Three-Dimensional Dithering and its effect on the Interfacial Strength of Different Multi-Material Additive Manufacturing Processes - Supplementary Document

Algorithm 1 Random Dithering

```
for z = 1 to Number of Layers do
    for y = 1 to Number of Columns do
        for x = 1 to Numbers of Rows do
            Threshold(x, y, z) = Random Integer between 0 and 255
            if ImageStack(x, y, z) > Threshold(x, y, z) then
                Output (x, y, z) = 1 (i.e. Material 1)
            else
                Output (x, y, z) = 0 (i.e. Material 2)
            end if
        end for
    end for
end for
```

Algorithm 2 Error Diffusion Dithering

```
for z = 1 to Number of Layers do
    for y = 1 to Number of Columns do
        for x = 1 to Numbers of Rows do
            if ImageStack(x, y, z) > 127 then
                Output (x, y, z) = 1 (i.e. Material 1)
            else
                Output (x, y, z) = 0 (i.e. Material 2)
            end if
            Old = ImageStack(x, y, z)
            New = 255 × Output(x, y, z)
            Error = New - Old                          ▷ Calculate the Error
            Propagate Error to surrounding pixels according to predefined 3D
Error Diffusion Kernel (e.g. Figure 3 in main body)
        end for
    end for
end for
```

Algorithm 3 Ordered Dithering

```
M1 = Basic Bayer Pattern   ▷ Create Four Bayer Dither Kernels (Figure 7 in main body)
M2 = Shifted Pattern
M3 = Shifted Pattern 2
M4 = Shifted Pattern 3
for z = 1 to Number of Layers do
    Layer Multiple = Remainder when dividing the current Layer number by 4
    if Layer Multiple = 1 then                ▷ Use M1 for Layers 1,5,9,etc.
        M = M1
    else if Layer Multiple = 2 then           ▷ Use M2 for Layers 2,6,10,etc.
        M = M2
    else if Layer Multiple = 3 then           ▷ Use M3 for Layers 3,7,11,etc.
        M = M3
    else if Layer Multiple = 0 then           ▷ Use M4 for Layers 4,8,12,etc.
        M = M4
    end if
    Threshold( : , : , z) = Repeat M across size of each image
    for y = 1 to Number of Columns do
        for x = 1 to Numbers of Rows do
            if ImageStack(x, y, z) > Threshold(x, y, z) then
                Output (x, y, z) = 1 (i.e. Material 1)
            else
                Output (x, y, z) = 0 (i.e. Material 2)
            end if
        end for
    end for
end for
```

Algorithm 4 Interfacial Surface Area Measurement

Area$_x$ = Voxel Dimension$_y$ × Voxel Dimension$_z$
Area$_y$ = Voxel Dimension$_z$ × Voxel Dimension$_x$
Area$_z$ = Voxel Dimension$_x$ × Voxel Dimension$_y$
for $z = 1$ to Number of Layers **do**
  for $y = 1$ to Number of Columns **do**
    for $x = 1$ to Numbers of Rows **do**
      if Material$(x, y, z) \neq$ Material$(x + 1, y, z)$ **then**
        $x_{count} = x_{count} + 1$
      end if
      if Material$(x, y, z) \neq$ Material$(x, y + 1, z)$ **then**
        $y_{count} = y_{count} + 1$
      end if
      if Material$(x, y, z) \neq$ Material$(x, y, z + 1)$ **then**
        $z_{count} = z_{count} + 1$
      end if
      Interface Area = x_{count} × Area$_x$ + y_{count} × Area$_y$ + z_{count} × Area$_z$
    end for
  end for
end for

Table 1: Raw Data from PolyJet VW / AB Testing.

Sample	**E** (MPa)		**UTS** (MPa)		ϵ_B (%)		$\mathbf{W}_B$ (N mm)		**Failure Location** (mm)	
	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**
1	0.366381	0.603619	1.34032	0.052974	155.4041	5.873099	206.3821	12.14238	57.8	7.5
2	1383.583	110.8564	19.92399	2.310952	1.212285	0.17195	33.08945	8.667378	64.5	8.9
3	0.907181	0.557454	1.442796	0.100722	81.41212	3.792137	128.6937	11.88225	68.3	1.7
4	1.31884	0.414583	1.150173	0.099673	73.10004	2.237376	96.63027	3.655903	58.4	5.6
5	1.728396	0.484559	0.903696	0.026108	56.80353	2.587358	68.665	5.329841	52.7	0.7
6	2.257339	0.591147	0.906561	0.02111	43.34562	1.578816	60.0743	2.00895	55.9	1.2
7	1.667461	0.616176	1.24686	0.090298	72.44258	2.102805	101.461	6.956213	59.8	5.9
8	1.877438	0.499472	1.23292	0.130677	58.73321	2.69506	88.00527	8.103229	62.1	2.3
9	2.889758	0.562455	1.355263	0.190089	34.58306	2.668557	66.14117	10.77532	63.4	2.2
10	1.202275	0.552644	1.401138	0.066461	72.57135	3.781729	112.5485	11.86812	63.4	6.8
11	1.726723	0.425177	1.460722	0.12512	61.42237	3.021288	104.5638	10.77176	62.6	3.0
12	3.488836	1.086739	1.595862	0.129277	34.94406	1.242384	77.26286	5.770314	64.3	1.7
13	1.89899	0.22757	1.493714	0.07084	73.26505	2.006521	125.0371	7.05728	63.9	4.7
14	1.639683	0.550513	1.629945	0.146162	63.41982	2.380368	125.6146	8.903227	59.7	4.0
15	3.337773	0.651458	1.589468	0.095595	35.97708	1.404216	86.46569	5.104641	66.0	2.6
16	1.59414	0.454622	1.317507	0.047275	70.98736	1.32257	103.4226	5.688957	57.0	0.8
17	1.756207	0.452324	1.220876	0.066208	53.86981	2.584798	78.72256	5.840448	61.6	0.6
18	4.072922	0.384496	1.409118	0.074548	22.27622	1.597279	39.15084	6.30904	66.4	0.5
19	0.716603	0.206845	1.165499	0.080903	89.44472	3.923407	123.2521	9.420243	61.9	7.9
20	1.65418	0.261719	1.472558	0.131421	65.48695	0.858602	109.9327	6.036954	63.1	5.9
21	3.28094	0.522478	1.520339	0.06867	33.09956	2.784102	67.58653	8.348932	66.5	1.4

Table 2: Raw Data from PolyJet VW / VB Testing.

Sample	**E** (MPa)		**UTS** (MPa)		ϵ_B (%)		$\mathbf{W}_B$ (N mm)		**Failure Location** (mm)	
	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**
1	2084.229	46.24491	28.9916	2.856702	1.303628	0.130426	52.61086	9.909285	64.7	4.5
2	1568.407	79.5	22.91043	3.65015	1.255871	0.171363	40.07725	12.31458	63.2	7.5
3	1867.903	63.55384	22.14928	1.42706	1.051515	0.091413	31.75546	5.268303	65.7	2.1
4	1798.557	57.81858	23.09515	2.409974	1.146835	0.153333	37.20971	10.07043	62.4	9.5
5	1654.229	50.42055	24.53547	2.383393	1.321244	0.138294	46.09889	10.40907	59.2	7.2
6	1667.876	93.66568	19.705	1.480063	1.046637	0.100734	28.64345	4.809445	60.1	6.3
7	1678.421	92.93726	22.22391	3.618201	1.165603	0.166413	37.12799	12.6696	61.0	6.7
8	1362.626	88.04622	17.88669	3.819402	1.123889	0.255778	29.08965	14.77482	62.4	7.3
9	1321.44	121.3696	16.33538	3.184314	1.05564	0.200699	24.55725	9.675046	56.6	3.2
10	1468.767	78.67422	19.15381	4.615952	1.137251	0.291666	30.95198	15.44465	66.5	2.5
11	1372.803	42.89214	22.24519	3.3431	1.420562	0.253102	44.64061	15.50444	61.7	5.5
12	1305.548	95.62628	19.01618	2.406671	1.246008	0.119773	32.93098	7.400609	65.3	7.1
13	1463.253	76.37319	20.05788	2.506084	1.190625	0.172816	32.62914	8.770334	60.2	6.1
14	1380.415	116.1	16.72226	2.266866	1.030562	0.114751	23.49454	5.771499	60.6	8.0
15	1272.788	72.41264	17.12178	2.753221	1.132677	0.172237	26.54793	8.816384	57.6	4.2
16	1497.013	38.23993	21.9959	3.624052	1.288946	0.230295	39.81024	13.23911	64.2	7.3
17	1401.349	86.55784	19.09206	1.094162	1.17195	0.063038	30.34392	3.256002	59.8	7.4
18	1307.271	83.18906	19.76118	1.92922	1.294977	0.176589	35.25674	8.656778	60.9	8.3
19	1511.231	82.34925	18.69143	2.041309	1.073196	0.123447	27.42326	6.328438	61.1	5.8
20	1363.704	63.07624	17.02137	2.472092	1.051827	0.162178	24.31998	7.400996	63.0	5.2
21	1216.008	42.38263	18.29367	4.339669	1.262578	0.281081	32.48814	14.93531	55.9	1.7

Table 3: Raw Data from STEP ABS / ABS Testing.

Sample	**E** (MPa)		**UTS** (MPa)		ϵ_B (%)		$\mathbf{W}_B$ (N mm)		**Failure Location** (mm)	
	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**	$\overline{x}$	**s.d.**
1	1791.746	23.71357	36.0785	0.366529	8.581004	0.665609	671.7916	53.2556	57.5	1.1
2	1835.55	23.18206	36.52094	0.359804	8.316727	1.150604	648.4001	97.20876	60.9	5.2
3	1792.08	6.25583	36.91603	0.143412	3.480677	0.441657	234.1631	41.05964	50.6	0.2
4	1781.791	19.22304	36.38414	0.266206	3.036574	0.2541	190.1195	24.43633	50.1	0.1
5	1787.346	10.29514	36.13513	0.220131	3.050695	0.114526	189.279	10.79194	51.8	0.4
6	1795.775	14.34459	36.34154	0.26053	3.538573	0.055202	232.8847	5.142432	52.0	0.5
7	1798.455	18.54551	36.31591	0.244636	2.664218	0.031408	154.123	3.16183	50.7	0.4
8	1819.67	13.12249	36.72746	0.270748	3.645203	0.303242	243.1626	27.62659	52.4	0.6
9	1808.594	6.901841	36.9963	0.119642	4.261019	0.534565	295.8486	46.96704	55.2	1.3
10	1807.223	15.50882	34.84346	0.335836	2.347638	0.046255	124.0478	4.558406	51.0	0.3
11	1838.219	39.9727	35.6162	0.730493	2.568873	0.130472	141.283	11.83255	53.0	0.2
12	1824.662	19.34979	36.42961	0.427492	3.031654	0.215803	179.5852	18.90406	55.3	0.2
13	1797.744	16.83904	34.91573	0.097246	2.408322	0.038166	129.4519	3.503755	50.7	0.1
14	1816.857	37.27328	35.61342	0.729683	3.50174	0.368971	224.1227	32.63196	52.9	0.7
15	1813.419	17.66201	36.70487	0.181424	4.787513	0.306404	329.6606	25.61751	54.9	1.3
16	1834.514	15.2356	36.62202	0.252098	2.884178	0.103023	178.2528	10.19736	50.7	0.6
17	1823.816	5.34861	35.83085	0.192669	2.90647	0.183267	177.3887	17.40385	54.0	0.3
18	1821.324	7.595346	35.67995	0.279576	3.068174	0.324183	189.1848	29.66576	54.0	0.3
19	1805.202	16.05611	35.13205	0.277299	2.440992	0.036611	134.0688	3.880118	51.2	0.2
20	1831.503	22.66781	35.05767	0.406181	2.682217	0.191413	152.6171	17.21799	53.0	0.3
21	1818.824	9.212654	34.98515	0.166757	2.79477	0.083522	158.6204	7.655309	55.9	0.2