Experimental Section

Photonic Tailoring: Representative Experimental Procedure

A step by step description of the photonic tailoring experimental protocols may be found herein. The entire process may be viewed as having three steps:

- Standardization of states;
- Meta-arrangement of symmetries, and;
- Dynamic exiting.

Also note that the timing for many of the steps (i.e., ring activation) follows a Fibonacci sequence multiplied by the base of choice. For example, if the base of choice is one minute, the timing sequence is 1, 1, 2, 3, 5, 8, etc. expressed in minutes.

In the first step, standardization of states, an appropriate sample is taken from an ingot previously treated via a hot metal tailoring protocol[1] and placed on a flat surface centered in the middle of the ring assembly. The experimental system is sealed to exclude ambient light. The sample is then held in darkness for 10 minutes. The ring assembly is then activated, typically following a timing based on the Fibonacci series. A generic ring activation sequence is described; however, this step should be catered to the material being tailored. Specific examples are appended for Cu, Mg, Al, and Si.

First, a 365 nm light emitting diode (LED) is turned on immediately followed by energization of the first or bottom coil (e.g., DC current). After 1 minute, the second coil from the bottom is energized (e.g., 60 Hz AC). After an additional 1 minute, a 740 nm LED is turned on followed by energization of the third coil from the bottom (e.g., 30 sec sinusoidal wave cycles between 987 Hz and 2.83 MHz). After an additional 2 minutes, the third coil is turned off. After 3 additional minutes, coil 4 is energized (e.g., DC or AC cycles). After 5 additional minutes, coil 3 is re-energized. After 8 additional minutes, a 530 nm LED is turned on and the 5^{th} coil (e.g., DC current), the top coil, is turned on. After 13 additional minutes, a preheated overhead mercury vapor motive is positioned above the radiation center, centered axially with respect to the ring assembly. Ring activation is complete.

The next step in the standardization of states involves the use of 2 X 4 assemblies detailed in Figure . One minute after the Hg-vapor motive has been positioned, the xenon 2 X 4 assembly (i.e., Xe lamp and 530 nm RC LED) is turned on. After an additional 1 minute, the argon 2 X 4 assembly (i.e., Ar and 365 nm LED) is turned on. After 2 minutes, a neon pencil lamp, centered over the sample, and positioned between the sample and the 2 X 4 assemblies, is turned on. After 3 additional minutes, a long-wave ultra violet pencil light (again, centered over the sample and positioned between the sample and the neon pencil lamp) is turned on. After 5 additional minutes, the sample is taken from the radiation center (ring assembly) and placed in a liquid

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[1] Nagel, C.J., "Composition of Matter Tailoring: System I," Patent No. 6,572,792, issued June, 2003. Nagel, C.J., "Composition of Matter Tailoring: System I CIP," Patent No. 6,921,497, issued July, 2005.

nitrogen bath. Standardization of states is now complete and meta-arrangement of symmetries is commenced.

When the sample reaches 77K, signal probes are placed on the ingot surface, to convey appropriate electromagnetic signals. First 1 mA is applied at 1700 kHz in a sinusoidal form for 2 minutes followed by ≥3 mA DC for ≥ 10 sec. Next a signal of 1 mA at 3500 kHz in a triangular wave form is passed through the liquid nitrogen for 3 minutes again followed by ≥3 mA DC for ≥ 10 sec. Next a signal of at least 1 mA at 200 Hz in a square wave form is passed through the solution for 5 minutes again followed by ≥3 mA DC for ≥ 10 sec. Laboratory (fluorescent) lighting is then turned on and ≥1 mA at 200 Hz is passed through the solution in a square wave form for an additional 8 minutes. The magnitude, duration (e.g., Fibonacci series multiplier), and form (e.g., sinusoidal, triangular, square) of these harmonic signal treatments are dependent on the desired experimental outcome. At the completion of the harmonic signal treatment (meta-arrangement of symmetries), the ingot is removed from the liquid nitrogen.

In the final step, dynamic exiting, the cold sample is placed into deionized (DI) water in a glass container. The container is then placed in the ring assembly at the radiation center. The sample should be centered on the 3rd coil. When the sample reaches ambient conditions, all of the lights should be turned off simultaneously and the sample held in darkness for 10 minutes. The sample is then held in the presence of fluorescent lighting for 10 minutes prior to WD-XRF analysis.

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Stepwise Protocol:

Definitions

- Radiation center

  The term radiation center refers to the physical center spot at base level from which all other positioning measurements are made.

- Motive lamp

  Motive lamp is a descriptor of a mercury vapor lamp (typically 50 watts or greater) with a reflector. Such high intensity lighting is typically employed in warehouse lighting.

- Pencil lamp

  Cylindrical gas filled lamp used for creating specialty light spectrums based on the gas used (e.g., Hg, Ne, etc.). Pencil lamps are commonly used in the calibration of optical equipment.

- Diode lamp

  A lamp using a light emitting diode (LED) to output a particular wavelength.

- Timing sequence

  Timing for each step (i.e., ring activation, step 1, step 2, and step 3) follows a Fibonacci sequence multiplied by the base of choice. For example, if the base of choice is one minute, the timing sequence is 1, 1, 2, 3, 5, 8, etc. expressed in minutes.

Material Selection

- Tailored metal of choice
- Positioning

    Centered in the Ring Assembly axially and radially

Equipment Design

- Ring assembly
- Argon '2x4' assembly (Figure 1)
- Xenon '2x4' assembly (Figure 1)

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Experimental Procedure: photonic tailoring

Step 1: standardization of states

Preparation

Hold in darkness for approximately 10 minutes

Step 1.1[2]: standardization of states; ring assembly energizing sequence

Turn on 365nm Ring_LED-1 (see Ring assembly reference drawing) immediately followed by energizing the 1st coil (i.e., bottom coil); Set Counter = T_0

At Counter = 1m:00s, energize the 2nd coil; Set Counter = T_0

At Counter = 1m:00s, turn on 740nm Ring_LED-1 immediately followed by energizing the 3rd coil; Set Counter = T_0

At Counter = 2m:00s, turn off the 3rd coil; Set Counter = T_0

At Counter = 3m:00s, energize the 4th coil; Set Counter = T_0

At Counter = 5m:00s, turn ON the 3rd coil; Set Counter = T_0

At Counter = 8m:00s, turn on 530nm Ring_LED-1 immediately followed by energizing the 5th coil (i.e., ring closest to the motive); Counter = T_0

At Counter = 13m:00s, position a preheated overhead mercury vapor motive above the radiation center centered axially with respect to the Ring assembly; Set Counter = T_0

Step 1.2: meta-arrangement of symmetries

At Counter = 1m:00s, turn on the xenon 2x4 assembly (e.g., xenon and 530nm_RC_LED simultaneously, see reference drawing); Set Counter = T_0

At Counter = 1m:00s, turn on the argon 2x4 assembly (e.g., argon and 365nm LED simultaneously, see reference drawing); Counter = T_0

At Counter = 2m:00s turn on a neon pencil lamp centered over the sample and positioned between the sample and the ‘2x4’ assemblies; Counter = T_0

At Counter = 3m:00s turn on a long wave ultraviolet pencil centered over the sample and positioned between the sample and the neon pencil lamp; Set Counter = T_0

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[2] Note: Step 1.1 is a ring assembly activation step which varies based upon the material to be tailored. The description found here is generic and may be used on all materials. Ring assembly activation sequences (i.e., Step 1.1) specifically designed for Cu, Mg, Al, and Si materials are attached.

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Step 1.3: dynamic exiting

At Counter = 5m:00s, retrieve the sample from the radiation center and place in a liquid nitrogen bath that is in close proximity to the radiation center

Step 2: meta-arrangement of symmetries

After the sample reaches 77K, Set Counter = T_0

Pass at least 1 milliamp at 1700 kHz through the liquid nitrogen for 2 minutes (sinusoidal wave form) followed be passing $\geq$3 milliamps DC of current through the sample for $\geq$10 seconds; Set Counter = T_0

Pass at least 1 milliamp at 3500 kHz through the liquid nitrogen for 3 minute (triangular wave form) followed be passing $\geq$3 milliamps DC of current through the sample for $\geq$10 seconds; Set Counter = T_0

Pass at least 1 milliamp at 200 Hz through the solution for 5 minutes (square wave form) followed be passing $\geq$3 milliamps DC of current through the sample for $\geq$10 seconds; Set Counter = T_0

Turn on laboratory lighting (e.g., fluorescence lights)

Pass $\geq$1 milliamp at 200 Hz through the solution for 8 minutes (square wave form)

Step 3: dynamic exiting

Retrieve the cold sample and place into a glass jar containing DI water, then position the glass jar within the Ring Assembly at the radiation center. [Elevate to achieve standard Ring cage positioning (i.e., centered relative to the 3^{rd} ring)]

After the sample reaches ambient conditions, turn off all lamps simultaneously

Hold in darkness for approximately 10 minutes

Turn on the fluorescence lights, then turn off all power sources to the Ring assembly

Hold for approximately 10 minutes under fluorescence lights then transfer to a WD-XRF for analysis

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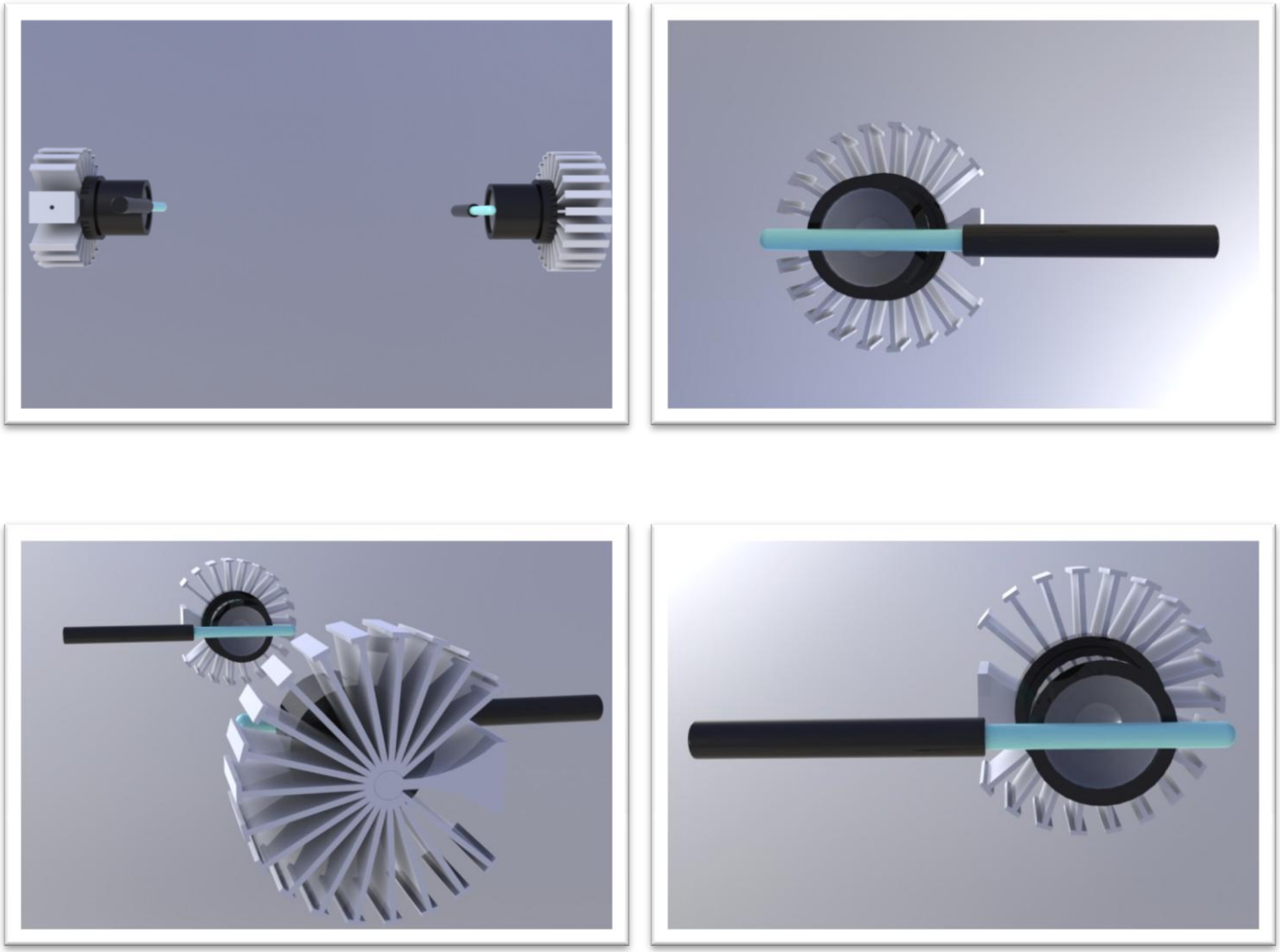

Figure 1: Renderings of 2 X 4 Assemblies

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Ring Assembly Activation Patterns for Various Materials

Definitions

- Coil Energization

  Application of DC or AC current to the coil to apply electromagnetic energy to the sample. In some cases, frequency sweeps (cycles) and DC offsets may be employed.

- Cycles

  Oscillation of current frequency between two specified frequencies. The range of frequency oscillations can be wide from 0 to 3 MHz, with more typical ranges in the 500 Hz to 1500 kHz range. Multiple wave forms may be employed (e.g., sinusoidal, square, triangular).

- Frequency Sweeps

  The number of cycles employed to oscillate the current frequency. The number of cycles should be kept constant throughout the entire run plan and should be a minimum of two complete cycles for a given time period. For example, if coil energization is 1 minute, and 2 complete cycles are desired, then the frequency sweeps would be specified as 15 sec up, 15 sec down. Shorter sweeps (e.g., 5 sec up, 5 sec down) and non symmetric sweeps can also be employed.

- DC Energization Pattern

  Application of DC power through one of two modes. With no DC offset, a 10 V peak to peak sine wave oscillates between +5 and -5 volts. Alternatively, a 2.5 V DC offset has been employed to oscillate between +7.5 V to -2.5 V.

- Harmonic Energy Patterns

  Application of AC frequency sweeps in addition to DC power. For the materials specified herein, activation of the 4^{th} coil in the ring assembly requires the implementation of harmonic energy patterns (e.g., 1700 kHz for Mg, Al, Si and 557 Hz to 157 kHz for Cu). Similarly, the activation of other coils may be improved through harmonic energy use (e.g. in this instance, the 3^{rd} coil for Cu 987 Hz to 2.83 MHz, the 1^{st} coil for Mg 557 to 157 kHz, the 5^{th} coil for Al 500 kHz to 20.2 MHz, and the 3^{rd} coil for Si 0 Hz to 3.5 MHz).

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Copper Activation Sequence:

Step 1.1: standardization of states; ring assembly energizing sequence

Turn on 365nm Ring_LED-1 (see Ring assembly reference drawing) immediately followed by energizing the 1st coil (i.e., bottom coil); Set Counter = T_0

At Counter = 1m:00s, energize the 2nd coil; Set Counter = T_0

At Counter = 1m:00s, turn on 740nm Ring_LED-1 immediately followed by energizing the 3rd coil; Set Counter = T_0

- Application of frequency sweeps and DC power with no offset

At Counter = 2m:00s, turn off the 3rd coil; Set Counter = T_0

At Counter = 3m:00s, energize the 4th coil; Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

At Counter = 5m:00s, turn on the 530 nm Ring_LED-1 immediately followed by energizing the 5th coil (i.e., coil closest to the motive); Set Counter = T_0

At Counter = 8m:00s, turn on the 3rd coil; Counter = T_0

At Counter = 13m:00s, position a preheated overhead mercury vapor motive above the radiation center centered axially with respect to the Ring assembly; Set Counter = T_0

Magnesium Activation Sequence:

Step 1.1: standardization of states; ring assembly energizing sequence

Turn on 365nm Ring_LED-1 (see Ring assembly reference drawing) immediately followed by energizing the 1st coil (i.e., bottom coil); Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

At Counter = 1m:00s, turn on 740 nm Ring_LED-1 immediately followed by energizing the 3rd coil; Set Counter = T_0

At Counter = 1m:00s, energize the 2nd coil; Set Counter = T_0

At Counter = 2m:00s, turn off the DC component of the 3rd coil; Set Counter = T_0

At Counter = 3m:00s, energize the 4th coil; Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

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At Counter = 5m:00s, turn on the DC component of the 3rd coil; Set Counter = T_0

At Counter = 8m:00s, turn on the 530 nm Ring_LED-1 immediately followed by energizing the 5th coil (i.e., coil closest to the motive); Set Counter = T_0

At Counter = 13m:00s, position a preheated overhead mercury vapor motive above the radiation center centered axially with respect to the Ring assembly; Set Counter = T_0

Aluminum Activation Sequence:

Step 1.1: standardization of states; ring assembly energizing sequence

Turn on 365nm Ring_LED-1 (see Ring assembly reference drawing) immediately followed by energizing the 1st coil (i.e., bottom coil); Set Counter = T_0

At Counter = 1m:00s, turn on 740 nm Ring_LED-1 immediately followed by energizing the 3rd coil; Set Counter = T_0

At Counter = 1m:00s, energize the 2nd coil; Set Counter = T_0

At Counter = 2m:00s, turn off the DC component of the 3rd coil; Set Counter = T_0

At Counter = 3m:00s, energize the 4th coil; Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

At Counter = 5m:00s, turn on the DC component of the 3rd coil; Set Counter = T_0

At Counter = 8m:00s, turn on the 530 nm Ring_LED-1 immediately followed by energizing the 5th coil (i.e., coil closest to the motive); Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

At Counter = 13m:00s, position a preheated overhead mercury vapor motive above the radiation center centered axially with respect to the Ring assembly; Set Counter = T_0

Silicon Activation Sequence:

Step 1.1: standardization of states; ring assembly energizing sequence

Turn on 365nm Ring_LED-1 (see Ring assembly reference drawing) immediately followed by energizing the 1st coil (i.e., bottom coil); Set Counter = T_0

At Counter = 1m:00s, energize the 2nd coil; Set Counter = T_0

At Counter = 1m:00s, turn on 740 nm Ring_LED-1 immediately followed by energizing the 3rd coil; Set Counter = T_0

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- Application of frequency sweeps with 2.5 V DC offset

At Counter = 2m:00s, turn off the DC component of the 3rd coil; Set Counter = T_0

At Counter = 3m:00s, energize the 4th coil; Set Counter = T_0

- Application of frequency sweeps with 2.5 V DC offset

At Counter = 5m:00s, turn on the DC component of the 3rd coil; Set Counter = T_0

At Counter = 8m:00s, turn on the 530 nm Ring_LED-1 immediately followed by energizing the 5th coil (i.e., coil closest to the motive); Set Counter = T_0

At Counter = 13m:00s, position a preheated overhead mercury vapor motive above the radiation center centered axially with respect to the Ring assembly; Set Counter = T_0