

Table 1*Physical properties of target materials used in the experiments.*

| Target material | Grain size [μm] | Friction angle [$^{\circ}$] | Density (δ) [g cm^{-3}] | Porosity [%] |
|------------------------|---------------------------------|----------------------------------|--|-----------------|
| Quartz sand (Boeing) | <1180: 100% | 39 $^{\circ}$ | 1.498 (max) | 44 |
| “Lane Mountain 20-30” | 850-1180: 2.5% | | | |
| 99.6% SiO ₂ | 600-850: 27% | | | |
| | 425-600: 55% | | | |
| | 300-425: 12.5% | | | |
| | <300: 3% | | | |
| Chromite sand (Boeing) | Not measured | Not measured | 3.81 (max) | 20 |
| Beach sand (EPIC) | 2000-1000: 0.18% | 34.6 \pm 0.8 (slow pour) | 1.795 (max) | 32 |
| 85% quartz | 1000-500: 56.94% | 30.4 \pm 1.7 (fast pour) | 1.576 (min) | 40 |
| 15% feldspar | 500-250: 38.0% | | | |
| | 250-125: 4.53% | | | |
| | <125: 0.24% | | | |
| Iron grit sand (EPIC) | 2000-1000: 42.6% | 41.0 \pm 1.4 (slow pour) | 4.440 (max) | 44 |
| | 1000-500: 56.6% | 32.0 \pm 0.8 (fast pour) | 3.627 (min) | 54 |
| | 500-250: 0.76% | | | |
| | 250-125: 0.04% | | | |