

Table S1: Ana(400)-fs&fs.

| f (Hz) | V_{fb} (V vs Ag/AgCl) | V_{fb} (V vs SHE) | E_F (eV) | N_d (cm⁻³) | ΔE (eV) | E_g (eV) | E_c (V vs SHE) | E_v (V vs SHE) |
|-------------------------|--|--|-------------------------------------|--|--------------------------|-------------------------------------|---|---|
| 10 | -0.46 | -0.255 | -4.185 | 2.06E+21 | 0.186 | 3.30 | -0.441 | 2.859 |
| 25 | -0.45 | -0.245 | -4.195 | 2.07E+20 | 0.128 | 3.30 | -0.373 | 2.927 |
| 50 | -0.50 | -0.295 | -4.145 | 7.20E+20 | 0.160 | 3.30 | -0.455 | 2.845 |
| 75 | -0.52 | -0.315 | -4.125 | 4.54E+20 | 0.148 | 3.30 | -0.463 | 2.837 |
| 100 | -0.46 | -0.255 | -4.185 | 1.38E+20 | 0.118 | 3.30 | -0.373 | 2.927 |
| 200 | -0.52 | -0.315 | -4.125 | 6.00E+20 | 0.155 | 3.30 | -0.470 | 2.830 |
| 400 | -0.51 | -0.305 | -4.135 | 1.26E+20 | 0.116 | 3.30 | -0.421 | 2.879 |
| 600 | -0.54 | -0.335 | -4.105 | 1.79E+20 | 0.125 | 3.30 | -0.460 | 2.840 |
| 800 | -0.55 | -0.345 | -4.095 | 3.67E+20 | 0.143 | 3.30 | -0.488 | 2.812 |
| 1000 | -0.52 | -0.315 | -4.125 | 8.43E+19 | 0.106 | 3.30 | -0.421 | 2.879 |
| 2000 | -0.54 | -0.335 | -4.105 | 2.32E+20 | 0.131 | 3.30 | -0.466 | 2.834 |
| 3000 | -0.53 | -0.325 | -4.115 | 7.50E+19 | 0.103 | 3.30 | -0.428 | 2.872 |
| 4000 | -0.56 | -0.355 | -4.085 | 1.43E+20 | 0.119 | 3.30 | -0.474 | 2.826 |
| 5000 | -0.53 | -0.325 | -4.115 | 5.92E+19 | 0.097 | 3.30 | -0.422 | 2.878 |
| 6000 | -0.55 | -0.345 | -4.095 | 6.77E+19 | 0.100 | 3.30 | -0.445 | 2.855 |

Table S2. Ana(400)-ss&ss.

| f (Hz) | V_{fb} (V vs Ag/AgCl) | V_{fb} (V vs SHE) | E_F (eV) | N_d (cm⁻³) | ΔE (eV) | E_g (eV) | E_c (V vs SHE) | E_v (V vs SHE) |
|-------------------------|--|--|-------------------------------------|--|--------------------------|-------------------------------------|---|---|
| 10 | -0.41 | -0.205 | -4.235 | 1.31E+21 | 0.175 | 3.30 | -0.380 | 2.920 |
| 25 | -0.46 | -0.255 | -4.185 | 1.26E+21 | 0.174 | 3.30 | -0.429 | 2.871 |
| 50 | -0.51 | -0.305 | -4.135 | 1.15E+21 | 0.172 | 3.30 | -0.477 | 2.823 |
| 75 | -0.55 | -0.345 | -4.095 | 1.14E+21 | 0.171 | 3.30 | -0.516 | 2.784 |
| 100 | -0.59 | -0.385 | -4.055 | 1.13E+21 | 0.171 | 3.30 | -0.556 | 2.744 |
| 200 | -0.64 | -0.435 | -4.005 | 9.79E+20 | 0.168 | 3.30 | -0.603 | 2.697 |
| 400 | -0.70 | -0.495 | -3.945 | 8.94E+20 | 0.165 | 3.30 | -0.660 | 2.640 |
| 600 | -0.75 | -0.545 | -3.895 | 7.32E+20 | 0.160 | 3.30 | -0.705 | 2.595 |
| 800 | -0.79 | -0.585 | -3.855 | 5.57E+20 | 0.153 | 3.30 | -0.738 | 2.562 |
| 1000 | -0.81 | -0.605 | -3.835 | 4.18E+20 | 0.146 | 3.30 | -0.751 | 2.549 |
| 2000 | -0.85 | -0.645 | -3.795 | 3.14E+20 | 0.139 | 3.30 | -0.784 | 2.516 |
| 3000 | -0.87 | -0.665 | -3.775 | 2.40E+20 | 0.132 | 3.30 | -0.797 | 2.503 |
| 4000 | -0.89 | -0.685 | -3.755 | 1.95E+20 | 0.127 | 3.30 | -0.812 | 2.488 |
| 5000 | -0.90 | -0.695 | -3.745 | 1.67E+20 | 0.123 | 3.30 | -0.818 | 2.482 |
| 6000 | -0.92 | -0.715 | -3.725 | 1.50E+20 | 0.120 | 3.30 | -0.835 | 2.465 |

Table S3. Ana-ss&ss.

| f (Hz) | V_{fb} (V vs Ag/AgCl) | V_{fb} (V vs SHE) | E_F (eV) | N_d (cm⁻³) | ΔE (eV) | E_g (eV) | E_c (V vs SHE) | E_v (V vs SHE) |
|-------------------------|--|--|-------------------------------------|--|--------------------------|-------------------------------------|---|---|
| 10 | -0.71 | -0.505 | -3.935 | 7.99E+19 | 0.104 | 3.33 | -0.609 | 2.721 |
| 25 | -0.74 | -0.532 | -3.908 | 7.40E+19 | 0.102 | 3.33 | -0.634 | 2.696 |
| 50 | -0.76 | -0.558 | -3.882 | 7.35E+19 | 0.102 | 3.33 | -0.660 | 2.670 |
| 75 | -0.78 | -0.576 | -3.864 | 7.31E+19 | 0.102 | 3.33 | -0.678 | 2.652 |
| 100 | -0.79 | -0.586 | -3.854 | 6.64E+19 | 0.100 | 3.33 | -0.686 | 2.644 |
| 200 | -0.81 | -0.607 | -3.833 | 6.36E+19 | 0.099 | 3.33 | -0.706 | 2.624 |
| 400 | -0.84 | -0.630 | -3.810 | 6.19E+19 | 0.098 | 3.33 | -0.728 | 2.602 |

| | | | | | | | | |
|------|-------|--------|--------|----------|-------|------|--------|-------|
| 600 | -0.85 | -0.648 | -3.792 | 6.09E+19 | 0.097 | 3.33 | -0.745 | 2.585 |
| 800 | -0.87 | -0.664 | -3.776 | 6.04E+19 | 0.097 | 3.33 | -0.761 | 2.569 |
| 1000 | -0.88 | -0.679 | -3.761 | 6.04E+19 | 0.097 | 3.33 | -0.776 | 2.554 |
| 2000 | -0.92 | -0.712 | -3.728 | 5.90E+19 | 0.097 | 3.33 | -0.809 | 2.521 |
| 3000 | -0.94 | -0.737 | -3.703 | 5.73E+19 | 0.096 | 3.33 | -0.833 | 2.497 |
| 4000 | -0.96 | -0.758 | -3.682 | 5.54E+19 | 0.095 | 3.33 | -0.853 | 2.477 |
| 5000 | -0.98 | -0.776 | -3.664 | 5.28E+19 | 0.094 | 3.33 | -0.870 | 2.460 |
| 6000 | -1.00 | -0.794 | -3.646 | 5.32E+19 | 0.094 | 3.33 | -0.888 | 2.442 |

Table S4. P25-fs&fs.

| f (Hz) | V_{fb} (V vs Ag/AgCl) | V_{fb} (V vs SHE) | E_F (eV) | N_d (cm⁻³) | ΔE (eV) | E_g (eV) | E_c (V vs SHE) | E_v (V vs SHE) |
|-------------------------|--|--|-------------------------------------|--|--------------------------|-------------------------------------|---|---|
| 10 | -0.74 | -0.535 | -3.905 | 9.15E+19 | 0.108 | 3.22 | -0.643 | 2.577 |
| 25 | -0.77 | -0.565 | -3.875 | 5.58E+19 | 0.095 | 3.22 | -0.660 | 2.560 |
| 50 | -0.75 | -0.545 | -3.895 | 4.56E+19 | 0.090 | 3.22 | -0.635 | 2.585 |
| 75 | -0.76 | -0.555 | -3.885 | 5.37E+19 | 0.094 | 3.22 | -0.649 | 2.571 |
| 100 | -0.76 | -0.555 | -3.885 | 5.30E+19 | 0.094 | 3.22 | -0.649 | 2.571 |
| 200 | -0.78 | -0.575 | -3.865 | 5.56E+19 | 0.095 | 3.22 | -0.670 | 2.550 |
| 400 | -0.85 | -0.645 | -3.795 | 5.15E+19 | 0.093 | 3.22 | -0.738 | 2.482 |
| 600 | -0.84 | -0.635 | -3.805 | 5.10E+19 | 0.093 | 3.22 | -0.728 | 2.492 |
| 800 | -0.85 | -0.645 | -3.795 | 5.77E+19 | 0.096 | 3.22 | -0.741 | 2.479 |
| 1000 | -0.83 | -0.625 | -3.815 | 9.24E+19 | 0.108 | 3.22 | -0.733 | 2.487 |
| 2000 | -0.83 | -0.625 | -3.815 | 5.85E+19 | 0.096 | 3.22 | -0.721 | 2.499 |
| 3000 | -0.91 | -0.705 | -3.735 | 3.81E+19 | 0.086 | 3.22 | -0.791 | 2.429 |
| 4000 | -0.88 | -0.675 | -3.765 | 4.00E+19 | 0.087 | 3.22 | -0.762 | 2.458 |
| 5000 | -0.89 | -0.685 | -3.755 | 3.62E+19 | 0.084 | 3.22 | -0.769 | 2.451 |
| 6000 | -0.86 | -0.655 | -3.785 | 3.80E+19 | 0.086 | 3.22 | -0.741 | 2.479 |

Table S5. P25(400)-fs&fs.

| f (Hz) | V_{fb} (V vs Ag/AgCl) | V_{fb} (V vs SHE) | E_F (eV) | N_d (cm⁻³) | ΔE (eV) | E_g (eV) | E_c (V vs SHE) | E_v (V vs SHE) |
|-------------------------|--|--|-------------------------------------|--|--------------------------|-------------------------------------|---|---|
| 10 | -0.46 | -0.255 | -4.185 | 2.06E+21 | 0.186 | 3.21 | -0.441 | 2.769 |
| 25 | -0.54 | -0.335 | -4.105 | 2.51E+21 | 0.191 | 3.21 | -0.526 | 2.684 |
| 50 | -0.52 | -0.315 | -4.125 | 3.61E+20 | 0.142 | 3.21 | -0.457 | 2.753 |
| 75 | -0.52 | -0.315 | -4.125 | 9.46E+20 | 0.167 | 3.21 | -0.482 | 2.728 |
| 100 | -0.59 | -0.385 | -4.055 | 1.13E+21 | 0.171 | 3.21 | -0.556 | 2.654 |
| 200 | -0.55 | -0.345 | -4.095 | 4.03E+20 | 0.145 | 3.21 | -0.490 | 2.720 |
| 400 | -0.62 | -0.415 | -4.025 | 7.23E+20 | 0.160 | 3.21 | -0.575 | 2.635 |
| 600 | -0.58 | -0.375 | -4.065 | 6.91E+20 | 0.159 | 3.21 | -0.534 | 2.676 |
| 800 | -0.55 | -0.345 | -4.095 | 1.19E+20 | 0.114 | 3.21 | -0.459 | 2.751 |
| 1000 | -0.59 | -0.385 | -4.055 | 4.96E+20 | 0.150 | 3.21 | -0.535 | 2.675 |
| 2000 | -0.60 | -0.395 | -4.045 | 3.89E+20 | 0.144 | 3.21 | -0.539 | 2.671 |
| 3000 | -0.63 | -0.425 | -4.015 | 2.98E+20 | 0.138 | 3.21 | -0.563 | 2.647 |
| 4000 | -0.69 | -0.485 | -3.955 | 2.84E+20 | 0.136 | 3.21 | -0.621 | 2.589 |
| 5000 | -0.64 | -0.435 | -4.005 | 2.32E+20 | 0.131 | 3.21 | -0.566 | 2.644 |
| 6000 | -0.68 | -0.475 | -3.965 | 2.34E+20 | 0.131 | 3.21 | -0.606 | 2.604 |

Table S6. P25(400)-ss&ss.

| f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 10 | -0.43 | -0.225 | -4.215 | 1.94E+21 | 0.185 | 3.21 | -0.410 | 2.800 |
| 25 | -0.52 | -0.315 | -4.125 | 1.89E+21 | 0.184 | 3.21 | -0.499 | 2.711 |
| 50 | -0.63 | -0.425 | -4.015 | 2.62E+21 | 0.192 | 3.21 | -0.617 | 2.593 |
| 75 | -0.66 | -0.455 | -3.985 | 1.20E+21 | 0.173 | 3.21 | -0.628 | 2.582 |
| 100 | -0.71 | -0.505 | -3.935 | 9.68E+20 | 0.167 | 3.21 | -0.672 | 2.538 |
| 200 | -0.75 | -0.545 | -3.895 | 4.95E+20 | 0.150 | 3.21 | -0.695 | 2.515 |
| 400 | -0.77 | -0.565 | -3.875 | 4.74E+20 | 0.149 | 3.21 | -0.714 | 2.496 |
| 600 | -0.79 | -0.585 | -3.855 | 4.04E+20 | 0.145 | 3.21 | -0.730 | 2.480 |
| 800 | -0.80 | -0.595 | -3.845 | 3.63E+20 | 0.143 | 3.21 | -0.738 | 2.472 |
| 1000 | -0.81 | -0.605 | -3.835 | 3.25E+20 | 0.140 | 3.21 | -0.745 | 2.465 |
| 2000 | -0.84 | -0.635 | -3.805 | 2.43E+20 | 0.132 | 3.21 | -0.767 | 2.443 |
| 3000 | -0.86 | -0.655 | -3.785 | 1.93E+20 | 0.127 | 3.21 | -0.782 | 2.428 |
| 4000 | -0.87 | -0.665 | -3.775 | 1.68E+20 | 0.123 | 3.21 | -0.788 | 2.422 |
| 5000 | -0.89 | -0.685 | -3.755 | 1.50E+20 | 0.120 | 3.21 | -0.805 | 2.405 |
| 6000 | -0.90 | -0.695 | -3.745 | 1.37E+20 | 0.118 | 3.21 | -0.813 | 2.397 |

Table S7. P25(400)-ss&ss+stir.

| f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 10 | -0.53 | -0.325 | -4.115 | 1.44E+21 | 0.177 | 3.21 | -0.502 | 2.708 |
| 25 | -0.69 | -0.485 | -3.955 | 1.71E+21 | 0.182 | 3.21 | -0.667 | 2.543 |
| 50 | -0.73 | -0.525 | -3.915 | 1.14E+21 | 0.171 | 3.21 | -0.696 | 2.514 |
| 75 | -0.74 | -0.535 | -3.905 | 9.91E+20 | 0.168 | 3.21 | -0.703 | 2.507 |
| 100 | -0.75 | -0.545 | -3.895 | 9.52E+20 | 0.167 | 3.21 | -0.712 | 2.498 |
| 200 | -0.76 | -0.555 | -3.885 | 6.17E+20 | 0.156 | 3.21 | -0.711 | 2.499 |
| 400 | -0.78 | -0.575 | -3.865 | 5.10E+20 | 0.151 | 3.21 | -0.726 | 2.484 |
| 600 | -0.79 | -0.585 | -3.855 | 4.16E+20 | 0.146 | 3.21 | -0.731 | 2.479 |
| 800 | -0.80 | -0.595 | -3.845 | 4.01E+20 | 0.145 | 3.21 | -0.740 | 2.470 |
| 1000 | -0.81 | -0.605 | -3.835 | 3.60E+20 | 0.142 | 3.21 | -0.747 | 2.463 |
| 2000 | -0.83 | -0.625 | -3.815 | 2.78E+20 | 0.136 | 3.21 | -0.761 | 2.449 |
| 3000 | -0.85 | -0.645 | -3.795 | 2.12E+20 | 0.129 | 3.21 | -0.774 | 2.436 |
| 4000 | -0.87 | -0.665 | -3.775 | 1.85E+20 | 0.126 | 3.21 | -0.791 | 2.419 |
| 5000 | -0.88 | -0.675 | -3.765 | 1.80E+20 | 0.125 | 3.21 | -0.800 | 2.410 |
| 6000 | -0.90 | -0.695 | -3.745 | 1.64E+20 | 0.122 | 3.21 | -0.817 | 2.393 |

Table S8. Ana(400)-ss&ss under UV.

| Time (min) | f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|---------------|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 12 | 400 | -0.44 | -0.235 | -4.205 | 3.13E+20 | 0.139 | 3.3 | -0.374 | 2.926 |
| 24 | | -0.40 | -0.195 | -4.245 | 3.61E+20 | 0.142 | | -0.337 | 2.963 |
| 36 | | -0.41 | -0.205 | -4.235 | 3.56E+20 | 0.142 | | -0.347 | 2.953 |
| 48 | | -0.42 | -0.215 | -4.225 | 3.91E+20 | 0.144 | | -0.359 | 2.941 |
| 60 | | -0.44 | -0.235 | -4.205 | 3.91E+20 | 0.144 | | -0.379 | 2.921 |
| 72 | | -0.45 | -0.245 | -4.195 | 3.46E+20 | 0.141 | | -0.386 | 2.914 |
| 84 | | -0.47 | -0.265 | -4.175 | 3.23E+20 | 0.140 | | -0.405 | 2.895 |

| | | | | | | | |
|----|-------|--------|--------|----------|-------|--------|-------|
| 96 | -0.49 | -0.285 | -4.155 | 3.22E+20 | 0.140 | -0.425 | 2.875 |
|----|-------|--------|--------|----------|-------|--------|-------|

Table S9. Ana(400)-ss&ss under laboratory light.

| Time (min) | f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|---------------|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 12 | 400 | -0.47 | -0.265 | -4.175 | 9.45E+19 | 0.109 | 3.3 | -0.374 | 2.926 |
| 24 | | -0.49 | -0.285 | -4.155 | 9.65E+19 | 0.109 | | -0.394 | 2.906 |
| 36 | | -0.51 | -0.305 | -4.135 | 9.87E+19 | 0.110 | | -0.415 | 2.885 |
| 48 | | -0.52 | -0.315 | -4.125 | 1.08E+20 | 0.112 | | -0.427 | 2.873 |
| 60 | | -0.54 | -0.335 | -4.105 | 1.06E+20 | 0.111 | | -0.446 | 2.854 |
| 72 | | -0.57 | -0.365 | -4.075 | 1.17E+20 | 0.114 | | -0.479 | 2.821 |
| 84 | | -0.58 | -0.375 | -4.065 | 1.18E+20 | 0.114 | | -0.489 | 2.811 |
| 96 | | -0.60 | -0.395 | -4.045 | 1.18E+20 | 0.114 | | -0.509 | 2.791 |

Table S10. Ana(400)-ss&ss in the dark.

| Time (min) | f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|---------------|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 12 | 400 | -0.52 | -0.315 | -4.125 | 5.38E+20 | 0.152 | 3.3 | -0.467 | 2.833 |
| 24 | | -0.56 | -0.355 | -4.085 | 6.87E+20 | 0.159 | | -0.514 | 2.786 |
| 36 | | -0.59 | -0.385 | -4.055 | 8.19E+20 | 0.163 | | -0.548 | 2.752 |
| 48 | | -0.61 | -0.405 | -4.035 | 9.65E+20 | 0.167 | | -0.572 | 2.728 |
| 60 | | -0.63 | -0.425 | -4.015 | 1.07E+21 | 0.170 | | -0.595 | 2.705 |
| 72 | | -0.65 | -0.445 | -3.995 | 1.07E+21 | 0.170 | | -0.615 | 2.685 |
| 84 | | -0.65 | -0.445 | -3.995 | 1.09E+21 | 0.170 | | -0.615 | 2.685 |
| 96 | | -0.66 | -0.455 | -3.985 | 1.06E+21 | 0.170 | | -0.625 | 2.675 |

Table S11. Ana(400)-ss&ss at Different pHs.

| pH | f (Hz) | V _{fb} (V vs Ag/AgCl) | V _{fb} (V vs SHE) | E _F (eV) | N _d (cm ⁻³) | ΔE (eV) | E _g (eV) | E _c (V vs SHE) | E _v (V vs SHE) |
|--------|-----------|-----------------------------------|-------------------------------|------------------------|---------------------------------------|------------|------------------------|------------------------------|------------------------------|
| 1.637 | 400 | -0.19 | 0.015 | -4.455 | 2.07E+20 | 0.128 | 3.3 | -0.113 | 3.187 |
| 2.166 | | -0.18 | 0.025 | -4.465 | 1.96E+20 | 0.127 | | -0.102 | 3.198 |
| 2.973 | | -0.28 | -0.075 | -4.365 | 3.15E+20 | 0.139 | | -0.214 | 3.086 |
| 4.462 | | -0.53 | -0.325 | -4.115 | 3.97E+20 | 0.145 | | -0.470 | 2.830 |
| 5.242 | | -0.50 | -0.295 | -4.145 | 3.92E+20 | 0.144 | | -0.439 | 2.861 |
| 6.218 | | -0.51 | -0.305 | -4.135 | 3.77E+20 | 0.143 | | -0.448 | 2.852 |
| 5.990 | | -0.56 | -0.355 | -4.085 | 1.24E+20 | 0.115 | | -0.470 | 2.830 |
| 7.222 | | -0.58 | -0.375 | -4.065 | 1.22E+20 | 0.115 | | -0.490 | 2.810 |
| 8.774 | | -0.59 | -0.385 | -4.055 | 1.27E+20 | 0.116 | | -0.501 | 2.799 |
| 9.081 | | -0.61 | -0.405 | -4.035 | 1.29E+20 | 0.116 | | -0.521 | 2.779 |
| 9.638 | | -0.63 | -0.425 | -4.015 | 1.38E+20 | 0.118 | | -0.543 | 2.757 |
| 11.556 | | -0.89 | -0.685 | -3.755 | 2.04E+20 | 0.128 | | -0.813 | 2.487 |
| 12.107 | | -0.97 | -0.765 | -3.675 | 1.76E+20 | 0.124 | | -0.889 | 2.411 |