgical instrument according to Claim 19, wherein the first and second resonant members are laminated together by a lamination process.

25. The ultrasonic surgical instrument according to Claim 19, wherein the plurality of resonant members are in the form of a laminate.

26. The ultrasonic surgical instrument according to Claim 19, wherein the plurality of resonant members are laminated together.

27. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes a plurality of transducers.

28. The ultrasonic surgical instrument according to Claim 19, wherein the manipulatable structure is a handle.

29. The ultrasonic surgical instrument according to Claim 19, wherein the manipulatable structure is located on a module remotely located from the instrument.

30. The ultrasonic surgical instrument according to Claim 29, wherein the body portion includes an elongated flexible member extending distally from the module to the end effector.

31. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes a plurality of staggered transducers.

32. The ultrasonic surgical instrument according to Claim 31, wherein transducers of the plurality of transducers are staggered, but resonant members of the plurality of resonant members are not staggered.

33. The ultrasonic surgical instrument according to Claim 19, wherein the transducer includes first and second transducers operatively connected to the first and second resonant members, respectively.

34. The ultrasonic surgical instrument according to Claim 19, wherein the end effector includes the transducer.

35. The ultrasonic surgical instrument according to Claim 19, wherein each resonant member of the plurality of resonant members includes a frame and a resonant structure, the transducer is operatively connected to the resonant structure, and the resonant structure includes the operating surface.

36. The ultrasonic surgical instrument according to Claim 35, wherein each resonant structure has a proximal end, and the proximal end of the resonant structure of the first resonant member is staggered relative to the proximal end of the second resonant member.

37. The ultrasonic surgical instrument according to Claim 35, wherein the transducer includes a plurality of transducers, and wherein the first resonant member further includes a transducer of the plurality of transducers, wherein the further included transducer is positioned in contact with the resonant structure of the first resonant member.

38. The ultrasonic surgical instrument according to Claim 19, further including an electrical conductor positioned within the ultrasonic instrument, and having a distal end operatively associated with the transducer means and a proximal end communicating with a power source.

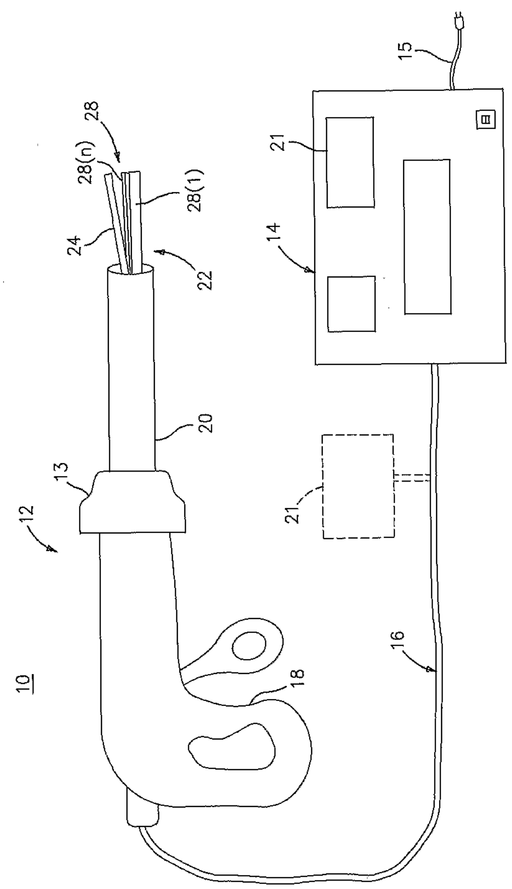

FIG. 1A

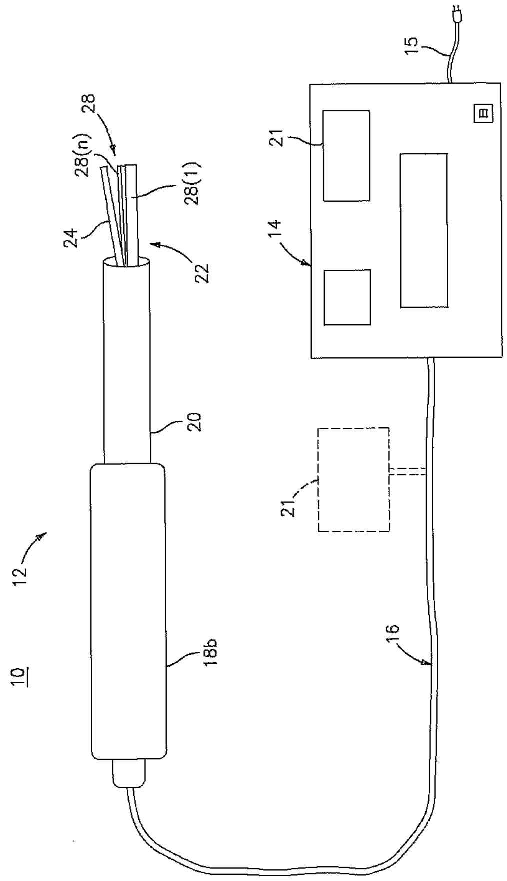

FIG. 1B

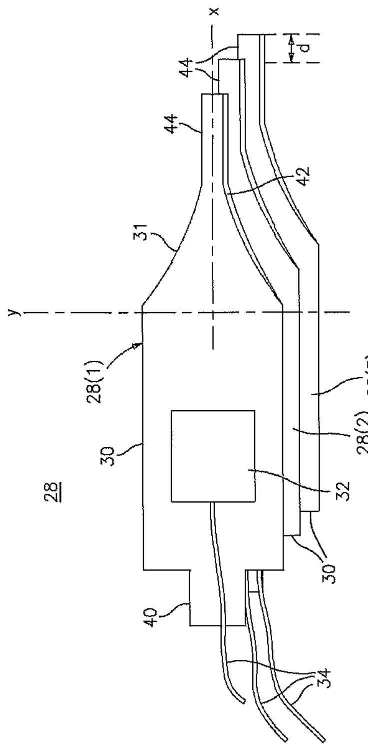

FIG. 2

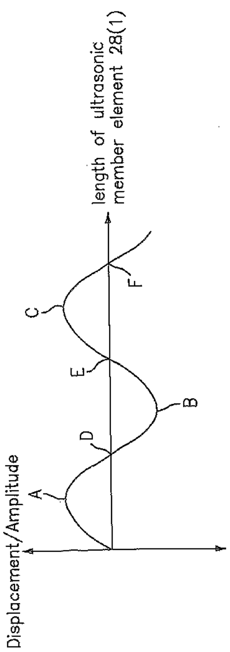
Displacement/Amplitude
length of ultrasonic member element 28(1)
A
B
C
D
E
F

FIG. 3

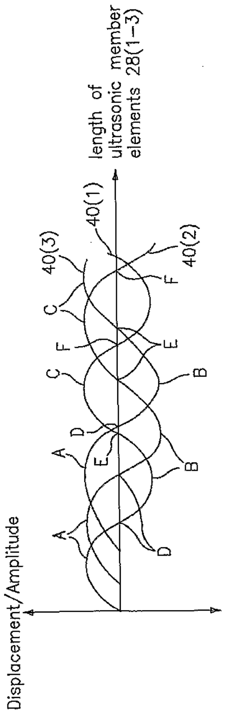
Displacement/Amplitude
length of ultrasonic member elements 28(1−3)
40(1)
40(2)
40(3)
A
B
C
D
E
F

FIG. 4

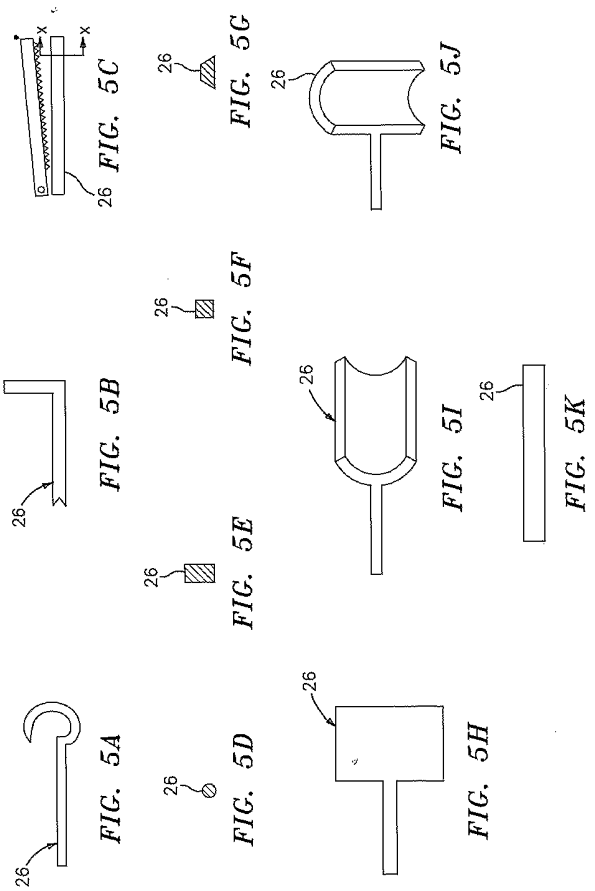

FIG. 5A FIG. 5B FIG. 5C FIG. 5D FIG. 5E FIG. 5F FIG. 5G FIG. 5H FIG. 5I FIG. 5J FIG. 5K

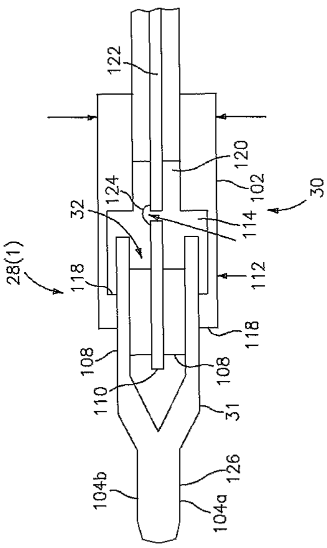
122
120
102
30
124
32
114
28(1)
118
112
118
108
108
110
31
104b
126
104a

FIG. 6

【国際調査報告】

INTERNATIONAL SEARCH REPORT

In ...tional Application No
PCT/US 02/32685

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B17/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 630 420 A (VAITEKUNAS JEFFREY J) 20 May 1997 (1997-05-20) column 2, line 57 -column 3, line 3 column 3, line 18 - line 23 column 4, line 3 - line 27; figure 1 column 8, line 53 - line 67; figures 4A-4C ---	1,2,6,7, 12,19, 20,24, 25,31,38
A	LAL A ET AL: "Micromachined silicon needle for ultrasonic surgery" , ULTRASONICS SYMPOSIUM, 1995. PROCEEDINGS., 1995 IEEE SEATTLE, WA, USA 7-10 NOV. 1995, NEW YORK, NY, USA,IEEE, US, PAGE(S) 1593-1596 XP010157413 ISBN: 0-7803-2940-6 figure 1A --- -/--	1,2,19, 20

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2003	20/01/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ducreau, F

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/32685

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 007, no. 154 (E-185), 6 July 1983 (1983-07-06) & JP 58 063300 A (KEISUKE HONDA), 15 April 1983 (1983-04-15) abstract -----	1,2,19, 20

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT
Information on patent family members

I tional Application No
PCT/US 02/32685

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5630420	A	20-05-1997	AU	709756 B2	09-09-1999
			AU	6556296 A	10-04-1997
			CA	2186721 A1	30-03-1997
			EP	0765637 A2	02-04-1997
			JP	9135842 A	27-05-1997
JP 58063300	A	15-04-1983	NONE		

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(81)指定国 AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZM,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,BG,CH,CY,CZ,DE,DK,EE,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,SK,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EC,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,OM,PH,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TN,TR,TT,TZ,UA,UG,US,UZ,VN,YU,ZA,ZM,ZW

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公开(公告)号	JP2005505341A5	公开(公告)日	2005-11-17
申请号	JP2003533791	申请日	2002-10-11
[标]申请(专利权)人(译)	柯惠有限合伙公司		
申请(专利权)人(译)	泰科医疗集团有限合伙企业		
[标]发明人	クニーダグラスジェイ		
发明人	クニー, ダグラス ジェイ.		
IPC分类号	A61B18/00 A61B17/22 A61B17/32		
CPC分类号	A61B18/00 A61B17/320068 A61B17/320092 A61B2017/22015 A61B2017/22018 A61B2017/320069 A61B2017/320071 A61B2017/320075 A61B2017/320078 A61B2017/320089 A61B2017/320094 A61B2017/320095		
FI分类号	A61B17/36.330		
F-TERM分类号	4C060/JJ13 4C060/MM24		
代理人(译)	夏木森下		
优先权	60/328597 2001-10-11 US		
其他公开文献	JP4284179B2 JP2005505341A		

摘要(译)

提供了一种超声外科手术器械的末端执行器，该超声外科手术器械具有可操纵的结构，可操作地连接到可操纵结构的主体部分，并且具有远端，换能器，并且末端执行器被支撑在远端外科器械的远端上。所述主体部分，所述末端执行器包括多个共振构件元件，每个共振构件可操作地连接到所述多个换能器中的换能器，用于实现沿着所述共振构件的长度的振动，并且包括被配置为实现组织解剖，切割的操作表面。，凝固，结扎和/或止血，其中与多个共振构件中的第一个共振构件的振动相关联的位移曲线相对于与多个共振构件中的第二个共振构件的振动相关联的位移曲线偏移。